



University of Wollongong

Institute for Superconducting & Electronic Materials

ANNUAL REPORT 1997



Some of the members and staff of the Institute for Superconducting and Electronic Materials with distinguished Professor A.A. Abrikosov , who gave a lecture at the University of Wollongong

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The Institute for Superconducting & Electronic Materials

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1. RESEARCH STAFF

The Institute consists of three programs;

- High Temperature Superconductors (HTS)
- Energy Storage Materials
- Solid State Physics*

and is involved with three Faculties and four Departments on campus.

*Solid State Physics was incorporated into the Institute recently. This report does not include details of this program except for membership.

HTS Program

Professor S.X. Dou, *Director, ARC Professorial Fellow*
Professor T.P. Beales, *Manager*
Assoc/Professor H.K. Liu, *ARC A/Professorial Research Fellow*
Mr M. Ionescu, *Assistant Director*,
Dr P. Mikheenko, *Senior Research Fellow*
Dr Y.C. Guo, *ARC Postdoctoral Research Fellow*
Dr J. Horvat, *Research Fellow*
Dr Q.Y. Hu, *Research Fellow*
Dr V.P.S. Awana, *Research Fellow*
Dr S. Moss, *Research Fellow*
Dr J.X. Jin, *Research Fellow*
Dr S. Li, *Research Fellow*
Dr J.N. Li, *Research Fellow*
Dr V. Murashov, *Senior Research Fellow*
Dr. V Rouessac, *International Fellow*
Mr B. Zeimetz, *Associate Fellow*
Mr C. Rossi, *Technical Officer*
Mr T. Shaw, *Technical Officer*

Associate Members

Professor C Cook (Electrical)
Dr D Martin
Dr C Zhang
Dr R Vickers
Dr J Boldeman (ANSTO)
Professor P Fisher

Energy Storage Materials Program

Associate Professor HK Liu, *Co-Ordinator*
Professor D Bradhurst
Dr W Boctor, *Principal Research Fellow*
Professor JS Wang, *Honorary Professor*
Dr S Zhong, *Research Fellow*
Dr V Murashov, *Senior Research Fellow*
Mr GX Wang, *Visiting Fellow*
Mrs JZ Wang, *Visiting Fellow*

Solid State Physics Program

Professor Peter Fisher, *Co-Ordinator*
Associate Professor Roger Lewis
Dr Carey Freeth, *Senior Lecturer*
Dr David Martin, *Senior Lecturer*
Dr Anotoly Rosenfeld, *Senior Lecturer*
Dr Chao Zhang, *Senior Lecturer*
Dr Rodney Vickers, *Lecturer*

Associate Members

Mr M Ionescu
Dr P Mikheenko
Dr V Murashov
Dr We Xu
Assoc/Professor B Zealey

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Faculty of Engineering
University of Wollongong

2. RESEARCH STUDENTS AFFILIATED WITH THE INSTITUTE

Program of High Temperature Superconductivity

Student Name	Degree	Commenced	Complete Thesis	PT/FT	Supervisors	Student Destination
Peter Bain	PhD	Jan, 95	Jan, 97	FT	Liu/Dou	
R. Bhasale	PhD	Jan, 93	July, 98	FT	Liu/Dou	
C B Cai	PhD	1998	2000	FT	Liu/Dou	
M S Gong	PhD	1998	2000	FT	Dou/Beales	
X.K. Fu	PhD	1998	2000	FT	Dou/J Horvat	
T. Green	Masters	Jan 97	1998	FT	Dou	
Q.Y. Hu	PhD	May, 92	July, 95	FT	Dou/Weber	Uni of Florida
M. Ionescu	PhD	Jan, 92	July, 97	FT	Dou/Collings	Uni of Wollongong
J.X. Jin	PhD	Jan, 94	July, 97	FT	Dou/Grantham	Uni of Wollongong
W.G. Wang	PhD	Nov, 94	Oct, 97	FT	Dou/Liu	NKT - Denmark
X.L. Wang	PhD	Jan, 96	Mar, 99	FT	Dou/Liu	
N.V. Vo	PhD	Jan, 94	Apr, 97	FT	Dou/Liu	Los Alamos Lab
B. Zeimetz	PhD	Jan, 95	Feb, 98	FT	Dou/Liu	Uni of Wollongong
M. Yavuz	PhD	Jan, 94	Dec, 96	FT	Dou/Liu	Tohoku Un i- Japan
J.M. Xu	PhD	Jan, 94	Jan, 97	FT	Dou/Cadogan	Uni of NSW
R. Zeng	PhD	Jan 97	1999	FT	Dou/Liu/Beales	

Energy Storage Materials Program

Student Name	Degree	Commenced	Complete Thesis	PT/FT	Supervisors	Student Destination
Benli Luan	PhD	1994	Feb, 97	FT	Liu, Dou	NRC - Canada
Ning Cui	PhD	1994	July, 97	FT	Liu, Dou, Bradhurst	Alberda Uni Canada
Zhong Shi	PhD	1995		FT	Liu, Dou, Kazacos	Uni of Wollongong
Fei Chen	ME (Hons)	1997	1998	FT	Liu/Bradhurst	
Jun Chen	PhD	1996		FT	Liu, Dou	
Sun Li	PhD	1997	1999	FT	Liu/Bradhurst	
Zahiri H. Saden	ME (Hons)	1995	Mch, 97	FT	Liu, Dou	
G X Wang	PhD	1998	2000	FT	Liu/Bradhurst	
J Z Wang	Masters	1998	1999	FT	Liu	
Ying-Shan Wu	ME (Hons)	1995	96	FT	Liu, Dou	ANU

3. ADVISORY COMMITTEE

Name	Company	Position
C. Adam	CSIRO	Director
A. Brownrigg	BHP-Research	Scientific Leader
G. Dudley	MM Cables	Managing Director
A. Johnston	ANSTO	Head of Division
Y.W. Mai	Sydney University	Director of Centre
M. Murray	CSIRO	Chief
D. Rand	CSIRO	Program manager
P. Robinson	UoW	Deputy Vice Chancellor, Chair
G. White	CSIRO	Applied Physics
H. Worner	ITC	Honorary Professor

4. STRONG INTERNATIONAL LINKS

The Institute has established a national and international multi-disciplinary collaborative network. This has led to information exchange, co-supervision of PhD students, joint grant proposals and joint publications with more than 40 research teams around the world as listed below:

1. CSIRO Division of Applied Physics, N. (Savvides, K. Muller)
2. CSIRO Division of Minerals, (D. Rand & D.A.J. Lam)
3. ANSTO, ER Vance, (J. Boldeman and S Kennedy)
4. Electron Microscope Unit, University of Sydney, (D.J.H. Cockayne)
5. UNSW Schools of Physics, Elec. & Chemical Eng, (G. Russell, J. Cadogan, C. Grantham & M. Skyllas-Kazacos)
6. Monash University, Dept of Elec. & Computer Eng.(W. Bonwick)
7. University of Melbourne, Dept of Physics (D. Jamieson)
8. Curtin Uni of Technol, Dept of Phys. (J. Low)
9. Uni of Queensland, EMU, (I. MacKinnon)
10. Australian National Uni, (M. Das)
11. Uni of Auckland, NZ, Dept of Mater. Eng., (W.Gao), School of Mathematical & Information Sciences, (T. Soboleva)
12. Industrial Research lab. NZ, (B. Buckley)
13. Blackett Lab. Imperial College London, UK, (A.D. Caplin)
14. Oxford University, Eng Dept (D. Dew-Hughes)
15. National Research Institute of Metals (H. Maeda, K. Togano, Y. Tanaka), Japan
16. Ames Lab. Iowa State University (D. Finnemore, J.R. Clem), Iowa, USA.
17. Ohio State University (E.D. Collings), Columbus, OH, USA.
18. University of Zagreb (E. Babic), Zagreb, Croatia.
19. National Physical Laboratory, New Delhi, India, (A.V. Nalekar)
20. Atomic Institute of Austrian Universities (H. Weber), Viena, Austria.
21. Houston Uni, (R. Weinstein), USA
22. Institute of Physics, Academy Science, Beijing, PRC (Z.X. Zhao)
23. Northeastern University, Shenyang, PRC, (Z.T. Sui, W.M. Bian).
24. National Institute of Standard Technology (J. Ekin), Boulder, USA

25. Institute of Non-ferrous Metals, Beijing, PRC, (RK Wang).
26. Singapore National Uni (A. Bourdillon)
27. Tokai University, Japan (T. Toyoda)
28. University of Alberta, Canada (Y. Tadahashi)
29. Osaka National Research Institute, Japan (I. Uehara and T. Sakai)
30. Northwestern Institute of Non-ferrous Metals (L.Zhou), PRC
31. Nakai Uni (Y.S. Zhang), PRC
32. Harbin Uni. (J.S. Wang), PRC
33. Yamagata University, Japan (S. Kambe)
34. Worcester Polytechnic Institute, Dept of Physics, MA, USA, (S.W. Pierson)
35. Polish Academy of Sciences, Institute of Physics, Poland, (S.J. Lewandowski, I.S. Abaliosheva)
36. Donetsk Physico-Technical Institute, NASU, Donetsk, Ukraine (V.A. Voloshin, A. Gusen)
37. Institute of General Physics, Moscow, Russia, (V. Miljaev)
38. Institute for Metal Physics, Kiev, Ukraine, (V.M. Pan)
39. Ben-Gurion University of the Negev, Physical Dept, Israel, (J.I. Yuzhelevskii)
40. New York Polytechnic University, Dept of Physics, New York, USA, (Y.M. Ivanchenko)
41. Max-Planck-Institut for Metalloforschung, Institut fur Physik, Germany, (E.H. Brandt)
42. Nanjing University, (W.M. Chen)

5. LINKS WITH INDUSTRY

- | | |
|--|-----------------------------------|
| • Metal Manufactures Ltd | • Huaao Batteries Technology Ltd. |
| • Alphatec International Ltd | • Zhuhai Tai-yi Battery Co Ltd |
| • BHP | • Readings of Lismore Pty Ltd |
| • Pacific Power (indirect fund) | • Division of Pasminco Australia |
| • Electric Supply Association of Australia | Ltd |

Metal Manufactures Ltd (MM) has financially supported the Institute's superconducting research since 1988, and established a Chair of Superconductivity which was held by Professor Dou until 1993. MM has sponsored two ARC collaborative projects and three APA(I) awards, in the Institute, which have formed an integral part of our research and training program. The company initiated a \$6M program "*A Plan for Australian Technology of HTSC Wires*" and the UoW group works closely with the MM HTS pilot plant based at the Australian Technology Park. This three year project is a continuation of previous collaborative efforts and builds on the past successes of MM, UoW and the CSIRO. Other funding agents include Department of Industry Science Tourism (DIST), Energy Research Development Corporation (ERDC), ESAA and the Department of Energy of NSW.

The Electric Supply Association of Australia (ESAA) Ltd has provided \$160,000 for a three year project on "*The Fabrication and Applications of HTS Wire*" (1996-1998).

Alphatec International Ltd, Zhuhai Tai-yi Battery Co Ltd, Huaao Battery Technology Ltd, Pasminco Ltd and Readings of Lismore Pty Ltd have contributed matching funds or in-kind support, to ARC-Collaborative projects.

6. LIST OF EQUIPMENT AND FACILITIES

The Institute has established a truly National and International centre of excellence. Its laboratory is equipped with modern facilities for processing and characterisation of HTS and energy storage materials. Materials processing capabilities include bulk, single crystals, thin film, powders, wires and tapes. A full range of materials characterisation includes thermal, electrical, magnetic, mechanical and electrochemical properties of HTS energy storage materials.

No	Description	Manufacturer	Qty
1	Freeze Drier, Lyph-Loch 4.5, 4.5l/24h	Labconco, USA	1
2	Spray Drier, GA-32, ~100g/h	Yamoto, Japan	1
3	Attrition Mill, 01-HD, 0-600rpm, zirconia and ss jars	Union Process, USA	1
4	Planetary Mill, Pulverisette 5, 0-300rpm, agate, zirconia, ss and pp jars	Fritsch, Germany	1
5	Drawing Bench, 8m, fixed die, 11.5kW, 0-100cm/s	Home made	1
6	Bull Block, 22cm diameter	Home made	1
7	Rolling Mill, 2x60mm flat and square rollers, 5cm/s	Cavallin, Italy	1
8	Rolling Mill, 2x25mm supported rollers, 5cm/s	Crofts, England	1
9	Swagging Machine, 15-1mm diameter	MGI, USA	1
10	Hydraulic Press, 10t	Enerpac, Australia	1
11	Hydraulic Press, 100t	Enerpac, Australia	1
12	Tube Furnace, 15cmID, 4 zones, 1100°C, ±1°C	Ceramic Eng, Australia	1
13	Tube Furnace, 11cmID, 4 zones, 1200°C, ±1°C	Ceramic Eng, Australia	1
14	Box Furnace, 190x100x60cm, 1200°C, ±1°C	Home made	1
15	Tube furnace, 5.5cmID, 1200°C, ±1°C	Ceramic Eng, Australia	20
16	Box Furnace, 60x60x60, 1200°C, ±1°C	Ceramic Eng, Australia	10
17	Tube Furnace, Au coated, 5.7cmID, 950°C, ±1°C	Transtemps, USA	1
18	DTA/TG, Setaram 18-92, 1750°C	Setaram, France	1
19	DSC, TA300, -170°C +600°C	Mettler, Switzerland	1
20	Particle Size Analyser, Mastersizer S, 0.05-900µm	Malvern, UK	1
21	XRD, PW1050, 3kW, Cu, W, Mo, Cr, Co	Philips, Holland /Diff.Tech. Australia	1
22	XRTexture, PW1078, 3kW, Cu, Co, Mo	Philips, Holland /Diff.Tech. Australia	1
23	XRD, M18XHF, 18kW, Cu rotating anode, with HT 2000°C camera	MAC Science, Japan	1

No	Description	Manufacturer	Qty
24	XRD Data Base	ICDD, USA	1
25	SEM, Stereoscan 440, with EDS and EBSP	Leica, UK	1
26	TEM, J2000FX1, with EDS	Jeol, Japan	1
27	AFM, Nanoscope IIIa	Digital Instruments, USA	1
28	PPMS, PPMS1, 2-400K, 0-9T DC field	Quantum Design, USA	1
29	VSM, MagLab, 2-400K, 0-12T DC field	Oxford Instruments, UK	1
30	DC Superconducting Magnet, 0-8T, 5-300K	China	1
31	Electromagnet, HSV-4H1, 0-4T, 100mm pole diameter	Walker Scientific, USA	1
32	Electromagnet, 3473-70, 0-4T, 150mm pole diameter	GMW Magnet Syst., USA	1
33	Power Supply, XKW, 0-40V, 0-75A	Xantrex, USA	1
34	Power Supply, DS 800, 0-60V, 0-70A	Danfysik System, Denmark	1
35	Power Supply, Keithley 288A, 0-10V, 0-10A	Keithley, USA	2
36	Power Supply, HP6672A, 0-20V, 0-100A	Hewlett Packard, USA	1
37	Power Supply, HP6680A, 0-5V, 0-875A	Hewlett Packard, USA	1
38	Digital Multimeter, Keithley2000	Keythley, USA	3
39	Digital Multimeter, Keithley2001	Keythley, USA	1
40	Digital Multimeter, Keithley196	Keythley, USA	1
41	Digital Multimeter, Keithley182	Keythley, USA	1
42	Digital Multimeter, HP34401A	Hewlett Packard, USA	1
43	Transconductance Amplifier, 1620	Ballantine, USA	1
44	Nanovolt Preamplifier, Keithley1801	Keithley, USA	1
45	Scanner, 10 Channels	Keithley, USA	1
46	Lock-in Amplifier, SR510, single channel	Stanford Research, USA	1
47	Lock-in Amplifier, SR830DSP, double channel	Stanford Research, USA	1
48	Function Generator, DS340	Stanford Research, USA	1
49	Digital Oscilloscope, TDS320	Tektronix, USA	1
45	Digital Teslameter,, DTM-132, with Hall Probe	Group-3, New Zealand	1
51	Fluxmeter, 916	Magnetic Instr., USA	1
52	Cryogenic Temperature Controller, ITC4, 0-500K	Oxford Instruments, UK	1
53	Excimer Laser, ComPex301, 9W, 10Hz, 248nm	Lambda Physik, Germany	1
54	Thin Films Deposition Chamber, 18" diameter, with high vacuum system	Kurt Lesker, USA/ Neocera, USA	
55	Cyclic Voltammograph, BAS CV-27	Bioanalytical Systems, USA	1
56	Scanning Potentiostat, M326	Eg&G, USA	1
57	Potentiostat, M363	EG&G, USA	1
58	Impedance Analyser, M6310	EG&G, USA	1

No	Description	Manufacturer	Qty
59	Automatic Battery Charge/Discharge	Home made	4
60	Automatic Battery Charge/Discharge	Dentaish Electr. Australia	4
61	Power Supply, DCS 20-50, 0-20V, 0-50A	Sorensen, USA	1
62	Four Channels Data Collection System, MacLab/4e	ADInstruments, Australia	1
63	Eight Channels Data Collection System, MacLab/8	ADInstruments, Australia	1
64	Automatic Battery Charge/Discharge, DC5-C, 16 channels	Zeng Fang, China	2
65	Controlled Atmosphere System (Glove Box), OP7	M. Braun, Germany	1
66	Temperature Controlled Water Bath, F10-MF	Julabo, Germany	1
67	He Recovery System, 10m ³ , Bauer K100, 1001/min	Bauer, Germany	1

Most of these facilities were founded through four ARC RIEF programs and Metal Manufactures Ltd consortium program over the past four years. The following Institutions and Chief Investigators have been involved with the ARC RIEF proposals:

- University of Queensland, (Prof DR Mackinnon)
- RMIT, (Prof PJK Paterson)
- CSIRO, (Dr N Saviddes, Dr K Müller, Dr GJ Slogget)
- Monash University, (Prof WJ Bonwick, Dr YB Cheng)
- University of New South Wales, (Prof C Grantham, Dr B Gleeson)
- ANSTO, (Dr ER Vance),
- ANU, (Dr M Das),
- University of Melbourne, (DN Jamieson)
- Griffith University, (Dr S Myhra)
- Curtin University (Prof DY and Dr I Low)
- Queensland University of Technology, (Dr PD Killen)
- University of Technology, Sydney, (Profs J Smith and JN Bell)

The support and participation of the above researchers is sincerely appreciated.

7. RESEARCH GRANTS AND INCOME CONTRIBUTION

Funding Type	Project Title	Chief Investigator	Duration	Amount
ARC - Large	Microstructure and Critical Current in Bi-HTS"	SX Dou, KH Muller, HW Webber	1997/99	\$180,000
ARC - Small	Nickel-Metal Hydride Alloy	HK Liu	1995	\$6,000
ARC - Collaborative	Microstructures and Critical Current of HTSC	SX Dou, L Vance, B Bonwick and N Savvides	1994-96	\$383,000
ARC - Collaborative	Thermomechanical processing of HTSC	HK Liu and T Chandra,	1995-97	\$273,000
ARC - Collaborative	Investigation of HTS High Gradient Magnetic Separator	SX Dou, RG Buckley and HK Liu	1997-99	\$270,000
ARC - RIEF	X-Ray Diffraction Unit with low and high Temperature Capability	SX Dou, D Dumne, HK Liu, B. Gleeson, YB Cheng	1998-99	\$360,000 \$180,000 ARC UoW, UNSW, Monash
ARC - RIEF	HTSC Laboratory	SX Dou, HK Liu, et al (from 11 institutions)	1995	\$300,000 \$120,000 ARC UoW
ARC - RIEF	Magnetic property measurement system	SX Dou, HK Liu, et al (from 7 institutions)	1996	\$250,000 \$72,000 ARC UoW
ARC - Fellowship	Doping of Silver-Alloy Sheath of Bi-HTS Wires	YC Guo	1997-99	\$151,800
ARC - Inter. Fellowship	Phase Evolution and Processing of HTS Tapes	SX Dou and HK Liu	1998-1999	\$60,000
ARC - Professorial Fellowship	Microstructure and J_c of HTSC	SX Dou	1993-97	\$520,000
ARC - Senior Research Fellowship	Long Wires of HTSC	HK Liu	1994-98	\$410,000
ARC Research Infrast. Block Grant	X-Ray Diffraction Facility	SX Dou, D Dumne and HK Liu	1997-98	\$58,169
ARC Research Initiative Program	International Workshop on Processing and Critical Current of HTS"	SX Dou, HK Liu, T Beales, P Mikheenko,	1998	\$29,000
ARC, APA (I)	HTS wires and Multi filaments	SX Dou	1992-94	\$60,000

Funding Type	Project Title	Chief Investigator	Duration	Amount
ARC, APA (I)	Critical Current density and Flux Pinning in HTS Wires	SX Dou, HK Liu	1993-97	\$70,000
ARC, APA (I)	HTS Magnets and Coils	SX Dou	1994-97	\$70,000
ARC, Small	2D basement for HTS	P Mikheenko	1998	\$4,000
ERDC	A Plan for Australian Technology in HTS Wire	SX Dou and HK Liu	1995-98	\$790,000
Energy Office of NSW	Fabrication and Application of HTS Wires and Tapes	SX Dou and HK Liu	1996-98	\$382,728
AINSE	Study on powder processing and li-doped HTS using neutron irradiation	SX Dou and L Vance	1994-97	\$47,120
AINSE	Nickel-Metal hydride Alloys, AINSE Award	HK Liu and S Kennedy	1995	\$1,100
AINSE	Microstructure and Defects in Nickel-Metal Hydride Alloys through Neutron Diffraction and Scattering Techniques, AINSE Award	HK Liu and S Kennedy	1996	\$7,350
AINSE	In-situ Neutron Diffraction study for Nickel-Metal Hydride Alloys, AINSE Award	HK Liu and S Kennedy	1997	\$9,355
AINSE	Detailed structural analysis of RE:1113. Superconducting systems: with neutron diffraction	SX Dou/VPS Awana and S Kennedy	1998	\$5,600
AINSE	Uranium doping & neutron irradiation of Ag/Bi-2223 superconducting tapes for improved critical current density	SX Dou/S Moss and J Boldeman	1998	\$2,000
AINSE	Enhancing the flux pinning in Li6 doped Bi2CaSr2Cu2O8 systems by fast neutron irradiation - continuation	SX Dou/S Moss and J Boldeman	1998	\$2,000
AINSE	Structure of electrode materials for rechargeable batteries	HK Liu & S Kennedy	1998	\$3,235
TIL, DEET	Targeted Institutional Link Program with Northeastern Uni and Institute of Physics of PRC on HTSC	SX Dou, HK Liu, CC Sorrell C.L. Ji, ZX Zhao (PRC)	1992-94	\$162,000
TIL, DEET	Investigation of Metal-Nickel Hydride Alloys for the use of Energy Storage	SX Dou, HK Liu I Uehara (Japan), YS Zhang, JX Wang (PRC)	1997-99	\$191,000 \$60,000
				DEET UoW

Funding Type	Project Title	Chief Investigator	Duration	Amount
DIST	A Plan for Australian Technology of HTSC Wires	SX Dou, HK Liu	1996-98	\$250,000
DIST Bilateral Program	Processing of Bi-based High T _c superconducting powders for Tape Technology", Bilateral Program with Prof. A.V. Nalekar in India	SX Dou and A. Nalekar (NPL India)	1997-98	\$3,900
DIST Bilateral Program	HTSC Wires	SX Dou and D Finnemore (Ames)	1994	\$5,500 NSF
DIST Bilateral Program	Links in HTS Tapes	SX Dou, J Horvat and E Babic (Zagreb Uni),	1997-98	\$8,200 USA
DIST Bilateral Program	Doping of Ag-Alloy Sheath of Bi-HTS Wires	SX Dou, YC Guo and R Togano (Japan),	1997-99	\$24,000
DIST, Bilateral Program	Magnetisation measurements for Bi-2223 tapes in magnetic field up to 40T	SX Dou and J. Li F.R. de Boer (Uni of Amsterdam)	1997-98	\$4,000
Australian Academy of Science	Japanese-Australian Exchange Program on HTSC	S Kambe (Yamagata Uni) and SX Dou	1995-96	\$14,000
DIST Bilateral Program	High Temperature Superconducting Materials	SX Dou, YC Guo and H Maeda (NRIM),	1995-96	\$8,000 DIST
DIST Bilateral Program	2212 HTSC Wires	HK Liu, M Ionescu and EW Collings (Ohio),	1996	\$5,000 STA Japan
DIST Bilateral Program	Critical Current and Flux Pinning of HTSC	SX Dou, J Horvat and D. Dew-Hughes (Oxford),		\$4,100
Alphatec Inter Ltd	HTS High Gradient Magnetic Separator	SX Dou, RG Buckley (IRL) and HK Liu	1997-99	\$90,000
ESAA Ltd	Fabrication and Application of HTS Wires and Tapes	SX Dou and HK Liu	1994-96	\$160,000
MM Ltd	Technology and Applications of HTSC Wires"	SX Dou and HK Liu	1994-98	\$375,000

Funding Type	Project Title	Chief Investigator	Duration	Amount
Taryi Ltd	Metal-Nickel Hydride Materials for Rechargeable Battery	HK Liu and SX Dou	1997-99	\$85,700
UoW	Energy Storage Material Research Group funding	HK Liu	1995-97	\$46,776
UoW	HTSC Lab.	SX Dou and HK Liu	1994-96	\$200,000
UoW	Centre for Superconducting Materials	SX Dou	1995-97	\$137,000
UoW	Institute of Materials Technology and Manufacturing).	SX Dou	1996-97	\$150,000
UoW University 1997 Industry Links Award	Novel Bipolar-Electrode Materials and Design for Electric-Vehicle Lead-Acid Batteries	HK Liu, SX Dou	1997	\$10,000
		TOTAL		\$7,099,233.00

Income Contribution through Supervision of Postgraduate Students

Year	Overseas Students	Australian Students	Income
1994	7	4	\$95,000
1995	7	7	\$140,000
1996	9	7	\$150,000
1997	7	7	\$140,000
	Total	Total	\$525,000.00

8. STAFF PROFILES

Professor Shi Xue Dou

Honours/Awards

- Fellow of Australian Academy of Technological Science & Engineering
- Fellow of International Academy of Electrotechnical Sciences
- President of Aus-China Scholar Association
- Order of International Fellowship (IBC)
- 1997 Man of the Year, American Biographical Institute
- Selected one of 500 leaders of influence, 6th Edition by American Biographical Institute
- X.L. Wang, S.X. Dou and H.K. Liu received Workshop Material Performance Award at the International Workshop of HTS jointly sponsored by MRS and ISTEC in July 1997

Committees

- Member of International Scientific Committee for 2nd International Symposium of New Materials for Fuel Cell and Modern Battery Systems
- Member of International Organising Committee of Thermec '97
- International Advisory Board of Superconductor Science and Technology
- Referee for J. Appl. Phys. Physica C, Superconductor Science and Technology
- Chairman of Organising Committee, International HTS Symposium, Wagga 98
- Member of Organising Committee of HTS Symposium of IUMRS, 97

Associate Professor Hua Kun Liu

- Member of Organising Committee of Thermec '97
- Advisory Board Member of an International Journal of New Materials for Electrochemical Systems
- X.L. Wang, S.X. Dou and H.K. Liu received Workshop Material Performance Award at the International Workshop of HTS jointly sponsored by MRS and ISTEC in July 1997
- Program Committee member of International HTS Symposium, Wagga 98

Professor Doug Bradhurst

- Fellow of the Royal Australian Chemical Institute. Research interests have included nuclear technology and solar energy.
- An Honorary Professorial Fellow in the Institute, Professor Bradhurst is currently involved in hydride-related work on rechargeable batteries.

Professor Timothy Beales

- Professor Timothy Paul Beales manages the global superconductor cable and wire activities for the BICC Group of companies, which has the main superconductor manufacturing and R&D sites located in the UK and Australia. Prof. Beales co-ordinates both the internal BICC activities and BICC's strategic commercial alliances and collaborative programs in superconductivity.
- He now works for BICC, managing a multidisciplinary team of scientists and engineers in superconductivity and is overseeing the commercialisation of superconductivity
- He is the UK Chairman of the BSI GEL/90 Electrotechnical International Standards Committee and has been a delegate on the UK DTI Overseas Technical Expert Mission Scheme. He is an Honorary Research Fellow at the University of Aberdeen, UK and Visiting Professor in the Faculty of Engineering at the University of Wollongong, Australia. He is also a monitor of EC funded BRITE-EURAM university collaborative programs in superconductivity and a member of the UK EPSRC materials committee.

9. INVITED TALKS & PAPERS

- 10th Anniversary Reviewed Paper for Superconductor Science and Technology.
- 6-8 March, 1997, International Workshop on critical Currents in Superconductors for Practical Applications.
- March 1997, Royal Chemical Society Annual Report on High Temperature Superconductivity.
- March 1998, MSU-HTSC U, Moscow
- October 1997, International union of Materials Research Society, Makuhara, Japan
- 1998 International Workshop on Superconductivity held by ISTEK Okinawa, Japan
- 4 - 9 May 1997, 91st Meeting of Electrochemical Society, Montreal, Quebec, Canada
- Invited paper for International journal of New Materials for Electrochemical Systems

10. SEMINARS BY VISITING SCIENTISTS IN 1997 INCLUDE:

Professor M. Skyllas-Kazacos, University of New South Wales, 22 January 1997
Professor T. Collings, Ohio State University, USA, 31 January 1997
Professor E. Babic, Croatia University, Zagreb, 19 February 1997
Professor J. Macfarlane, University of Strathclyde, UK, 20 February 1997

Professor K. Salama, University of Houston, USA, 7 April 1997
 Dr T Beales, BICC Cables, UK, 29 April 1997
 Dr D Caplin, Imperial College, UK, 5 May 1997
 Dr M Das, ANU, Australia, 23 May 1997
 Dr S Kennedy, ANSTO, Australia, 30 May 1997
 Professor L. Zhou, Institute for Non Ferrous Metal, China, 10 June 97
 Dr H Fujii, Okayama University of Science, 16 July 1997
 Professor J. Sestak, 18 July 97
 Professor N. Chen, Shanghai Institute of Metallurgy, China, 18 July 1997
 Professor S. Kambe, Yamagata University, 22 July 97
 Professor T. Beales, BICC Cables, 22 July 97
 Prof. A.A. Abrikosov, Condensed Matter Theory Group, Argonne National
 Laboratory, 25 July 1997
 Professor I. Kaplan, Instituto de Fisica, UNAM, Mexico, 29 July 97
 Dr G Jakob, Johannes Gutenberg University, Mainz, Germany, 20 August 97
 Dr H. Jones, Oxford University, 11 August 97
 Dr D. Spiller, BICC Cables, UK, 28 August 97
 Dr N. Avery, CSIRO, Division of Manufacturing Science & Tech., 9 October 97
 Dr H Azacs, Brouhaven Lab, 26 November 97
 Professor W. Boctor, University of New South Wales, 4 December 97
 Professor D. Shi, University of Cincinnati, USA, 17 December 97
 Dr I. Uehara, Osaka National Research Institute, 18 December 97

11. FINISHED THESIS

B.L. Luan	PhD	"Investigation On Ti_2Ni Hydrogen Storage Alloy Electrode For Rechargeable Nickel-Metal Hydride Batteries", 1997
M. Yavuz	PhD	"Powder Processing of Bi-Pb-Sr-Ca-Cu-O Superconducting Materials" 1997
N.V. Vo	PhD	"Processing of HTS Coils and Magnets" 1997
N. Cui	PhD	"Magnesium Based Hydrogen Storage Alloy Anode Materials for Ni-MH Secondary Batteries, 1997
S. Zhong	PhD	"Investigation on Pb-Ca-Sn-Al Grid Alloy for Valve-Regulated Lead-Acid Batteries, 1997
M Ionescu	PhD	"Growth and Characterisation of Bi-2212 Crystals and Improvement of Bi-2212 Superconducting Tapes, 1997

J.M. Xu	PhD	“Phase Formation and Transformation in the R-Fe-T Systems (R=Nd, Gd, Tb Dy, Er, Ho, Tm and Lu, T=Si, Ti and Zr)”
J.X. Jin	PhD	“(Bi,Pb) ₂ Sr ₂ Ca ₂ Cu ₃ O _{10+x} /Ag High T _c Superconductors and their applications in an Electrical Fault Current Limiter and an Electronic High Voltage Generator, 1997
W.G. Wang	PhD	“Fabrication and Improvement of Silver Sheathed (Bi,Pb) ₂ Sr ₂ Ca ₂ Cu ₃ O ₁₀ Tapes by Powder-In-Tube Technique”, 1997
F. Chen	Hons Master	“The Influence of Selenium on Lead-Calcium-Tin-Aluminium Grid Alloy”, 1997
H. (Saden) Zahiri	ME (Hons)	“A New Method for Production and Study of Electrical Properties of Carbon Foam”.

12. STATISTICS

	1994	1995	1996	1997
Postgraduate students	11	14	16	14
Full time staff	6	8	12	16
Visiting staff	6	5	6	4
Academic staff involved	10	10	8	11
No of publications referred & full conference papers only	51	39	43	110
Research Grants (accumulative)	12	24	33	48
Total funds/per annum	\$1,550K	\$1,500K	\$1,700K	\$1,900K
Collaborative Institutions	15	20	33	42
Distinguished Visitors	9	12	8	26
Invited talks & papers to members of our Institue	4	5	6	6
Industry Links	5	6	8	9
PhD & Master Thesis completed	1	3	1	11

13. 1997 PUBLICATIONS

C. Andrikidis, K.H. Müller, H.K. Liu and S.X. Dou, "Intergranular magnetisation of Pb-Bi-Sr-Ca-Cu-O/Ag tapes", Proceedings of 16th International Cryogenic Engineering Conference / International Cryogenic Materials Conference, pp 1545-1548, Ed: T Huruyama, T Mitsui and K Yamafuji, Pub: Elsevier Science, Oxford, 1997, ISBN: 0-08-042688-3

S. A. Awan, S. Sali, C. M. Friend and T. P. Beales, "Study of self-field AC losses in mono and multi-filamentary Bi-2223 tapes at power frequencies", IEEE Transactions On Applied Superconductivity, 7, 335, 1997.

V.P.S. Awana, Rajvir Singh, D.A. Landinez Tellez, J.M. Ferreira, J. Albino Aguiar and A.V. Narlikar, "Superconductivity, Synthesis And Magnetism Of $\text{Calabacu}_{3-x}(\text{Zn,Fe})_x\text{O}_7$ Tetragonal System", Physica C 282-287, 1997, p. 779-780

V.P.S. Awana, D.A. Landinez Tellez, J.M. Ferreira, J. Albino de Aguiar, S.K. Malik, A.V. Narlikar, W.B. Yelon, Rajvir Singh, S. Uma and E. Gmelin, "Superconductivity And Ordering Of Pr In $\text{Cal}_{1-x}\text{Pr}_x\text{bacu}_3\text{O}_7$ Compound", Physica C 282-287, (1997), p. 807-808.

V.P.S. Awana, Rajvir Singh, D.A. Landinez Tellez, J.M. Ferreira, J. Albino Aguiar, S. Uma, E. Gmelin, and A.V. Narlikar, "Superconductivity And Magnetic Ordering Of Pr In $\text{Cal}_{1-x}\text{Pr}_x\text{bacu}_3\text{O}_7$ System" Mod. Phys. Lett. B vol.11, No.7, (1997) 323-331.

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T. P. Beales J. Jutson, L. Le Lay and M. Mölgg, "A comparison of the powder-in-tube processing properties of two $(\text{Bi}_{2-x}\text{Pb}_x)\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+\delta}$ powders", Journal of Materials Chemistry, 7, 653, 1997.

T. P. Beales and M. Mölgg, "The role of $\text{BaMnO}_{3-\delta}$ in the formation of $\text{YBaMn}_2\text{O}_{6-\delta}$ ", Journal of Materials Science Letters, 16, 663, 1997.

T. P. Beales, M. Mölgg, J. Jutson and C. M. Friend, "Synthesis and properties of $\text{YBaMn}_2\text{O}_{5+\delta}$ ", Physica Status Solidi A, 161, 271, 1997.

T. P. Beales and J. M. Parberry, "The electrical and magnetic properties of the $(\text{Bi}_{1-y}\text{Cd}_y)\text{Sr}_2(\text{Y}_{1-x}\text{Ca}_x)\text{Cu}_2\text{O}_{7-8}$ series", *Materials Research Bulletin* Vol 32 No 9 pp 1293-1301.

T.P. Beales and J.M. Parberry, "Phase Equilibria and the Effect of Processing on the Electrical Transport and Magnetic Properties of $(\text{Pb}_{1-y}\text{CD}_y)\text{Sr}_2(\text{Y}_{1-x}\text{Ca}_x)\text{Cu}_2\text{O}_{7-8}$ " *Phys. Stat. Solid (a)* 162 689, 1997 pp 689-700.

J. Chen, N. Cui, D.H. Bradhurst, B. Luan, H.K. Liu and S.X. Dou, "Metal hydride electrodes for rechargeable batteries", 191st Society Meeting, Vol 97-1, Spring Meeting, Montreal, Quebec, Canada, May 4-9, 1997

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J. Chen, S.X. Dou, D. Bradhurst and H.K. Liu, "Studies on the electrochemical impedance spectroscopy of Zr-based laves phase metal hydride electrodes", *Proceedings of the 12th Annual Battery Conference on Applications and Advances*, IEEE 97th 8226, pp 313-316, 1997.

J. Chen, S.X. Dou and H.K. Liu, "Hydrogen desorption and electrode properties of $\text{Zr}_{0.8}\text{Ti}_{0.2}(\text{V}_{0.2}\text{Ni}_{0.6}\text{M}_{0.1})_2$ alloys", *Journal of Alloys and Compounds*, 257, Elsevier Science, pp 3104-3108, 1997.

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- S.X. Dou and H.K. Liu, "Improvement of flux pinning of Bi-(Pb)-Sr-Ca-Cu-O through introduction of pinning centres", *The 1997 International Workshop on Superconductivity Co-sponsored by ISTEC and MRS*, pp 182-183, 1997.
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C. Grantham, J.X. Jin, M.Y. Xue, T. Blackburn, F.M. Rahman and SX Dou, "Micro-cap simulation of a novel high voltage generator", *Proceedings of OPAC*, 1997, pp 587-600.

Y.C. Guo, J. Horvat, H.K. Liu and S.X. Dou, "Improvement of transport properties in Bi-based superconducting tapes through the modification powder and heat treatment", *Physica C* **282-287**, 1997 pp 2595-2596.

Y.C. Guo, H.K. Liu, S.X. Dou and E.W. Collings, "Microstructure and electromagnetic properties Bi2223/Ag wires and tapes prepared by 'continuous tube forming/filling (CTFF)' technique", *Physica C* **282-287**, 1997 pp 2597-2598.

Y.C. Guo, W.G. Wang, H.K. Liu and S.X. Dou, "Effect of Ca_2PbO_4 in precursor powder on the heat treatment of Bi2223/Ag superconducting tapes", *Proceedings of 16th International Cryogenic Engineering Conference / International Cryogenic Materials Conference*, pp 1393-1396, Ed: T Huruyama, T Mitsui and K Yamafuji, Pub: Elsevier Science, Oxford, 1997, ISBN: 0-08-042688-3

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J. Horvat, R. Bhasale, Y.C. Guo, H.K. Liu and S.X. Dou, "Improvement of Flux Pinning by Thermo-mechanical Treatment of Bi-2223/Ag Superconducting Tapes", *Supercond. Sci. Technol.* **10**, pp 409-415, 1997.

J. Horvat, Y.C. Guo, S.X. Dou and H.K. Liu, "Thermo-mechanical treatment of Ag/Bi2223 superconducting tapes on I_c Vs. H at elevated H", *Physica C* **282-287**, 1997 pp 2283-2284.

J. Horvat, Y.C. Guo, R. Bhasale, W.G. Wang, H.K. Liu, S.X. Dou, "Non-Exponential Decrease of Critical Current with Field in Bi-2223/Ag Superconducting Tapes at Elevated Fields", *Physica C*, **277**, pp 183-188, 1997.

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M. Ionescu, V. Murashov and S.X. Dou, "Crystallisation in Bi₂O₃-SrO-CaO-CuO system, and the influence of stoichiometry, and oxygen content on the T_c of Bi-2212 crystals", Physica C **282-287**, 1997 pp 437-438.

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14. SELECTED ABSTRACTS

14.1 High Temperature Superconductors

S. A. Awan, S. Sali, C. M. Friend and T. P. Beales

Study of self-field AC losses in mono and multi-filamentary Bi-2223 tapes at power frequencies

IEEE Transactions On Applied Superconductivity 7 (1997) 335.

The self-field ac losses in mono, 7, 37 and 49 filament tapes near power frequencies are presented. Although the losses in a mono and 37 filament tape showed good agreement with those predicted for a 'strip' and 'elliptical' geometry, respectively, the measured losses in the 7 and 49 filament tapes could not be accurately described by the Norris equations. This difference in loss behaviour can be attributed to the inter-filament connectivity and inhomogeneous J_c distribution in the tapes. Non-linear inductance variation, due to flux linkage with the measuring leads, with applied current, is compared to a model for a homogeneous elliptical conductor and its significance to the corresponding measured ac losses is also discussed.

S. A. Awan, S. Sali, C. M. Friend and T. P. Beales

Self-field AC losses in mono and multi-filamentary Bi-2223 tapes at power frequencies *Cryogenics* 37 (1997) 633.

The measured self-field a.c. losses in mono- and multi-filamentary tapes with varying transport current, frequency and voltage tap configurations are compared to theoretical models. The observed losses are found to approach asymptotic values when the loop of the voltage taps is comparable to the width of the tapes. The measured quadrature electric field is found to be nonlinear with applied current. A model is presented to describe this nonlinearity for homogeneous elliptical and strip geometries. The possible significance of the model to the observed losses is also discussed.

V.P.S. Awana, Rajvir Singh, D.A. Landinez Tellez, J.M. Ferreira, J. Albino Aguiar and A.V. Narlikar

Superconductivity, Synthesis And Magnetism Of $\text{CaLaBaCu}_{3-x}(\text{Zn,Fe})_x\text{O}_7$ Tetragonal System

Physica C 282-287, 1997, p. 779-780

The results of superconductivity, structure and normal state magnetism of the $\text{CaLaBaCu}_{3-x}(\text{Zn,Fe})_x\text{O}_7$ are studied by x-ray diffraction and SQUID magnetization measurements. X-ray diffraction results show that both Zn and Fe substitute isostructurally in $\text{CaLaBaCu}_3\text{O}_7$ system. The superconducting transition temperature T_c of the samples, determined from ac susceptibility measurements, decreases with increasing Zn or Fe concentration. The relative T_c depression rate (dT_c/dx), is larger (12K/at%) for Zn than the Fe (6K/at%) substituted samples. For both the Zn and Fe substituted samples a Curie-Weiss behaviour is observed due to the

presumed creation of local moments on Cu for Zn doped samples, and to the magnetic moment of Fe³⁺/Fe⁴⁺ ions in case of Fe substituted samples.

V.P.S. Awana, D.A. Landinez Tellez, J.M. Ferreira, J. Albino de Aguiar, S.K. Malik, A.V. Narlikar, W.B. Yelon, Rajvir Singh, S. Uma and E. Gmelin,

Superconductivity And Ordering Of Pr In $\text{CaLa}_{1-x}\text{Pr}_x\text{BaCu}_3\text{O}_7$ Compound

Physica C 282-287, (1997), p. 807-808.

We present the results of superconductivity, normal state magnetism, heat capacity and neutron diffraction of the La-site Pr substituted $\text{CaLa}_{1-x}\text{Pr}_x\text{BaCu}_3\text{O}_7$ system. The T_c vs x behaviour of this system appears to be different than that predicted for orthorhombic $\text{La}_{1-x}\text{Pr}_x\text{BaCaCu}_3\text{O}_7$ system. Normal state de magnetic measurements done in an applied field of 5kOe show a Curie-Weiss behaviour in terms of the paramagnetic moment of Pr. The effective paramagnetic moment of Pr appears to be the intermediate between that of the free Pr³⁺/Pr⁴⁺ known moments. For the non superconducting samples, i.e., for $x=0.70$ and 1.0 , we observed an antiferromagnetic ordering temperature T_N of nearly 4K for the former and 8K for the later from our demagnetic and heat capacity measurements. The X-ray and neutron diffraction result show that Pr substitutes isostructurally until $x=1.0$ in $\text{CaLa}_{1-x}\text{Pr}_x\text{BaCu}_3\text{O}_7$ system with a few small intensity lines of unreacted BaCuO_2 and CaCuO_2 . The lower T_N of 8K for $\text{PrBaCaCu}_3\text{O}_7$ than the known 17K for $\text{PrBa}_2\text{Cu}_3\text{O}_7$ is presumably due to the intermixing of Pr and Ba site in the former compound.

V.P.S. Awana, Rajvir Singh, D.A. Landinez Tellez, J.M. Ferreira, J. Albino Aguiar, S. Uma, E. Gmelin, and A.V. Narlikar,

Superconductivity And Magnetic Ordering Of Pr In $\text{CaLa}_{1-x}\text{Pr}_x\text{BaCu}_3\text{O}_7$ System

Mod. Phys. Lett. B vol.11, No.7, (1997) 323-331.

We present the results of superconductivity, normal state magnetic susceptibility and heat capacity measurements on the tetragonal $\text{CaLa}_{1-x}\text{Pr}_x\text{BaCu}_3\text{O}_7$ compound. Ac susceptibility measurements show that the transition temperature T_c of the unsubstituted sample decreases with an increase in the Pr concentration. Normal state de magnetic susceptibility measurements performed in an applied field of 0.5 T show a Curie-Weiss behaviour in terms of the paramagnetic moment of Pr. The effective paramagnetic moment of Pr appears to be intermediate between those of the free Pr³⁺ and Pr⁴⁺ ions. For the nonsuperconducting samples i.e., $x = 0.70$ and 1.0 , we observe an antiferromagnetic ordering temperature T_N of nearly 4K and 8 K respectively. The X-ray diffraction results show that the $\text{CaPrBaCu}_3\text{O}_7$ compound is free from other phases, having a minor (less than 8%, in terms of peak intensity) impurity phase. The lower T_N (8 K) of $\text{PrBaCaCu}_3\text{O}_7$ as compared to the known antiferromagnetic ordering temperature of 17 K for $\text{PrBa}_2\text{Cu}_3\text{O}_7$ indicates a less deleterious effect of Pr in the present case.

V.P.S. Awana, Rajvir Singh, D.A. Landinez Tellez, J.M. Ferreira, J. Albino Aguiar, A.V. Narlikar,

Structure, Superconductivity And Normal State Magnetism Of Calabacu_{3-x}Fe_xO₇ Superconductor

Physica C 277, (1997) P. 265-270.

The results of structure, superconductivity and normal state, i.e. above T_c, magnetism of the CaLaBaCu_{3-x}Fe_xO₇ superconductor, obtained using powder X-ray diffraction and a SQUID (superconducting quantum interface device) magnetometer have been presented. The critical temperature (T_c) of the pristine sample determined from ac susceptibility measurements decreases with Fe concentration. The normal state high field (5 kOe) de magnetism of these samples infers a nearly temperature independent and relatively small molar susceptibility for the x=0.0 sample, while for the Fe doped samples the same follows a Curie-Weiss temperature dependence, in terms of a localized moment presumably on doped Fe ions, The effective paramagnetic moment on Fe in the doped samples appears to be less than known Fe²⁺/Fe³⁺ moments, Namely it is 5.09, 4.53 2.79 and 3.37 mu(beta) respectively for x=0.03, 0.06, 0.12 and 0.24 samples. The reduced moment of Fe is probably due to the presence of crystal field effects in these systems, which has an increasing trend with an increase in Fe concentration.

T. P. Beales, J. Jutson, L. Le Lay and M. Mölgg

A comparison of the powder-in-tube processing properties of two

(Bi_{2-x}Pb_x)Sr₂Ca₂Cu₃O_{10+δ} powders

Journal of Materials Chemistry 7 (1997) 653.

The processing and formation kinetics in air of two commercial (Bi_{2-x}Pb_x)Sr₂Ca₂Cu₃O_{10+δ} powders (Bi_{1.87}Pb_{0.34}Sr_{1.89}Ca_{1.94}Cu_{3.00}O_{10+δ} and Bi_{1.84}Pb_{0.33}Sr_{1.84}Ca_{2.07}Cu_{3.06}O_{10+δ}) in a silver-sheathed tape using the powder-in-tube manufacturing technique has been investigated. The highest concentration of the (Bi_{2-x}Pb_x)Sr₂Ca₂Cu₃O_{10+δ} phase was found to occur at the ceramic-silver interface. The results over a range of times and processing temperatures were fitted to an Avrami equation. In the process range that yielded the optimum volume fraction of (Bi_{2-x}Pb_x)Sr₂Ca₂Cu₃O_{10+δ} the Avrami exponent was found to be $m = 1.2$, indicative of plate-like growth. In this same region the critical current densities were found to be the maximum and show that if the entire ceramic cross section can be processed to have a high volume fraction of the (Bi_{2-x}Pb_x)Sr₂Ca₂Cu₃O_{10+δ} phase, then critical current densities in excess of $5 \times 10^8 \text{ Am}^{-2}$ should be routinely achieved. The difference in physical properties of the two powders was attributed to the different starting morphologies of the powders, which determined the properties of the final product.

T. P. Beales, M. Mölgg, J. Jutson and C. M. Friend

Synthesis and properties of YBaMn₂O_{5+δ}

Physica Status Solidi A, 161 (1997) 271.

We report on the synthesis of YBaMn₂O_{5+δ}, a new double-layered perovskite material having a tetragonal unit cell with $a = 3.9221(3)$ Å and $c = 7.6648(8)$ Å. Magnetic susceptibility measurements show $\chi_{\text{mol}} = (8.9 \pm 0.1 \times 10^{-3})$ emu mol⁻¹ at 300 K which obeyed a Curie-Weiss law ($\theta = -43 \pm 1$ K) down to 166 K (T_N) where a large magnetic transition occurs. Above T_N , a temperature independent $\mu_{\text{eff}} = (4.19 \pm 0.07)$ μ_B was observed, this is attributed to arising from a magnetic lattice with mixed oxidation state with the main ion being high spin Mn^{III} (d⁴) with $S = 2$.

T. P. Beales and J. M. Parberry

The electrical and magnetic properties of the (Bi_{1-y}Cd_y)Sr₂(Y_{1-x}Ca_x)Cu₂O_{7-δ} series

Materials Research Bulletin 32 (1997) 1293.

(Bi_{0.33}Cd_{0.67})Sr₂YCu₂O_{7-δ} can be synthesised single phase by XRD, between 800 to 950 °C. It has a tetragonal structure, space group P4/mmm and lattice parameters $a = 3.802$ Å and $c = 11.96$ Å. The Cd site can be fully replaced with an appropriate M^{II} ion and the Y site can be also be chemically substituted up to 100 % by lanthanide ions with ionic radii falling between those of Nd and Gd with a measurable shift in a and c axis lattice parameters. As synthesised, (Bi_{0.33}Cd_{0.67})Sr₂YCu₂O_{7-δ} is semiconducting and paramagnetic down to 4 K. Superconductivity can be induced by a post-synthesis anneal in high pressure oxygen to give $T_C = 40$ K. Thermopower measurements show that the material is underdoped with $S_{290\text{ K}} = 50$ μVK^{-1} . Introduction of extra charge carriers to raise T_C by doping Ca on the Y site is not chemically possible using the synthesis techniques used.

T. P. Beales, J. D. Johnson and J. M. Parberry

Magnetic and electrical transport properties of (Pb_{0.5}Cd_{0.5})(La_{2-x}Sr_x)CuO_{5-δ}

Superconductor Science and Technology 10 (1997) 502.

(Pb_{0.5}Cd_{0.5})(La_{2-x}Sr_x)CuO_{5-δ} is relatively easily synthesised at temperatures between 750 °C and 900 °C for $x = 1.0 \pm 0.2$. Magnetisation curves show that the strongest Meissner signal and highest T_C occur for $x = 1.0$, with an intragrain J_C for the material of the order of 1×10^9 Am⁻² at 4 K and low field. λ_L is found to be the smallest for the $x = 1.0$ composition with $\lambda_L = 3.8$ μm and 4.4 μm for the applied field orientation along the ab and c axes respectively. The anisotropy ratio (λ_{ab} / λ_c) for all samples is close to 1, showing small anisotropy. Changes in resistivity and in thermopower with x show that the samples are intrinsically highly overdoped with high hole concentrations ≥ 0.2 and close to $T_{C(\text{MAX})}$.

T. P. Beales and J. M. Parberry

The effect of processing on the magnetic properties of $(\text{Pb}_{1-y}\text{Cd}_y)\text{Sr}_2(\text{Y}_{1-x}\text{Ca}_x)\text{Cu}_2\text{O}_7$

Physica Status Solidi A 162 (1997) 689.

We have prepared polycrystalline $(\text{Pb}_{0.5}\text{Cd}_{0.5})\text{Sr}_2(\text{Y}_{1-x}\text{Ca}_x)\text{Cu}_2\text{O}_{7-8}$ ($0.0 \leq x \leq 0.5$) powder samples and determined the single phase region using X-ray diffraction. Substitution of Y for lanthanide elements and Cd for an M^{II} metal with an effective cationic size close to 0.1 nm to produce single phase samples is possible for $x = 0.0$. Superconductivity in $x = 0.0$ samples is optimised ($T_C \text{ max} = 60 \text{ K}$) after a high pressure oxygen anneal. For $x > 0.0$ samples, the single phase region exists up to a value of $x = 0.15$. The highest $T_C = 92 \text{ K}$ occurs at the nominal $x = 0.3$ composition. Rietveld analysis of the $x = 0.3$ material shows the presence of calcium in the rock salt layer resulting in a stoichiometry of $(\text{Pb}_{0.5}\text{Cd}_{0.392}\text{Ca}_{0.108})\text{Sr}_2(\text{Y}_{0.864}\text{Ca}_{0.136})\text{Cu}_2\text{O}_{7-8}$ with $(\text{Ca}_{0.45}\text{Cd}_{0.55})\text{O}$ as an impurity phase.

M. Dhallé, M. Cuthbert, M. D. Johnston, J. Everett, R. Flükiger, S. X. Dou, W. Goldacker, T. Beales and A. D. Caplin

Experimental assessment of the current-limiting mechanisms in BSCCO/Ag high-temperature superconducting tapes

Superconductor Science and Technology 10 (1997) 21.

The current-voltage characteristics and the magnetic field dependence of the critical current of a range of mono-core BSCCO 2223 tapes are presented, illustrating the complementary use of transport and magnetisation experiments in determining and analysing the current-limiting dissipation processes in these HTS conductors. Below a magnetic cross-over field H^* the samples resemble a Josephson-linked current network, with the dominant dissipation at the weakest grain boundaries. In this regime, increasing field leads to a gradual fragmentation of the network. The network homogeneity and connectivity can be inferred from screening current length-scale measurements and comparison of transport and magnetisation measurements. Above the cross-over field H^* , flux motion within the surviving strongly linked backbone dominates the dissipation. The details of the dependencies of the critical current and flux creep rate on magnetic field can be used to examine the intragranular pinning potential in the tapes. We show that, despite the wide range of transport critical-current values of the samples examined, the intragranular pinning proves to be remarkably sample independent. We conclude that while J_c at low fields may be increased by improved processing that yields better intergrain connectivity, the high-field J_c can be enhanced only by strengthening the pinning within the BSCCO 2223 crystallites themselves.

S.X. Dou, P. Mikheenko, X.L. Wang and H.K. Liu

High Temperature Superconductors

Royal Society of Chemistry, Annual Reports, Section C, 93(1997)363-399

The present review gives state of the art of the high temperature superconductivity (HTSC) mainly on the period from the end of 1994 to the beginning of 1996. The

special attention is paid to the new HTSC compounds, their processing and characterization. The related questions of the theory of HTSC, electric and magnetic properties are also reviewed.

S.X. Dou, X.L. Wang, Y.C. Guo, Q.Y. Hu, P. Mikheenko, J. Horvat, M. Ionescu and H.K. Liu

Introduction Of Pinning Centres Into Bi-(Pb)-Sr-Ca-Cu-O Superconductors

Supercond. Sci. Technol. 10(1997)A52-A67

High critical current density (J_c) is essential for most large scale applications of high temperature superconductors (HTS). In addition to the weak link problem, weak flux pinning is a major cause for the rapid decline of J_c with magnetic field at high temperatures. Through intensive research in the past ten years the weak pinning problem has been partially overcome and the J_c has reached a level approaching the requirement for some commercial applications. In this article, a number of techniques by which effective pinning centres can be introduced to improve flux pinning in Bi(Pb)SrCaCuO high temperature superconductors are reviewed. These include surface pinning through a spiral growth, fine precipitates produced through phase transformation or phase-formation-decomposition, inclusions through chemical doping or addition, cascades and columnar defects created by fast neutron and heavy ion beam irradiation and various defects induced by mechanical deformation. In particular, the results of Bi-2223 formation-decomposition and cold deformation vs hot deformation have a significant implication for HTS wire fabrication. Comparative studies with comprehensive electrical, magnetic and microstructural characterisations have been carried out to assess the effectiveness of these techniques.

Improvement of Electromagnetic Properties of Ag-clad Bi-Based Superconducting Tapes Through Process Control

Proceedings of 16th ICEC/ICMC, pp1353-1356, Ed. T. Huryama, T. Mitsui and K. Yamafuji (1997)

Improvement of critical current density of the Ag-clad Bi-based superconducting tapes have been recently achieved through control of initial phase composition, formation of high T_c phase and melting in varying atmosphere. The amount of Ca_2PbO_4 in the precursor powder was found to have a significant effect on sintering temperature and time. Incorporation of Ca_2PbO_4 into $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+x}$ (2212) phase can reduce the duration of $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ (2223) tape process to below 100h. The irreversibility line for the 2212 tape is positioned at higher temperatures than those for the 2212 crystals. The intragranular current declines with increasing magnetic field more rapidly than intergranular current at high temperatures, suggesting that the flux creep controls the critical current at high temperatures.

S.X. Dou, J. Horvat, M. Ionescu, H.K. Liu,
**Irreversibility Behavior Of Different Types Of Bi-(Pb)-Sr-Ca-Cu-O
Superconductors**
Physica C, 281(1997)321-324

Comparative studies on Bi-2212 single crystal, Ag/Bi-2212 tape and Ag/Bi-2223 tape have been carried out using ac susceptibility measurements. The irreversibility line for the Ag/Bi-2223 tape is positioned at higher temperatures than that for the 2212 tape which is in turn positioned at higher temperatures than that for the 2212 crystals. A comparison between multifilamentary Ag/Bi-2223 tapes shows that the position of the irreversibility line shifts from low temperatures to high temperatures in the sequence of hot-pressed, rolled and cold pressed tapes. These results indicate that the defects induced by mechanical deformation act as pinning centres in these tapes, responsible for the improvement in flux pinning.

S.X. Dou, R. Zeng, T.P. Beales and H.K. Liu
A New Method to Substantially Reduce the Processing Time of Ag/Bi-2223 Tapes
Submitted to *Physica C*

Multi-stage thermal cycling is commonly used in the processing of Ag/Bi-2223 tapes requiring a total annealing time often in excess of 100 hours, which is very undesirable for large scale production. A new process was investigated that reduced the heat treatment time for Ag/Bi-2223 tapes. In this process, the tape was quenched at the end of the first thermal cycle. Following either pressing or rolling, these were rapidly heated to the sintering temperature. In doing so, the usual decomposition and recovery of Bi-2223 during cooling and heating was eliminated, along with a reduced formation time for Bi-2223. By using this new procedure, the zero-field J_c and the Bi2223 volume fraction in tapes sintered for a total time of 20 to 30h were comparable to those treated for 100h using a conventional process. The results further confirm that a low temperature annealing at 825°C in the end of the last thermal cycle eliminates residual 2201 and hence improves J_c . It was also found that tapes, containing a large number of filaments had a higher Bi-2223 volume fraction and exhibited a better J_c vs. H performance than for tapes with a small number of filaments, when both were processed for the same time period.

S.X. Dou
**Optimization Of Processing To Improve Critical Current Density Of Ag/Bi:2223
Tapes**
*To be presented at International Symposium of HTS held at Wagga Wagga 2nd o 4th Feb
1998*

Because of the extremely complicated chemical and phase composition, chemical reaction and microstructures processing of Ag/Bi:2223 tape has presented a great challenge to HTS community. Although enormous effort has been made to improve the materials processing in last decade a number of critical issues on processing are not well understood. It is commonly accepted that understanding and improving the materials

processing is the key to further improvement of critical current density of Ag/Bi:2223 tape. In this talk, based on the understanding of phase relation and reaction, a number of important processes recently developed by UoW group in collaboration with MM Ltd consortium will be presented. A two-stage annealing procedure in the final thermal cycle has been developed to eliminate the residual 2201 phase which has been identified to be one of the major causes of weak links in the tape. Annealing at temperatures below 800°C results in a rapid decomposition of Bi:2223 to 3221. I_c declines monotonically with increasing 3221, indicating that 3221 acts as weak links in the tape. By incorporating Pb into Bi-2212 phase the sintering temperature can be raised to above 840°C, resulting in a significant reduction of sintering time from several hundred hours to 120h. Recently, a new process to eliminate the decomposition and recovery of Bi-2223 during cooling and heating was developed that further reduced the heat treatment time for Ag/Bi-2223 tapes to 20 to 30h while the J_c and the Bi:2223 volume fraction in tapes were comparable to those treated for 120h. By combining the cold deformation, hot-deformation and two-step process a high J_c of 57,000 A/cm² with high I_c of 36.6A at 77K has been achieved in multifilamentary tapes.

C. M. Friend, S. A. Awan, L. Le Lay, S. Sali and **T. P. Beales**

Explaining the self-field AC loss behaviour of silver-clad (Bi,Pb)-2223 tapes for power engineering applications

Physica C 279 (1997) 145.

The ac losses of mono- and multi-filamentary (Bi,Pb)-2223 silver-sheathed tapes due to an applied ac current have been measured. The data are compared to the Norris equations for the ac loss of elliptical and thin-strip superconductors. Reasons for the observed differences between theory and measurement for these tapes and others in the literature are discussed. It is suggested that the main factors determining the self-field ac loss in such practical superconductors are the *transverse J_c distribution* in monofilaments and the *filament distribution* in multifilamentary tapes. For the latter, evidence is provided that tapes with filaments arranged in columns have a lower loss. For the development of low loss conductors for power applications these factors need to be accurately controlled over long lengths - requiring much improvement to existing processing techniques.

C. M. Friend, L. Le Lay and **T. P. Beales**

Current connectivity in Bi-2223 silver-sheathed tapes for power cables

IEEE Transactions On Applied Superconductivity 7 (1997) 1821.

The mechanism limited the transport critical currents of long-length (Bi,Pb)₂Ca₂Cu₃O_x tapes is still debatable. Such knowledge is important for improving the current performance of tapes for their use in superconducting applications. Transport and magnetic measurements have been used to study the current connectivity in tapes fabricated for power cable prototypes. The field dependence does not clearly distinguish between the different mechanisms of connectivity but is a useful parameter for characterising these tapes, even if they may be operated only in very low fields.

Future improvements will come from better processing control and for operation at 77K the intragranular pinning may need to be increased.

C. M. Friend, L. Le Lay, **T. P. Beales**, M. Penny and C. Beduz

Intergranular coupling and secondary phases in $(\text{Bi}_{2-x}\text{Pb}_x)\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$ / Ag tapes

Proceedings of 16th International Cryogenic Engineering Conference / International Cryogenic Materials Conference" vol. 3, p 1541, Ed: T. Huruyama, T. Mitsui and K. Yamafuji, Pub: Elsevier Science, Oxford (1997).

Intergranular coupling in $(\text{Bi}_{2-x}\text{Pb}_x)\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ /Ag tapes has been investigated using ac susceptibility and dc magnetisation measurements. The differential of the zero-field cooled dc moment with temperature was used to identify changes in coupling between grains. Some grains were decoupled even in very small external fields (≥ 1 mT) and across a wide range of temperatures. The possible role of secondary phases located at grain boundaries is discussed.

X.K. Fu, Y.R. Zhou, W. Lin, P. W. Hua, **R. Zeng** X.H. Wang S. Chang, X. Wang, S. Chang, N. Song, P. Ye, G. Yuan, L.Z. Lin

The effect of processing parameters on property of Bi(2223) current lead,

Physica C 282-287(1997)2651

The Bi(2223) current leads were fabricated by C.I.P. method (Cold-isostatic-pressing). The purpose of this paper is to analyze the effect of processing parameters on the critical current density. The materials of Bi(2223) current leads have been investigated by X-ray diffraction and SEM in order to study the phase structure and morphology. The maximum value of critical transport current density for bar current leads reached as high as $480\text{A}/\text{cm}^2$ at 77K.

Y.C Guo, J. Horvat, H.K. Liu, and S.X. Dou

Improvement of transport properties in Bi-based superconducting tapes through the modification of precursor powder and heat treatment

Physica C 282-287(1997) 2595-2596

By controlling the sintering temperature and time, Bi2223 precursor powders containing small and large amount of Ca_2PbO_4 were prepared. Multifilamentary tapes were fabricated using both powders and heat treated with parameters optimized to each powder. It was found that, compared to the tapes made from powder with large Ca_2PbO_4 content, tapes made from powder with small Ca_2PbO_4 content had much higher optimal sintering temperature and shorter optimal sintering time. Electrical measurements show that the later powder resulted in an improved J_C dependence on magnetic field and increased fraction of strong links between grains. $I_{C(1T)}/I_{C(0T)}$ of 26% at 77K and strong links fraction of 40% achieved for tapes made from powder with small amount of Ca_2PbO_4 , which are 18% and 25% respectively for tapes made from powder containing large amount of Ca_2PbO_4 .

Y.C Guo, H.K. Liu, S.X. Dou and E.W. Collings

Microstructure and electromagnetic properties of Bi2223/Ag superconducting wires and tapes prepared by the “continuous tube forming/filling (CTFF)” technique

Physica C 282-287(1997)2597

The “Continuous Tube Forming/Filling (CTFF)” technique is a novel process for manufacturing silver sheathed superconducting wires in which powder is continuously fed onto a long silver strip and the silver strip is then wrapped into a tube, forming superconductor/silver wire. In our previous paper [1], we reported results on the processing and heat treatment of Bi2223/Ag wires and tapes produced by the CTFF technique. In this paper, results on the microstructure and electromagnetic properties of CTFF-processed tapes are presented. The microstructural properties examined include core/Ag interface, grain alignment, density and impurity inclusions. Critical current (I_c) dependence on magnetic field, voltage-current characteristics and weak and strong links were investigated. All the results obtained were related to the features of the CTFF process.

S.Q. Guo, **R. Zeng**

Are There Lorentz-force-independent Critical Current in Bi(2223)/Ag Tape

Physica C, 282-287(1997)2269

The I_c of Bi(2223)/Ag tape has been measured at temperature 4.2K and 77K in magnetic field up to 7T. Both the field and current are in ab plane, the sample can be rotated the c-axis. So the measurements were made for variable Lorentz-force. All of the experimental data show that the I_c looks like Lorentz-force-independent. This phenomenon can be explained probably in terms of some micro-part current along c direction. The flux pinning and moving mechanism still play a major role in the critical current of Bi(2223)/Ag tape.

J. Horvat, W. G. Wang, R. Bhasale, Y. C. Guo, H. K. Liu and S. X. Dou,

Critical Currents in Ag/Bi-2223 superconducting tapes: grain connectivity and flux pinning

Physica C 275 (1997)327-332

Critical current (I_c) was measured for a large number of different Ag/Bi-2223 tapes at 77K, with field H perpendicular to the tape plane. I_c vs. H shows weak and strong link regimes. Critical current through strong links (for $H > 100$ mT) was described by: $I_c^s(H) = I_{c0}^s \exp(-(H/H_0)^{n+1})$. It was shown that I_{c0}^s/I_{c0} is correlated with critical current density (J_{c0}) and it can be used as a reliable parameter for determining the quality of the links between the grains. A method for obtaining accurate values of I_{c0}^s/I_{c0} was presented. I_{c0}^s/I_{c0} increases with J_{c0} and attains a constant value of about 0.36 for $J_{c0} > 20$ kA/cm². Similarly, normalized critical current for a parallel field of 1T ($I_c(1T)/I_{c0}$) increases with J_{c0} and reaches a constant value of about 0.2 for $J_{c0} > 20$ kA/cm².

J. Horvat, Y. C. Guo, R. Bhasale, W. G. Wang, H. K. Liu and S. X. Dou,
**Non-exponential decrease of critical current with field
in Bi-2223/Ag superconducting tapes at elevated fields**
Physica C 277 (1997) 183-188

Non-exponential decrease of critical current (I_c) with magnetic field (H) was studied for a variety of Bi-2223/Ag superconducting tapes. The measurements were performed by a four-probe dc method using $1\mu\text{V}/\text{cm}$ criterion. The field dependence of I_c at elevated fields was described as: $I_c = I_{c0} \exp[-(H/H^*)^{a+1}/(a+1)]$, where H^* is the field of the peak of the pinning force density and a is a positive parameter responsible for the non-exponential behaviour. Values for both, H^* and a were obtained from experimental data. It was shown that a decreases with improvement of the texture of the grains and the quality of the links between the grains, but increases with flux pinning. The former factor influences a more strongly than the latter. Experimental results give support to flux entanglement as a source of the non-exponential behaviour.

J. Horvat, R. Bhasale, Y. C. Guo, H. K. Liu and S. X. Dou
**Improvement of flux pinning by thermo-mechanical treatment of Bi-2223/Ag
superconducting tapes**
Supercond. Sci. Technol. 10(1997)409-415

Measurements of transport critical current (I_c) in magnetic field (H), hysteresis loops and ac susceptibility were performed on Bi-2223/Ag tapes that were subjected to different degree of mechanical deformation and subsequently sintered. I_c vs. H for some of the tapes was also measured at different stages of thermo-mechanical treatment. All the measurements (the field of the peak of the pinning force, irreversibility field obtained from hysteresis loops and the temperature of the peak of ac susceptibility for different dc fields) clearly show an increase of the pinning with the degree of mechanical deformation. Measurements of samples at different stages of thermo-mechanical treatment indicate that the pinning depends not only on the degree of mechanical deformation, but also on the conditions of the grain growth. It is proposed that sintering can provide imperfect healing of micro- and nano-cracks, introduced upon mechanical deformation, and result in improved pinning.

J. Horvat, Y. C. Guo and S. X. Dou
**Difference in mechanical properties of weak and strong links in Bi-2223/Ag
superconducting tapes**
Physica C, in press

Transport critical current (I_c) was measured as a function of magnetic field (H) at 77K, for Bi-2223/Ag tapes which were progressively bent. The field was perpendicular to the tape plane. Proportion of critical current through strong links in total I_c (I_{c0}^s/I_{c0}) was used as a measure of grain connectivity by strong links (J. Horvat et al., *Physica C* 275 (1997)327). It was found that I_{c0}^s/I_{c0} changes with bending, going through a peak as the tapes progressively bend. A change of flux pinning with bending was also observed. However, the effect of the change of flux pinning on I_{c0}^s/I_{c0} was only a minor one.

Therefore, change of I_{c0}^s/I_{c0} with bending is defined by grain connectivity and it reflects qualitatively different electromagnetic and mechanical properties of weak and strong links. This is in agreement with previous studies of electromagnetic properties and formation of weak and strong links.

J. Horvat, Y. C. Guo, B. Zeimetz, H. K. Liu and S. X. Dou

Improvement of grain connectivity in Bi2223/Ag tapes by reducing Bi2201 phase at grain boundaries

Physica C, in press

The critical current of Bi2223/Ag tapes with different secondary phase content was measured in an applied magnetic field at 77K. The phase content was altered using different cooling rates after the final sintering, or by using an additional sintering stage at a lower temperature. The difference in strong link grain connectivity in the tapes was obtained by extracting strong link critical current (I_{c0}^s) from the I_c vs. H curves. Flux pinning was monitored via the field of the peak of pinning force density. Secondary phase content was assessed using X-ray diffraction. SEM analysis was used to study the secondary phase distribution and microstructure in the tapes. Normally prepared tapes showed an initial increase of normalized I_{c0}^s with J_{c0} . For $J_{c0} > 20 \text{ kA/cm}^2$, however, normalized I_{c0}^s saturated at about 35% (Physica C 275 (1997) 327), while tapes with low Bi2201 content did not show this saturation of normalized I_{c0}^s . This resulted in a substantial improvement of field dependence of I_c over conventional PIT tapes. For the field direction parallel to the tape plane, 28% of I_{c0} was retained at 1T. SEM analysis revealed that the Bi2201 was located between the grains. It is suggested that by removing Bi2201 from low angle tilt boundaries, a higher number of strong links was formed in the tapes.

Q. Y. Hu, H. K. Liu, S. X. Dou

Fabrication of Ag sheathed Bi2223 tape with supercold rolling process

Physica C 274(1997)204

A novel mechanical deformation process has been developed to fabricate high quality HTS tapes. In this process, the rolling step in the powder in tube technique is replaced by a supercold rolling conducted in liquid nitrogen. The critical current density of the Ag sheathed Bi2223 tapes is significantly enhanced by the super cold rolling. The microstructure observations of the tapes demonstrate that the supercold rolled tape has higher mass density and better grain alignment than the room temperature rolled tape, which are responsible for the high critical current density.

Q. Y. Hu, H. K. Liu, S. X. Dou, M. Apperley

Microstructure and Critical Current of Hot-Pressed $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$

Transactions on Applied Superconductivity 7(1997)1849

After being sintered for different times, $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$ bulk samples were pressed isothermally at 850C under constant pressure of 15 MPa for 1 hour. The

samples were examined using SEM, EDS, XRD, and the mass density, critical temperature (T_C) and critical current density (J_C) were measured. As a result of removing voids in the materials under pressure and high temperature, it was found that the mass density significantly increased. In addition to high mass density, grain alignment within the samples was also improved which produced a significant improvement in the J_C . To achieve high J_C , samples require sintering prior to hot pressing for a reasonably long time.

M. Ionescu, V. Murashov, and S. X. Dou

Crystallisation in Bi_2O_3 -SrO-CaO-CuO System, and the Influence of Stoichiometry, and Oxygen Content on the T_c of Bi-2212 Crystals

Physica C, vol. 282-287, 437-438, (1997)

The homogenous crystallisation zones in the $1/2\text{Bi}_2\text{O}_3$ -SrO-CaO-CuO system were investigated in air, by melt-solidification. A large number of powder precursors having different cation compositions were melted in yttria stabilised zirconia crucibles, and slowly (5°C/h) cooled in an axial temperature gradient of -60°C/cm . The size, morphology, and the transition temperature of the grown crystals led to the determination of the homogenous crystallisation volume of the main superconducting phases. The Bi^{3+} , Sr^{2+} , and Ca^{2+} cation inter-substitution provided a way to increase the T_c of this phase up to 95-96K, without the contribution of yttrium. For some Bi-2212 crystals, the oxygen content was determined, and correlated with the transition temperature of this phase.

M. Ionescu, B. Zeimetz, and S. X. Dou

Microhardness Anisotropy of Bi-2212 Crystals

Physica C, in press

The microhardness of a high quality Bi-2212 crystal, grown by using the temperature gradient, method was measured with the direction of the applied force parallel, and perpendicular to the (a,b) crystallographic plane. The measurement was carried out using a technique which is capable to monitor both the applied force, and the displacement of the indenter relative to the sample surface. A maximum force of 10mN was used, applied in 20 steps in a square root sequence on a diamond pyramid indenter, having a tip radius of $1\mu\text{m}$. From the load-unload cycle, a number of physical parameters of the Bi-2212 phase were deduced: Young's modulus, Poisson's ratio, the yield strength in compression, the elastic recovery rate, and the energy loss during the indentation process. The results show a strong hardness anisotropy between the two directions of the applied force: 3.78GPa for the applied force perpendicular, and 0.78GPa for the applied force parallel to the (a,b) crystallographic plane.

H. Jhans, S.K. Malik, V.P.S. Awana, W.B. Yelon,
Superconductivity And Magnetism In The System $Y_{1-x}Pr_xBa_{1.5}Sr_{0.5}Cu_3O_7$
J. Appl. Phys. 81(8), (1997), 4247-4249.

The results of superconducting and magnetic studies on the $Y_{1-x}Pr_xBa_{1.5}Sr_{0.5}Cu_3O_7$ -delta system with $0 \leq x \leq 1.0$ are reported. Superconducting transition temperature (T_c) decreases with increasing x . The behavior of $T_c(x)/T_c(0)$ versus Pr concentration x in this system is similar to that observed in the $Y_{1-x}Pr_xBa_2Cu_3O_7$ -delta system but the critical Pr concentration (x_{cr}) required for complete suppression of superconductivity appears to be higher in the present system. Surprisingly, the Neel temperature T_N of $PrBa_{1.5}Sr_{0.5}Cu_3O_7$ -delta is found to be higher (similar to 21 K) than that for $PrBa_2Cu_3O_7$ -delta (similar to 17 K) with nearly the same oxygen content. This may imply stronger interaction of Pr-4f moments with the carriers in the Cu-O-2 planar network in the present system and yet the T_c suppression is relatively weaker. (C) 1997 American Institute of Physics. [References: 26]

J. X. Jin, S. X. Dou, H. K. Liu, C. Grantham, Z. J. Zeng, Z. Y. Liu and T. R. Blackburn
X. Y. Li, H. L. Liu and J. Y. Liu

Electrical Application of High T_c Superconducting Saturable Magnetic Core Fault Current Limiter

IEEE Transactions on Applied Superconductivity, 1997, Vol. 7, No. 2, pp. 1009-1012.

A saturable magnetic core electrical fault current limiter (FCL) designed with a high T_c superconducting (HTS) dc bias winding is described. The HTS winding is prepared by using a Ag-clad $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+x}$ HTS wire. The limiting behaviour of this FCL is investigated, and its electrical application is considered in an electrical power transmission system. The results show that this FCL limits fault currents effectively, and is a possible solution for reducing power system fault currents.

J. X. Jin, S. X. Dou and H. K. Liu, C. Grantham

High Voltage Generation with a High T_c Superconducting Resonant Circuit

IEEE Transactions on Applied Superconductivity, 1997, Vol. 7, No. 2, pp. 881-884.

An electronic resonant circuit is introduced with the consideration of using an inductor made by a Ag-clad $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+x}$ HTS wire. With this inductor, substantially higher voltages compared with using normal copper winding inductor can be built up by the circuit. Therefore this method can be used to generate high voltages with the HTS inductor from a low voltage source. An electronic controller has been built and used for the testing, and the resonant circuit, using the HTS inductor, is analyzed.

J.X. Jin, S.X. Dou, C. Grantham, Y.C. Guo, V. Murashov, B. Zeimetz, M.Y. Xue, M. Ionescu, J. Horvat, H.K. Liu, M. Apperley, F. Darmann and A.C.G. Secrett

**Preparation Of High T_c Superconductors
For Electrical Applications**

Proceedings of the Australasian Universities Power Engineering Conference / Institution of Engineers Australia Electric Energy Conference (AUPEC'97 / EECON'97), Australia, 29 September - 1 October 1997, Vol. 3, pp. 453-458. (ISBN: 0 7334 1594 6)

High T_c superconductors (HTSs) have been developed since 1986. The successfully produced HTSs, especially the Ag clad Bi-based HTS wire, with long length, high critical current density and mechanical flexibility, has demonstrated a potential to be operated at 77 K liquid nitrogen temperature for some electrical applications. This paper introduces studies on the HTSs with regard to their electrical applications developed in Australia. The Ag clad $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ HTS wires and $\text{Y}_1\text{Ba}_2\text{Cu}_3\text{O}_{7-x}$ bulk materials are introduced with respect to their use for various electrical applications. Some applications introduced include a HTS coil for a winding and a magnet, an electrical fault current limiter, an electronic high voltage generator device, high current leads, and a HTS levitator.

J.X. Jin, H.K. Liu and S.X. Dou, C. Grantham

A High T_c Superconducting Liquid Nitrogen Level Sensor

Accepted by the Proceedings (CD-ROM) PacRim 2 (Australia, July 15th - 17th, 1996).

The dramatic resistance change in the superconducting-normal transition temperature range enables a high T_c superconductor (HTS) to be considered for use as a liquid nitrogen level sensor. The $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ Ag clad HTS wire has approximately 110 K critical temperature, with more flexible and stable properties compared with bulk shape ceramic high T_c superconductors. A $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ Ag clad HTS wire is tested as a continuous liquid nitrogen level sensor to investigate the possibility for this application.

J.X. Jin, H.K. Liu and S.X. Dou

Magnetic Separation Techniques And Hts Magnet

To be presented at International Symposium of HTS held at Wagga Wagga 2nd o 4th Feb 1998.

Magnetic separation techniques have been widely used, and the separation efficiency is related to the strength of the magnetic field applied and the field gradient to trap the magnetic particles. Conventional low T_c superconducting wire has been used to increase the field and to reduce normal electromagnetic winding resistive loss, and now the Bi-2223/Ag HTS wire provides a new opportunity for higher magnetic field and efficiency for use in a high gradient magnetic separator as the magnetic field winding. Magnetic separation techniques are reviewed with regard to their magnetic fields, and the magnetic field winding required for this application is analyzed with the consideration of using the HTS wire.

Jian-Xun Jin, Shi-Xue Dou, Tim Beales and Miles Apperley

On Using $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}/\text{Ag}$ Tape To Make A Toroidal Coil

To be presented at International Symposium of HTS held at Wagga Wagga 2nd o 4th Feb 1998.

High T_c superconducting (HTS) $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}/\text{Ag}$ multifilamentary tape, was used to prepare an HTS toroidal coil. Magnetic field behaviour of the HTS coil is studied for this toroidal configuration. The magnetic field distribution of the HTS coil is investigated for use at 77 K and 4.2 K with the anisotropic HTS wire having strong magnetic field dependent critical current. Since the magnetic field component along the HTS wire c-axis is significantly reduced in the form of a toroid, it is suitable to make a high ampere-turn or high inductance coil with the present HTS $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}/\text{Ag}$ tape having anisotropic transport property.

J. X. Jin, C. Grantham, H. K. Liu and S. X. Dou

A Bi-2223/Ag High T_c Superconducting Coil And Its Magnetic Field Properties

Philosophical Magazine B, 1997, Vol. 75, No. 6, pp. 81-826.

High T_c superconducting (HTS) $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ Ag clad multifilament wire, is used to prepare a HTS coil. This anisotropic HTS wire has strong magnetic field dependent critical current, which causes critical current degradation when used in the form of a coil. The magnetic field behaviour of the HTS coil is studied with respect to its critical current and magnetic field properties. Experiments carried out include magnetic field measurements of the HTS coil, DC magnetic field, AC magnetic field, and critical current ampere-turns when used as a magnetic core bias winding. The magnetic field distribution of the HTS coil is also investigated with a magnetic field analysis program. The experimental results and analysis provide basic information for design and operation of a HTS coil made from the anisotropic HTS $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ Ag clad wire.

M. D. Johnston, J. Everett, M. Dhallé, A. D. Caplin, C. M. Friend, L. Le Lay,

T. P. Beales, G. Grasso and R. Flükiger

Current and field distribution within multifilamentary Bi2223/Ag tapes

IEEE Transactions On Applied Superconductivity 7 (1997) 1339.

The magnetic self-flux distribution around high current mono- and multi-core BSCCO 2223 tapes with various filament configurations has been measured with a scanning micro-Hall probe. Using a simple model, the measured field component perpendicular to the tapes was deconvoluted to give an estimate of the way the transport current distributes itself across the width of the tape. From the changes in flux profile as the applied transport current is varied, the current distribution across the width of the tape can be inferred. In the untwisted tapes, the outer filaments tend to screen the inner ones and carry the bulk of the current; in a twisted sample, the current is shared more equally between filaments.

Lang, W.; Heine, G.; Liebich, W.; Wang, X.L.; Wang, X.Z.

Magnetoresistance in HTSC far above T_c: fluctuations versus normal-state contributions

Fluctuation Phenomena in High Temperature Superconductors. Proceedings of a NATO Advanced Research Workshop, p. xi+441, 81-90, 1997

We discuss the temperature dependence of the anisotropic magnetoresistance in high temperature superconductors with a focus on the magnetoresistance at temperatures significantly above T_c. Recent results on YBa₂Cu₃O_{7-δ} thin films and single crystals are analyzed and measurements of the in-plane and out-of-plane magnetoresistance in optimally doped Bi₂Sr₂CaCu₂O_{8+x} single crystals are reported. The in-plane magnetoresistance of both YBa₂Cu₃O_{7-δ} and Bi₂Sr₂CaCu₂O_{8+x} is positive for magnetic fields oriented perpendicular and parallel to the current. The out-of-plane magnetoresistance of Bi₂Sr₂CaCu₂O_{8+x} is negative from 94 to 180 K. The results are discussed considering the magnetic-field suppression of superconducting fluctuations including the Aslamazov-Larkin and Maki-Thompson terms, the normal-state magnetoresistance of quasiparticles, and the reduction of the quasiparticle density of states due to condensation into superconducting fluctuations. A crossover from fluctuation-induced in-plane magnetoresistance close to T_c to the quasiparticle effect was found around 1.25T_c. The out-of-plane magnetoresistance is dominated by the density-of-states contribution. All results indicate that superconducting fluctuations persist up to at least 2T_c.

L. Le Lay, C. M. Friend and T. P. Beales

Fabrication and performance of long Bi-2223 composite tapes

Cryogenics 37 (1997) 583.

Recent advances in the performance of multifilamentary silver-sheathed Bi-2223 tapes made at BICC Cables are reported. 7 and 19-core multifilamentary tapes of up to 100 metres in length have been fabricated by the oxide-powder-in-tube process using conventional manufacturing techniques. Individual filaments appear to have regular shape in the case of the 19-core tapes and the sheath-oxide interface is smooth. Transport critical currents of 23 A over 5 cm and 12 A over 99 m have been measured (77 K, 0 T). The critical current varies by about 10 to 15% along the tape length over 90 m and engineering critical current densities of over 2,000 A/cm² were measured over 99 m. Such performances now allow the construction of transmission power cable prototypes.

S. Li, Q.Y. Hu, H.K. Liu, S.X. Dou and W. Gao

The grain alignment of Bi₂₂₂₃, Bi₂₂₁₂ and Bi₂₂₂₃ + Bi₂₂₁₂ phases in mechanical deformation and annealing processes

Physica C 279(1997)265

It is believed that the grain alignment of oxide superconductors plays an important role in improving the critical current density. Although mechanical deformation and thermal treatment are widely used to produce grain alignment in the BSCCO system, the

alignment mechanisms have not been well understood. The present work studies the grain alignment behaviours of Bi2223, Bi2212 and Bi2223 + Bi2212 compounds using X-ray diffraction. Results indicate that the effects of mechanical deformation on the grain alignment of Bi2212 and Bi2223 phases during the fabrication process of Bi2223 superconductors are quite different. Heavy deformation produces a high degree of grain alignment for Bi2212 in the early stage of Bi2223 fabrication but not for the Bi2223 phase in later stages. The subsequent annealing clearly improves the grain alignment for Bi2223, Bi2212 and Bi2212 + Bi2223. Based on these experimental results, optimal mechanical-thermal processes were suggested for BSCCO superconductor fabrication.

S. Li, W. Gao, Q.Y. Hu, H.K. Liu, S.X. Dou

The effect of silver sheath on annealing texture of $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ superconductor tapes

Physica C 276(1997)229

It is believed that, in BSCCO tapes, silver can promote phase transformation from Bi2212 to Bi2223, but the effect of the silver sheath on the texture formation of Bi2223 is not clearly understood. The present paper studies the effect of silver sheath on grain alignment of Bi2223 superconductors. Results indicate that the silver sheath serves as a wall that restricts the outward growth of the Bi compound, and also promotes the recrystallisation and growth of the *a-b* plane oriented Bi2223 grains. Based on the experimental results, the mechanisms of annealing texturing with the presence of silver sheath are discussed. This understanding can be used to control the microstructure of high temperature superconductors in an effort to improve their critical current density.

S. Li, M. Bredeh`ft, Q.Y. Hu, H.K. Liu, S.X. Dou and W. Gao

The effect of annealing and mechanical deformation on the grain alignment of $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+x}$ superconductors

Physica C 275(1997)259

Mechanical deformation and annealing treatments are widely used in the processing of $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+x}$ superconductor wires to produce grain alignment. Annealing texture has been suggested as one of the possible grain alignment mechanisms, but very little experimental evidence and understanding have been reported. The present paper reports a detailed study of the relationships of mechanical deformation, annealing, grain alignment and grain size in Ag-sheathed Bi2223 tapes. Results indicated that (1) the (00 l) grain alignment on the specimen surface after annealing is considerably higher than before annealing, (2) the surface grain alignment decreases with increasing mechanical deformation, and (3) the grain size after recrystallization decreases with increasing mechanical deformation. Based in the experimental results, the mechanisms of annealing/recrystallisation induced grain alignment were discussed. This understanding can be used to control the microstructure of high temperature superconductors in order to improve their transport properties.

H.K Liu, J. Horvat, R. Bhasale, Q.Y. Hu and S.X. Dou, K.H. Muller, C.Andrikidis
Effect on Critical Current Density and Irreversibility Behaviour of Mechanical Deformation of Bi-(Pb)-Sr-Ca-Cu-O Superconducting Tapes
Transactions on Applied Superconductivity 7(1997)1841

Comparative studies on the Ag-clad 27-filamentary Bi-2223 tapes deformed under different conditions have been carried out using ac susceptibility and critical current measurements. Hot pressing improves the grain alignment and grain connectivity, resulting in a noticeable improvement in the critical current density in the low field region. However, the irreversibility line for cold pressed Ag/Bi-2223 tape is positioned at higher temperatures than that for the rolled tape which is in turn positioned at higher temperatures than that for the hot pressed tape. These results indicate that the hot deformation is only beneficial to the improvement of weak links whereas the cold deformation induces defects which act as pinning centres in these tapes, responsible for the improvement of flux pinning.

H.K Liu, R.K. Wang, X.H. Wang, R. Bhasale, S.X. Dou
TEM study of Ag-clad Bi-based (2223) Multifilamentary Tapes in Various Stages of Processing
Physica C 282-287(1997) 2587

The microstructures of 27-filament BPSSCO 2223 tapes in various heat treatment stages have been studied by using TEM. It is found that there are nearly no dislocations in the tapes sintered for initial 60 h, dislocation densities of 10^{11} /cm² at grain boundaries and 10^8 /cm² in the grains for the tapes sintered for 140 h and rolled once, the average dislocation density of 10^{12} /cm² at the grain boundaries for the tapes sintered for 220 h and rolled twice, misarrangement of (001) atomic planes 2223 grains and subgrain boundaries in 2223 colonies for the tapes sintered for 300 h and rolled three times. The results indicate that the repetitive rolling and sintering for 220 h is the optimum process for fabrication of tape since it shows the maximum dislocation density and optimum phase purity of 2223 phase.

H.K. Liu, R. Bhasale, Y.C. Guo, J. Horvat, W.G. Wang, and S.X. Dou
Effect Of Final Annealing Temperature On Critical Current Density Of Ag/Bi-(Pb)-Sr-Ca-Cu-O Tapes
To be published in *Applied Superconductivity*

A two-stage annealing procedure in the final thermal cycle has been tested for processing Ag/Bi:2223 tapes. The effect of various annealing temperature in the final stage of heat treatment on phase transition, microstructure and critical current (I_c) was investigated for Ag/Bi:2223 tapes. It was found that annealing at higher temperatures (835 to 845°C) leads to a relatively purer Bi:2223 phase but a small fraction of Bi:2201 always coexists with Bi:2223. Whereas annealing at lower temperatures (800 to 825°C) results in conversion of Bi:2201 to Bi:2212 and possibly partial decomposition of Bi:2223. I_c was reduced to half for tapes annealed at 835 to 845°C due to the presence of Bi:2201 compared with tapes annealed at low temperatures. SEM study shows that although the

amount of Bi:2201 is small, it resides along the Bi:2223 colony boundaries, blocking the current flow between colonies. The drastic weak link effect of Bi:2201 is attributable to the combination of the elongated plate-like morphology and insulating property.

P.N.Mikheenko, J.Horvat, M. Ionescu, S.X.Dou

Two-dimensional effects in ac losses of $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_x$ tapes

Physica C, vol 274, N 1/2, 1997, p. 9-16.

Two new effects: the existence of the limiting temperature for constant AC losses with the increase of magnetic field and a node point of minimum AC losses give a clear evidence of predominant two-dimensional nature of dissipation in $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_x$ tapes. The effects are explained in the assumption of exponential suppression of Josephson interaction in two types of stacks containing two and three well-connected unit-cells. Superconducting layers of isolated unit-cells are intact in magnetic field which leads to saturation of the temperature of constant losses at non-zero value. The stacks with more than three unit-cells behave in the same way as the ones with three unit cells. Suppression of Josephson interaction in stacks up to separation of superconducting layers, and the increase of eddy current losses in Ag sheath give the node point of AC losses in Ag-sheathed tapes near the temperature of Kosterlitz-Thouless transition of single superconducting layer.

P N Mikheenko, J Horvat, Q Y Hu, M Ionescu and S X Dou

Grain-boundary links and critical current of $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_x/\text{Ag}$ tapes

Superconductor Science Technology, 10, N6, 444-449, 1997.

The nature of grain-boundary links in the high quality $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_x$ tapes is clarified. The investigations are focused on the role that various types of links play in the restriction of the critical current. The multiple exponential function is found to be a good approximation for the magnetic field dependence of critical current $I_c(H)$. The behavior of $I_c(H)$ at different temperatures gives clear evidence of two-dimensional character of critical current. It is shown that at all temperatures higher than Kosterlitz-Thouless transition temperature of isolated superconducting layer the critical current is totally defined by the Josephson interaction between the layers.

P. N. Mikheenko, J. Horvat, M. Ionescu and S. X. Dou

Reflection of two-dimensionality on the temperature dependence of AC susceptibility

Physica C, 282-287, p. 1991-1992, 1997.

The reflection of two-dimensionality on the temperature dependence of the imaginary part of magnetic susceptibility (χ'') of $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_x/\text{Ag}$ tapes is observed. It is found that the two-dimensional character of $\chi''(T)$ is the consequence of the presence of low-number stacks of CuO_2 layers in the intergranular boundaries of the tapes.

P. N. Mikheenko, M. Ionescu, J. Horvat and S. X. Dou

Two-peak structure of AC susceptibility of Bi₂Sr₂CaCu₂O_x tapes

Physica C, 282-287, p. 2621-2622; p. 877-878, 1997

An additional broad peak in the imaginary part of AC susceptibility of Bi₂Sr₂Ca₁Cu₂O_x tapes is observed. Using the model of separated stacks, it is found that the peak reflects the near grain boundary intergrowths of Bi₂Sr₂CuO_x. Kosterlitz-Thouless transition temperatures of different stacks for Bi₂Sr₂Ca₁Cu₂O_x and Bi₂Sr₂CuO_x are determined. The presence of intergrowths is confirmed by the direct TEM measurements.

P.N. Mikheenko, S.J.Lewandowski

Two-dimensional behaviour of YBa₂Cu₃O_x films on SrTiO₃ substrates

Acta Physica Polonica A, Vol.92 No.1, p.152-156 (1997)

One of the restrictive properties of HTSC films is their metastability at the room temperature. As was found by direct X-Rays Diffraction study, during the exposition of single crystal YBa₂Cu₃O_x films they partly undergo the transformation in Cu-rich compounds Y₂Ba₄Cu₇O₁₅ and YBa₂Cu₄O₈. 50 percent decomposition time of 123 compound was found to be approximately 4 years.

In this paper we investigate the long-term (up to 18 months) degradation of textured YBa₂Cu₃O_x films prepared by laser ablation and magnetron sputtering on single crystal SrTiO₃, MgO and Al₂O₃ substrates with the emphasis on the films on SrTiO₃ substrates.

It is found that all the films at each stage of exposition display clear visible 2D-like behavior. Analyzing it, we have found that thickness of isolated CuO₂ plane in these samples is equal to 2 Å. The presence of two close-spaced active layers increase *d* up to 7 Å. Third layer in perfect stack makes HTSC films practically 3-dimensional. The Kosterlitz-Thouless transition temperature that plays role of critical temperature in these films undergoes step-like behavior with the number of layers. This is in accordance with the data obtained on YBa₂Cu₃O_x films with small (1,2,3...) number of unit cells (M.Z. Cieplak et al., Phys. Rev. B **50**, 12876 (1994)).

P.N. Mikheenko, J.H. Horvat, S.X. Dou

Diamagnetic transition of Bi₂223/Ag tapes: the role of low-number stacks of superconducting layers

Physica C, 1997, accepted

A new interpretation of the diamagnetic transition of Bi₂223/Ag tapes to the superconducting state is proposed. The main distinction from the previous models is the proper treatment of the low-number stacks of superconducting layers. The arguments to the existence of these stacks are given. The onset temperature of the real part of AC susceptibility (χ') is interpreted as the temperature of Kosterlitz-Thouless transition, or melting temperature of the thickest stack. The middle temperature of $\chi'(T)$ transition

and the peak temperature of the imaginary part (χ'') define the melting temperature of dominant stacks. The pinning and the critical current behavior are analyzed in connection with the appearance of low-number stacks and suppression of Josephson interaction between layers.

P.N. Mikheenko

Discrete temperatures of Kosterlitz-Thouless transition in high temperature superconductors

Phys. Rev. B, 1997, submitted.

The imaginary part of the AC susceptibility for an intact and the deformed Bi2223/Ag tape has been measured as function of temperature, frequency and DC magnetic field. Deformation results in the splitting of a $\chi''(T)$ peak into three peaks situated near 30, 60 and 90 K. These temperatures are identified as Kosterlitz-Thouless transition temperatures belonging to low-number stacks of superconducting layers. An external magnetic field redistributes the dissipation among the peaks, moves them to lower temperatures and completely suppresses the highest temperature peak. The change of the peak position is interpreted as the transformation of T_{KT} into vortex melting temperature T_m . In the deformed tape, the melting takes place in different stacks separately. The melting temperature in each stack is a field dependent parameter with a minimum value, equal to the T_{KT} of the previous thickness stack. The T_m decreases exponentially with the field, and the rate of decrease depends strongly on the interstack Josephson interaction. At a universal set of T_{KT} , the vortex melting line of a tape is a linear combination of $T_m(H)$ for the low-number stacks.

P. N. Mikheenko, S.X. Dou

Origin of vortex melting line in Bi2223/Ag tapes

Superconductor Science Technology, special issue of Symposium of Processing and Critical Current of HTS, 1998, submitted

Using AC diamagnetic and transport measurements we reconstruct a three-dimensional H- J_c -T diagram (H is magnetic field, J_c is critical current and T is temperature) for high-quality Bi2223/Ag tapes. Both transport and magnetization data are taken or adjusted to a voltage criterion of 1 μ V/cm. The diagram shows an abrupt decrease of critical current caused by the melting of a vortex glass. Melting line is defined as the contour line of $J_c(H, T)$ surface at a current J_{cm} at which J_c shows the steepest decrease with H and T. For Bi2223/Ag tapes $J_{cm} \sim 10$ -100 A/cm². It is found that melting line can be determined as a locus of points on H-T plane where imaginary part of AC susceptibility reaches its maximum, being measured at frequency of 117 Hz and AC field amplitude of 0.1-1 Oe.

It is shown that in Bi2223/Ag tapes the melting line reflects a process of separation of unit-cell stacks which conduct a high supercurrent. In this process, most important role belongs to low-number stacks that contain one to three unit-cells. These stacks have extremely low temperatures of Kosterlitz-Thouless transition (T_{KT}) and, as a consequence, low vortex melting temperatures (T_m), the latter being the case of a finite field. Magnetic field causes separation of stacks, suppresses Josephson interaction (JI)

between them, transforms T_{KT} to T_m , separates T_m of different stacks, and decreases each T_m to its lowest value that corresponds to negligible JI between stacks.

T_{KT} is T_m in zero field. At well-defined T_{KT} ($\approx 30, 60$ and 90 K for Bi2223) a vortex melting line is a linear combination of $T_m(H)$ for low-number stacks. Each $T_m(H)$ is a function of JI and decreases exponentially with H . The existence of low discrete T_{KT} is checked directly in experiments on Bi2223/Ag tapes and melt grown Y123 crystal. $T_m(H)$ of separate low-number stacks registered in experiment on a deformed Bi2223/Ag tape.

S. D. Moss, J. Horvat, R. Zeng, M. Ionescu, S. X. Dou, J. Boldeman*, R. Weinstein**, Weber***

Changes in the Irreversibility Line of Bi-2223 Superconducting Tapes after Uranium Doping and Neutron Irradiation

To be presented at International Symposium of HTS held at Wagga Wagga 2nd to 4th Feb 1998

The combination of uranium doping and neutron irradiation produces improved flux pinning in Bi-2223 tapes over neutron irradiation alone. Uranium doping alone has no positive effect on critical current. Changes in the irreversibility line will be discussed.

S. D. Moss, W.G.Wang, S. X. Dou, R. Weinstein

Uranium Doping and Neutron Irradiation of Bi-2223 Superconducting Tapes for Improved Critical Current Density

Proceedings of the 10th Australian Conference on Nuclear Techniques of Analysis, 24-26 November 1997

Preliminary data suggests that the combination of uranium doping and neutron irradiation produces improved flux pinning in Bi-2223 tapes over neutron irradiation alone. Before neutron irradiation, uranium doping has no effect on critical current. The uranium appears to be homogeneously distributed throughout the oxide core of the tape. Finally, the presence of $\sim 5\%$ 2212 and other secondary phases in the doped tapes suggest further refinement of the sintering procedure is necessary.

S. D. Moss, P. J. K. Paterson, P. Johnston, J. Gorman, A. Katsaros and N. Savvides.

YBa₂Cu₃O₇ Surface Oxygen Loss with Low Energy Electron Irradiation.

Presented at the 14th IUVSTA Ultra Thin Film Workshop, Newcastle, 1997

The effect of low energy electron on the oxygen content of YBa₂Cu₃O₇ thin film has been studied using X-ray Photoelectron Spectroscopy (XPS) and Nuclear Reactions Analysis (NRA). At 3.5keV an electron dose of 10^{18} electrons/cm² XPS measured no change in the oxygen content. At a depth of approximately 2000Å NRA measured a region of oxygen reduction of approximately 30% percent, indicating a change from O₇ to O_{7-x} where $x \approx 2$.

Rajvir Singh, R. Lal, U.C. Upreti, D.K. Suri, A.V. Narlikar, V.P.S. Awana, J. Albino Aguiar, Md. Shahabuddin.

Normal-state properties. T-c degradation. Transport-properties. Cuprate superconductors $YBa_2(Cu_{1-x}Zn_x)_3O_7$

Phys. Rev. B. 55, (1997) p. 1216-1222.

Resistivity and ac susceptibility of Zn-doped samples of the LaBaCaCu₃O_{7-δ} (LBCCO) system have been measured for Zn content of 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, and 3.0% at. wt. X-ray diffraction has been used to find the lattice parameters of the samples. The samples remain tetragonal for all the considered concentrations of Zn. Idometry and thermogravimetric analyses have been done to estimate the oxygen content of different samples. Analyzing the resistivity and ac susceptibility data, the following conclusions are drawn about the role of Zn in the LBCCO samples. (1) The conduction mechanism of electrons appears to follow a crossover from the purely metallic regime to the localization regime due to either weak localization or electron-electron interaction effects after about 1.5% Zn (2) The superconducting transitions revealed by the resistivity vs temperature curves or susceptibility vs temperature curves becomes sharper with Zn increasing content of Zn up to 1.0%. After 1.5% the resistive and ac susceptibility transitions become broader with increasing Zn. (3) T-c depression up to Zn content of 1.0% seems due to direct suppression of the effective pairing interaction, while at and above 2.5% Zn Tc depression is expected to be due to disorder effects such as reduction of density of states at the Fermi energy. [References: 40]

Nghia Van Vo; Hua Kun Liu; Shi Xue Dou

Construction and normal zone propagation analysis of high-Tc superconducting Bi(Pb)-2223/Ag class II coils and magnets

IEEE Transactions on Applied Superconductivity, vol.7, no.2, pt.1, p. 893-5, 1997

Once the production of high quality long length Bi(Pb)- 2223/Ag tapes have been achieved considerations such as fabrication into practical applications without degrading the performance of the tape become the major issues. Here, the application involves the construction of class II coils and magnets. The main problems concerned are usually related to the winding procedures (e.g. wind-react and react-wind), the insulating material, the construction or stacking of coils if they are pancake-shaped and the study of quench propagation parameters. This paper investigates these issues in coil design and construction by means of measurement techniques from small scale coils and magnets made from high-Tc superconducting Bi(Pb)-2223/Ag composite tapes

V.A.Voloshin, P.N.Mikheenko, A.A.Gusev

Structure And Superconducting Properties Of

$Y_{1-x}Pr_xBa_2Cu_3O_x$

Superconductor Science Technology, special issue of Symposium of Processing and Critical Current of HTS, 1998, submitted

We give a new insight into the problem of the suppression of superconductivity in $Y_{1-x}Pr_xBa_2Cu_3O_x$ considering the phenomenon of the vibronic state that arises when the distance between O and Pr becomes less than 2.38 Å. The vibronic state unites the

electronic and nuclear modes into a motion with broad excitation spectrum. In the vibronic state, the 4f configuration of Pr cease to be isolated, and its magnetic moment spreads on the whole Pr-O complex. This is the reason for the suppression of superconductivity.

Analysis of structural data obtained by neutron diffraction and X-ray absorption fine structure measurements shows that Pr resonates between the states of different valence with a period less than 10^{-13} s. Because this is less than lifetime of Cooper pair, the existence of the long range superconducting order in $\text{PrBa}_2\text{Cu}_3\text{O}_7$ becomes impossible.

Wang, W.G, Liu, H.K.; Dou, S.X.

Effect of sintering temperature on phase composition and J_c of Ag-sheathed Bi-2223 single and multifilamentary tapes

IEEE Transactions on Applied Superconductivity, vol.7, no.2, pt.2, p. 1845-8, 1997

The sintering temperature window of Ag sheathed Bi-2223 tapes was studied by a temperature gradient method for fabrication of tapes. The J_c of the tapes was found to be very sensitive to the sintering temperature. For the single filament tapes, the I_{sub} / c reaches the maximum value at a temperature higher than that at which the 2212 percentage reaches the minimum. Around 6.5% of 2212 still exists in the best single filamentary tapes, while just a half of this 2212 fraction (about 3.5%) remains in the best 19 filamentary tapes. The J_c was found to be more sensitive to Bi-2212 phase content in the multifilamentary tapes than that in the single core tapes. A J_c of $4.5 \times 10^4 \text{ A/cm}^2$ ($J_e 1 \times 10^4 \text{ A/cm}^2$) for single core tapes and of $3.3 \times 10^4 \text{ A/cm}^2$ ($J_e 0.65 \times 10^4 \text{ A/cm}^2$) for 19 core multifilament tapes were achieved reproducibly with sintering time of 100 hours and one intermediate pressing. 70% of maximum J_c can be retained within 4 degrees sintering temperature window for both single and 19 filamentary tapes

W.G. Wang, J. Horvat, B. Zeimetz, H.K. Liu, S.X. Dou

Effect of (Bi,Pb) $2\text{Sr}_2\text{CuO}_6$ phase on critical current density of Ag/(Bi,Pb) $2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$ tapes

Physica C 291 (1997) 1-7

The phase evolution, critical current density (J_c) and irreversibility field (H_{irr}) for (Bi,Pb) $2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$ (2223) tapes have been studied through a two-step sintering process. The tapes sintered at 840 C without second-step annealing at 820 C contain a small fraction of (Bi,Pb) $2\text{Sr}_2\text{CuO}_6$ (2201). 2201 phase vanishes when the tapes are annealed at 820 C for 30 h after sintering at 840 C. (Bi,Pb) $2\text{Sr}_2\text{CuO}_6$ (2201) phase was found to be the predominant factor for the depression of J_c of the tapes. The J_c vs. magnetic field shows that the depression of J_c occurs only in the low field region, indicating that 2201 phase act as weak links in the tapes.

X.L. Wang, J. Horvat, H.K. Liu, and S.X. Dou

Spin-glass state in $Y_{0.7}Ca_{0.3}MnO_3$

J. Magn. Magn Mater. in Press

Magnetisation and ac susceptibility were measured on perovskite $Y_{0.7}Ca_{0.3}MnO_3$ at dc fields up to 5 Tesla and ac field of 1 Oe with frequencies of 21, 217, and 2000 Hz. A large irreversibility was observed in the zero-field cooled and field-cooled magnetisation with a cusp at T_{cusp} in ZFC magnetisation. Ac susceptibility also showed a cusp at the T_{cusp} which shifts to high temperature with increasing frequencies. This suggests a spin-glass state in the $Y_{0.7}Ca_{0.3}MnO_3$. The spin-glass state was totally suppressed at high field of 5 T.

X.L. Wang, Peter Gehringer, Wolfgang Lang, H.K Liu, and S.X. Dou

Colossal and constant magnetoresistance over a large temperature range between 230 and 4.2 K in $La_{0.8}Li_{0.2}MnO_3$ prepared by partial melting technique

J. Alloys & Comp. in press

$La_{0.8}Li_{0.2}MnO_3$ was prepared by a partial melting technique. The Li-doped $LaMnO_3$ compound has a rhombohedral perovskite structure and shows a wide semiconductor-to-metal transition between 230 and 175 K in resistance versus temperature. Nearly constant magnetoresistance, $\Delta\rho/\rho_0$, above 20 - 60 % was achieved with application of magnetic fields from 1 to 8 Tesla over a very large temperature range from the ferromagnetic transition at 230 K to 4.2 K. As comparison, a partial melted $La_{0.7}Ca_{0.3}MnO_3$ shows a very narrow ferromagnetic transition around 230 K which is same as that of single crystals and epitaxy thin films.

Wang, X.L.; Horvat, J.; Liu, H.K.; Dou, S.X.

Spiral growth of $Bi_2Sr_2CaCu_2O_y$ single crystals using KCl flux technique

Journal of Crystal Growth, vol.173, no.3-4, p. 380-5, 1997

Crystals of $Bi_2Sr_2CaCu_2O_y$ (Bi2212) have been grown using KCl as flux. It was found, for the first time, the Bi2212 single-crystal growth was mainly controlled by a spiral growth mechanism if the crystals were grown on the flux surface. Single, double and three-head spirals with square and polygonized shapes were observed. Magnetisation measurements show an enhanced flux pinning in the spiral grown crystals compared with crystals grown through a layer-by-layer mechanism. The enhancement in flux pinning may be attributable to the spiral edges and the screw dislocations induced by the spiral growth of the crystals.

Wang, X.L.; Weber, H.W.

On the chemical stability of $(Tl,Pb)(Sr,Ba)_2Ca_2Cu_3O_y$ single crystals

Materials Letters, vol.31, no.3-6, p. 215-19, 1997

The chemical stability of $(Tl,Pb)(Sr,Ba)_2Ca_2Cu_3O_y$ single crystals was studied in environments such as solutions of inorganic acids, air, water and organic solvents.

Optical microscopy was used to check the surface changes of the crystals and the colors of the reaction products in the solutions or of the particles formed on the sample surface. The microscopic morphologies of reacted surfaces and the elements contained in the reaction products were investigated by scanning electron microscopy and energy dispersive analysis, respectively. It was found that the stability of $(\text{Tl,Pb})(\text{Sr,Ba})_2\text{Ca}_2\text{Cu}_3\text{O}_y$ single crystals in water is better than that of the YBCO and BiSCCO superconductors. Their reaction with HCl and HNO_3 is very quick, but slow with H_2SO_4 or HF. Possible corrosions of Tl-1223 crystals in organic solvents were also checked (methanol, ethanol, acetone solvents).

Wang, X.L.; Horvat, J.; Liu, H.K.; Li, J.N.; Dou, S.X.

Anomalous magnetization peak effect in spiral-grown $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ crystals
Physical Review B (Condensed Matter), vol.55, no.6, p. R3402-5, 1997

Magnetic hysteresis loops were measured on spiral-grown $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ (Bi-2212) crystals. An anomalous peak effect at a magnetic field of 1000-2600 Oe was observed both in high- T_c (86 K) and oxygen underdoped ($T_c = 76$ K) spiral-grown crystals between 20 and 40 K. The peak effect was observed to be stronger than that induced by oxygen vacancies, defect dislocation networks reported in Bi-2212 crystals. Further, the anomalous peak almost completely disappeared after removing growth spiral patterns from the crystal surface, edge barriers associated with the growth spirals are suggested to be responsible for the strong peak effect for the spiral-grown Bi-2212 crystals and not oxygen vacancies or screw dislocations.

Wang, X.L.; Liu, H.K.; Dou, S.X.

Morphologies of square shape spirals and (110) twins in spiral-grown $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ crystals
Physica C, vol.273, no.3-4, p. 349-53

It is reported that $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ crystals were grown by a spiral growth mechanism if crystals were grown at KCl flux surface. It was observed that all the growth spirals have square shape with single and multiple spirals generated together if the growth temperatures are lower than 850 degrees C. Furthermore, (110) growth twins were found to coexist with the square shape single or multiple spirals by polarized optical microscope. It is the coexistence of spiral growth and (110) growth twins that leads to the square shape of the growth spirals.

Wang, X.L.; Horvat, J.; Liu, H.K.; Dou, S.X.

Enhanced flux pinning from CuO inclusions in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ crystals
Journal of Applied Physics, vol.81, no.1, p. 533-5, 1997

$\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ (Bi2212) crystals with CuO inclusions were grown on the surface of KCl flux. The density of CuO incorporations of $10^9/\text{cm}^2$ was similar to that for

Y2BaCuOy in melt-textured YBa2Cu3Oy. The CuO inclusions are needlelike particles with diameter of less than 1 μ m. Magnetization measurements show enhanced flux pinning at high magnetic field, compared to crystals without CuO.

Guoyang Xu, Yuping Sun, Jiaju Du, Yiru Zhou, **Rong Zeng**, Xuekui Fu, and Peiwen Hua

In-plane and out-of-plane dissipation in c-axis-oriented (Bi,Pb)₂Sr₂Ca₂Cu₃O_x silver sheathed tapes,

J. Appl. Phys. 81(3), (1997)1331

The temperature dependence of the out-of-plane and in-plane resistance of a c-axis-oriented (Bi, Pb)₂Sr₂Ca₂Cu₃O_x silver-sheathed tape with high critical current density ($J_c > 2 \times 10^4$ A/cm², 77K,)t) has been investigated under applied fields up to 0.9T. It is found that the in-plane and the out-of-plane resistance transitions are quite different: (1) the out-of-plane zero resistance temperature is much higher than the in-plane one, i.e., $T_c^{ab}(H) \ll T_c^c(H)$, and the difference increases with magnetic field; (2) the out-of-plane zero resistance temperature corresponds to the c-axis decoupling temperature. These phenomena are attributed to different dissipation mechanism. The in-plane dissipation at low temperature results from the thermally actated flux-flow, while the out-of-plane dissipation originates from the Josephson junction dissipation of weakly coupled c-axis grain boundaries and/or intrinsic Josephson junctions.

R. Zeng, Q.Y. Hu, J.N. Li, H.K. Liu and S.X. Dou,

Finite Voltage along c-Direction of Bi-2223/Ag Multifilament Tapes,

Superconductor Science and Technology, 10(1997)342

We have observed the finite voltages along the c-direction of the Ag-sheathed Bi-2223 multifilament tapes, which was detected by the voltage leads attached on the opposite broad faces of the tape. A theoretical analysis using magnetic flux creep and flow model and simplified electric network model is provided. The non-uniformity of the mass core density of the core and unsymmetric distribution of the cores over the transverse cross section result in the finite voltage.

R. Zeng, J.N. Li, Q.Y. Hu, Y.C. Gou, H.K. Liu and S.X. Dou,

Characteristics of the Bi-2223 multifilamentary tapes using powder/wire-in-tube technique

Advances in Cryogenic Engineering Vol. 44. (in press)

A novel simple concept of periphery length of Ag/superconductor interface in per unit area in cross-section of the tapes(E) have introduced and the dependence between E and properties of several difference kinds of tapes have compared. The J_c and the strain tolerance were improved with the increasing of the E. it was attributable to the improvement of grain alignment and the crack stopping at the Ag/superconductor interface. A new design of macrostructural multifilamentary tapes have been developed by packing powder and wires into the silver tube at the second stage of the powder-in-

tube process. The critical current of multifilamentary tapes made by this Powder/Wire-in-Tube were improved in comparison with those made using the wire-in-tube multifilamentary tapes. The enhancement of J_c is attributable to the improvement of grain alignment by increasing the interface between Ag and oxide superconductor. The J_c -B properties and the J_c -strain characteristics of the tapes have been studied.

R. Zeng, T.P. Beales, H.K. Liu and S.X. Dou

Optimal reduction in rolling Ag-sheathed Bi-2223 Multifilamentary Tapes
Supercond. Sci. Technol. (in press)

The difference in mechanical deformation of the cladding material and ceramic superconductor during cold-working of Ag-sheathed Bi-based superconducting composite tapes has been analysed. From this, an optimal rolling procedure has been developed in order to improve the uniformity of the tapes by gradually increasing the reduction per-pass during rolling. Using this technique, a uniform stress was achieved within the tapes which improved both the transverse and longitudinal filament interfacial homogeneity and reduced the sausageing effect. A more improved and uniform J_c was observed in long length tapes fabricated using this procedure, than in those fabricated using a non-optimised route.

R. Zeng, Y.R. Zhou, P.W. Hua, X.K. Fu, B. Ye, M. Zhou, G.S. Yuan,

Design, Construction and Properties of 1T(4.2K) Bi-2223 High T_c Superconducting Prototype Magnet,
Submitted to Supercond. Sci. Technol.

Ag-sheathed monofilamentary Bi-2223 high temperature superconducting tapes were fabricated using "powder-in-tube" method with powders of $\text{Bi}_{1.8}\text{Pb}_{0.4}\text{Sr}_2\text{Ca}_{2+x}\text{Cu}_3\text{O}_y$ ($x=0, 0.14, 0.24$) chemical composition. It was found that there were the highest critical current density (J_c) and the shortest time for Bi-2223 phase completing in tapes with $x=0.24$. The $x=0.24$ composition tapes with reproducible critical current density of between $3.0\sim 4.0\times 10^4\text{A/cm}^2$ for short sample, average $1.5\times 10^4\text{A/cm}^2$ for 4m long length tapes and $8\times 10^3\text{A/cm}^2$ for 100m long length tapes at 77K in self field have been produced using conventional "powder-in-tube"(PIT) method. A test magnet designed and constructed by stacking together eight pancake coils. Each pancake coil co-wound react-and-wind (R&W) with three tapes on 18mm-diameter mandrel. Dimensions and parameters of this magnet are as follow: height, 46mm; winding ID, 18mm; OD, 56mm; total number of turns, 290. Total conductor length in the magnet was $\sim 100\text{m}$. The coils were connected in series and then tested at 4.2K and 77K. The field constant at mid-plane of the magnet, determined by introducing a Hall probe in the bore of the magnet, was 29Gs/A and it could generate 0.12T magnetic field at 77K, and 1.07T at 4.2K. Eight pancake coils stacked a testing magnet using two coils parallel connection and four double coils series connection method, this make it possible to use a mix of good and less good tapes and to use fully the critical current of each tape. A detailed investigation of the J_c -B properties and J_c -strain characteristic of the Bi-2223 tapes as designing parameters and properties of the test magnet have been carried out.

R. Zeng, V. Murashov, T.P. Beales, H.K. Liu and S.X. Dou

High temperature superconducting magnetic levitation train prototype

Submitted to Appl. Supercond.

With the improvement in both materials and processing techniques, very large-grained $\text{YBa}_2\text{Cu}_3\text{O}_7$ samples with overall dimension of several centimetres in length were produced. Each sample was capable of levitating over a kilogram in weight. A high temperature superconducting magnetic-suspension (levitation) train prototype was constructed, to validate the concept of using an HTS Meissner effect magnetic suspension system. The measurements of various magnetic suspension parameters, such as relative suspension stability and suspension force, as well as magnetic field intensity and distribution are reported and discussed.

R. Zeng, H.K. Liu and S.X. Dou

A New Structural Powder/Wire-In-Tube(PWIT) Ag-sheathed Multifilamentary Bi-2223 Tape And Its Properties

Physica C (in press).

A new design of macrostructural multifilamentary tapes has been developed by parking powder and composite wires into the silver tube (PWIT) at the second stage of the powder-in-tube (PIT) process. The critical current J_c and the strain tolerance for this PWIT multifilamentary tape were significantly improved in comparison with the PIT multifilamentary tapes. The enhancement of both J_c and the strain tolerance are attributable to the increased interface between Ag and oxide superconductor. We have introduced a simple concept of the periphery length of the Ag/superconductor interface per unit area in the cross-section of tapes (E) and have compared its properties in PWIT and PIT tapes. Both J_c and the strain tolerance were improved with increasing E . This was attributed to the improved grain alignment and crack termination at the Ag/superconductor interface. The J_c - B properties and the J_c -strain characteristic of two tapes have been compared.

R. Zeng, J. Wang, H.K. Liu and S.X. Dou,

The formation mechanism and the development of grain texture in the preparation of Ag-sheathed Bi-2223 superconducting tapes,

Submitted to Supercond. Sci. Technol.

The mechanism and development of cold - working and grain-growth texture of Bi - 2212 and the corresponding inheritance of texture by Bi - 2223 in Ag-sheathed tapes has been investigated. Precursor powder in the Ag tube was found to flow, rotate and fracture along the crystallites. This along with sliding among crystallites forms the basis of the deformation process in Bi-2212 texturing during the cold - working process. Bi-2212 was formed via a rapid melting process, yielding a strong epitaxial melt-textured microstructure from a subsequent heat treatment. Bi-2223 was found to form on Bi-2212, with the Bi-2223 texture being inherited from the Bi-2212 texture. This is best explained by an intercalation mechanism for Bi-2223 phase formation

R. Zeng, B. Ye, J. Horvat, Y. C. Guo, B. Zeimetz,
X.F. Yang, T.P. Beales, H.K. Liu and S.X. Dou

Grain Connectivity And Flux Pinning In Hot-Pressing Bi-2223/Ag PIT Tapes

Submitted to Waga Waga conference

A hot-pressing technique was used to prepare Ag-sheathed Bi-2223 multifilamentary tapes in order to study its effect on grain connectivity and flux pinning. The self field critical current density (J_c) after hot-pressing were significantly enhanced, the maximum increase reached more than double that before, Hot pressing raised the $J_c(B=0)$ from $22000\text{A}/\text{cm}^2$ ($I_c=18\text{A}$) to $56800\text{A}/\text{cm}^2$ ($I_c=36.5\text{A}$) for 81-filament tape and $26000\text{A}/\text{cm}^2$ ($I_c=36.2\text{A}$) to $56000\text{A}/\text{cm}^2$ ($I_c=56.6\text{A}$) for 19-filament tape. However, the J_c in applied magnetic field was not improved or degraded by hot-pressing. The J_c retention in magnetic field of 1T decreased from 33% for the original tape to 21% for the hot-pressing tapes and remained the same (24%) for 19-filament tape before and after hot-pressing. The effect of cooling rate on connectivity and flux pinning in hot-pressing Bi-2223 PIT tape has been investigated. The fraction of strong links (I_{c0}^s/I_{c0}) were improved from 64% to 73% for 81-filament tape and from 47% to 68% for 19-filament tape due to hot pressing and slow cooling. However it was reduced to 42% for hot-pressed and normally cooled tape. Microstructural analysis showed that hot-pressing chiefly improved grain connectivity, increased core density and reduced the impurities secondary phase.

14.2 Energy Storage Materials

W.H.Boctor, S.Zhong, H.K.Liu and S.X.Dou

Electrometric method for evaluation of corrosion of lead alloys in sulphuric acid solution I. evaluation of a Pb-Sb-As alloy vs. pure lead under continuous polarisation in sulphuric acid solution

Journal of Power Sources, in press

In an electrometric method the lead electrode is subjected to electrolyte, temperature and various states of polarization that simulates the service conditions. The resulting corrosion layer is first reduced to lead sulphate then to sponge lead. A linear relation was observed between the weight of the corroded lead and the surface area of the sponge lead remaining after cathodic reduction of the corrosion layer. The surface area was determined by measuring the time needed to completely cover it again with lead sulphate at a specified current density and standardized conditions, irrespective to the test solution and temperature. The results were very well reproducible. The Pb-Sb-As alloy tested was more corrosion resistant than pure lead.

J. Chen, S.X. Dou and H.K. Liu

Hydrogen desorption and electrode properties of $Zr_{0.8}Ti_{0.2}(V_{0.3}Ni_{0.6}M_{0.1})_2$ alloys

J. Alloys and Compounds, Vol.256, 1997, p.40-44.

Hydrogen desorption and electrode properties of $Zr_{0.8}Ti_{0.2}(V_{0.3}Ni_{0.6}M_{0.1})_2$ alloys (M=Si, Mn, Co, Mo) were studied. The Si, Mn-substituted alloys had the C14 Laves phase structure, but the Co, Mo-added alloys had the C15 Laves phase structure. The pressure-composition desorption isotherms were sloped. Among the four additive elements, manganese led to the fastest activation and highest discharge capacity and cobalt to the longest cycle life. These features were attributed to the different microstructures.

J. Chen, S.X. Dou, D. Bradhurst and H.K. Liu

Studies on the electrochemical impedance spectroscopy of Zr-based Laves phase metal hydride electrodes

Proceedings of the twelfth Annual Battery Conference on Applications and Advances, Long Beach, CA, Jan.14-17 (1997), IEEE 97th 8226, pp.313-316.

The impedance spectra of $Zr(V_{0.4}Ni_{0.6})_2$, $Zr(V_{0.2}Mn_{0.2}Ni_{0.6})_2$, $Zr(V_{0.2}Mn_{0.2}Ni_{0.55}Si_{0.05})_2$ alloys have been investigated. An equivalent circuit for the reaction of an MH electrode is proposed. The results reveal that: (1) the additions of Mn and Si have significant effects on the reaction resistances of the alloys; (2) Ni powder is an appropriate additive material in the manufacturing process of an MH electrode; (3) the amounts of Ni powder in the alloy electrode also should be considered in the practical utilisation.

J. Chen, D.H. Bradhurst, S.X. Dou and H.K. Liu

Properties of chemically prepared $MmNi_{4.52}Mn_{0.49}$ alloy

J. Alloys and Compounds, Vol 260, 1997, p.260-264.

$MmNi_{4.52}Mn_{0.49}$ (Mm is mischmetal) alloy was prepared by a coprecipitation-reduction process. The alloy structure, chemical composition, particle size and surface properties were investigated by using the analysis of X-ray diffraction, inductively coupled plasma emission spectroscopy, particle size analysis and X-ray photoemission spectroscopy. Pressure-composition isotherms of the chemically prepared alloy were measured. The alloy powder was evaluated as the active material of a metal hydride electrode. It is found that the alloy thus obtained has larger specific surface area, different surface states, lower activation energy for hydrogen absorption/desorption and better electrode characteristics than the alloy prepared by conventional arc-melting.

J. Chen, S.X. Dou, D.H. Bradhurst and H.K. Liu

Metal hydride electrodes with high charging efficiency

Proceedings of the 2nd International Symposium on New Materials for Fuel Cell and Modern Battery Systems, Montreal, Canada, July 6-10, 1997, Ed: O. Savadogo and P.r. Roberge, ISBN 2-553-00624-1, pp.594-600.

The effects of additive materials on the $\text{MmNi}_{3.55}\text{Co}_{0.75}\text{Mn}_{0.4}\text{Al}_{0.3}$ (Mm is mischmetal) alloy electrodes have been investigated. Experiments were conducted to optimize (1) appropriate additive materials, such as Co powder, Ni powder, teflonized carbons and acetylene black; (2) ratio of the amount of the additives to the alloy; and (3) the best percentage of the composite additives in the metal hydride electrodes. The high charging efficiency is probably due to the high electrocatalytic properties of the added Co, Ni powder in the electrodes, which not only catalyse the electrochemical reaction in the electrode, but also facilitate the diffusion of hydrogen through the alloy/hydride.

J. Chen, S.X. Dou, D. Bradhurst and H.K. Liu

Studies on the diffusion coefficient of hydrogen through metal hydride electrodes

Int. J. Hydrogen Energy, 1997 (in press).

The potentiostatic discharge method was used to determine the hydrogen diffusion coefficient in MmNi_5 , $\text{MmNi}_{4.5}\text{Mn}_{0.5}$, $\text{MmNi}_{3.55}\text{Co}_{0.75}\text{Mn}_{0.4}\text{Al}_{0.3}$ (Mm is mischmetal), ZrVNi , $\text{ZrV}_{0.6}\text{Ni}_{1.2}\text{Mn}_{0.2}$ and $\text{Zr}_{0.5}\text{Ti}_{0.5}\text{V}_{0.6}\text{Ni}_{1.0}\text{Mn}_{0.4}$ alloy electrodes. The values obtained were in the range of 10^{-10} cm^2/s for the MmNi_5 system alloys and 10^{-11} cm^2/s for the Zr-based Laves phase alloys. It was found that the higher the content of Mn in the alloy, the larger the value of hydrogen diffusion coefficient. The effect of the Ni/alloy ratio in the mixture (alloy and Ni powder) on the diffusion coefficient and on the high rate of discharge were studied. The advantages of the potentiostatic discharge method is also discussed.

J. Chen, S.X. Dou, D. Bradhurst and H.K. Liu

Studies on charging efficiency of metal hydride electrodes

J. Power Sources, 1997 (in press).

Charging efficiency of MmNi_5 , $\text{MmNi}_{4.5}\text{Mn}_{0.5}$, $\text{MmNi}_{3.8}\text{Co}_{0.7}\text{Mn}_{0.5}$, $\text{ZrV}_{0.6}\text{Ni}_{1.4}$, $\text{ZrV}_{0.6}\text{Mn}_{0.4}\text{Ni}_{1.0}$, $\text{ZrV}_{0.6}\text{Mn}_{0.4}\text{Co}_{0.2}\text{Ni}_{0.8}$ alloy electrodes (Mm is mischmetal) have been investigated through hydrogen evolution. Experiments were conducted to optimize (1) element adding in MmNi_5 -system and Zr-based Laves phase hydrogen storage alloys; (2) additive materials, such as Co powder, Ni powder, teflonized carbons and acetylene black; (3) ratio of the amount of the additives to the alloy; and (4) the best percentage of the composite additives in the metal hydride electrodes. The results show that the electrode activation, charging efficiency and high rate discharge greatly depend on the active materials, the kind and the amount of the additives in the electrodes.

J. Chen, D.H. Bradhurst, S.X. Dou and H.K. Liu

Surface and electrode properties of $Zr(V_{0.25}Ni_{0.75})_2$ alloy treated with ultrasound-solution

J. Alloys and Compounds, 1997 (in press).

An ultrasound treatment in a 1M KF + 0.02M KH_2PO_2 solution was carried out to modify the surface of $Zr(V_{0.25}Ni_{0.75})_2$ alloy. The effects of this treatment on the surface and structure properties were investigated by Scanning electron microscopy, X-ray diffraction and Auger electron spectroscopy. The untreated and treated alloys were used as the hydride electrodes of a nickel-metal hydride cell, which were studied to compare the activation, charge-discharge at different discharge current density, the exchange current density and the polarization resistance of the electrodes. The results reveal that the characteristics of the treated alloy electrode are significantly improved owing to a new nickel rich protuberance and a thin hydride surface layer.

J. Chen, D.H. Bradhurst, S.X. Dou, H.K. Liu, Y.S. Zhang and D.Y. Song

Development of High Energy Nickel-Metal Hydride Cell

The 13th Annual Battery Conference on Applications and Advances, Long Beach, CA, Jan.13-16 (1998), Session XI.

High energy nickel-metal hydride cell (71 Wh/kg and 230 Wh/L) has been developed by combining two kinds of electrodes: a pasted nickel hydroxide positive electrode using high density nickel hydroxide powder, and $Zn(OH)_2$ additive (2.8% weight), and a metal hydride negative electrode using a $Zr(V_{0.1}Mn_{0.3}Co_{0.05}Ni_{0.55})_{2.05}$ alloy annealed at 950°C for 12 hours and surface treated with an ultrasound solution.

J. Chen, D.H. Bradhurst, S.X. Dou and H.K. Liu

The effect of ball-milling with Co on the electrode properties of $Mg_{2.0}Ni$ alloy

Electrochimica Acta, 1997 (submitted).

$Mg_{2.0}Ni$ alloy was ball-milled with Co powder. The effects of the ball-milling on the surface appearance, the structure of the alloy and the electrode properties were investigated. The discharge capacity and cycle life of the ball-milled alloy electrode were greatly increased in comparison with values for the bare alloy. The results are explained in terms of the enhanced electrocatalytic activity and effective protection provided by the cobalt-milled layer.

N. Cui, B.Luan, H.Zhao, H.K.Liu, S.X.Dou

Comparative Study Of Electrochemical Behaviour Of Single-Crystalline And Polycrystalline $LaNi_5$ Alloy Electrodes

Journal of Alloys & Compounds. 248(1-2):159-163, 1997 Feb 15.

A.c. impedance, cyclic voltammetry and linear polarization techniques were applied to the electrochemical characterization of $LaNi_5$ single crystalline and polycrystalline smooth electrodes in 6 M KOH solution. The single crystalline electrode was found to

have a lower charge-transfer resistance and higher electrocatalytic surface activity along the [001] direction compared with the polycrystalline electrode. The total impedance of the hydriding reaction is much less for the single crystalline alloy than for the polycrystalline alloy. The mechanism of electrode hydriding reaction is related to the crystalline structure and orientation.

H.K. Liu, N. Cui, B. Luan, J. Chen, S.X. Dou and D.H. Bradhurst

To Improve The Performance Of Hydrogen-Storage Alloy Electrodes By Using Some New Methods

To be published, Journal of New Materials for Electrochemical Systems

In order to improve the performance of hydrogen storage alloy anodes, some new methods used by the Institute for Superconducting and Electronic Materials in recent years are summarised in this paper. The methods include low-temperature surface micro-encapsulation, ultrasound treatment, particle inlaying, mechanical alloying and elemental substitutions. These novel techniques are very important for the growing need for high-specific-power, high-specific energy battery systems suitable for use in spacecraft, communications, propulsion of civilian and military vehicles, and for similar demanding applications.

B. Luan, H. K. Liu, S. X. Dou

On The Elemental Substitutions Of Titanium-Based Hydrogen-Storage Alloy Electrodes For Rechargeable Ni-Mh Batteries

Journal of Materials Science. 32(10):2629-2635, 1997 May 15.

Partial substitutions of nickel in Ti₂Ni intermetallic compound with cobalt, potassium, boron and aluminium have been studied in the present paper. It is found that cobalt and boron additions are beneficial but aluminium addition is detrimental to the specific capacity of the electrode. Potassium does not have any significant effect on the specific capacity of the electrode from our work. Cobalt, potassium and aluminium additions are all found effective in increasing the cycle life of Ti₂Ni electrode, although by different mechanisms.

B. Luan, H. Zhao, H.K. Liu, S.X. Dou

On The Discharging Process Of Titanium-Based Hydrogen Storage Alloy Electrode Via Ac Impedance Analysis

Journal of Power Sources. 62(1):75-79, 1996 Sep.

An a.c. impedance technique is applied to study the frequency response during the discharging process of an electrode fabricated from titanium-based hydrogen storage alloy. Conditions are discussed under which either diffusion or adsorption of hydrogen control the overall electrode process. The impedance spectra obtained at different discharge states of the electrode reveal that the rate-determining-step (RDS) of the discharging process varies from an electrochemical process to diffusion of hydrogen along with the discharging of the electrode. The impedance spectra obtained at different

temperatures of discharging also show a significant variation of RDS. A further understanding of the discharging process of titanium-based hydrogen storage alloy electrode is discussed.

L.Sun, H.K.Liu, S.X.Dou

The Effect Of Ball Milling And Rapid Quenching On The Catalytic Activity Of The Cu₃₀Al₇₀ Alloy

Materials Letters. 33(1-2):79-83, 1997 Nov.

A nanocrystalline Cu₃₀Al₇₀ alloy with average grain size of about 12 nm was produced by mechanically milling the vacuum induction melted Cu₃₀Al₇₀ alloy. The weight ratios of ball to sample and the milling time have a significant effect on the grain size of the Cu₃₀Al₇₀ alloy. The catalytic activity of the ball milled Cu₃₀Al₇₀ alloy is much higher than that of both the vacuum induction melted Cu₃₀Al₇₀ alloy and the rapidly quenched Cu₃₀Al₇₀ alloy in hydrogenation of xylose. The catalytic activity of the rapidly quenched Cu₃₀Al₇₀ alloy is also higher than that of the vacuum induction melted Cu₃₀Al₇₀ alloy.

S.Zhong, J.Wang, H.K.Liu, S.X.Dou and M.Skylas-Kazacos

Influence of alloying with Bismuth on electrochemical behaviour of lead-calcium-tin grid alloys

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The effect of bismuth, in the range 0.002 wt.% to 0.073 wt.%, on the electrochemical properties of lead-calcium-tin-aluminium alloy in sulphuric acid solutions at room temperature and 50 °C have been investigated by potentiodynamic and a.c. impedance methods. Bismuth is added in a common grid alloy of lead-calcium-tin-aluminium, and the amount of bismuth in the alloys depends essentially on whether the alloying process is governed by equilibrium or kinetic processes. Potentiodynamic measurements provided a qualitative overview of the activating, passivating and transpassivating processes which correspond to $Pb \rightarrow PbSO_4$, $PbSO_4 \rightarrow PbO_2$ reactions respectively. Addition of bismuth increases the passivating current density, i_{pass} , and modifies the conductivity of the passivating film on the electrode surface. The increased anodic attack has been observed from cyclic voltammetric measurements and a more porous oxide layer was examined by SEM for various bismuth additions. The results show that the relationship between the extent of the anodic attack and bismuth content is not linear.

S.Zhong, J.Wang, H.K.Liu, S.X.Dou and M.Skylas-Kazacos

Influence of alloying with Bismuth on hydrogen and oxygen evolution of lead-calcium-tin grid alloys

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Hydrogen and oxygen evolution on lead-calcium-tin-aluminium alloys with different bismuth additions, in the range 0.002 wt.% to 0.073 wt.%, in sulphuric acid solutions at room temperature have been investigated. Hydrogen evolution rates were measured by linear sweep voltammetry (LSV). Kinetic parameters of the hydrogen evolution reaction

on electrodes show that the incorporation of bismuth in the alloys decreases the hydrogen overpotential and increases the hydrogen evolution rate. Oxygen evolution rates were measured by a step-potentiostatic method, together with gas collection. The results show that oxygen evolution rates were enhanced by the bismuth additions and also influenced by the quantity of lead dioxide on the electrode surface. The effect of structure of the alloy surface on hydrogen evolution rate is also discussed.

S.Zhong, J.Wang, H.K.Liu, S.X.Dou and M.Skylas-Kazacos

Influence of Ag on electrochemical and corrosion behaviours of Pb-Ca-Sn-Al grid alloys. I. Potentiodynamic and potentiostatic studies

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The influence of silver, in the range of 0.02 wt.% to 0.07 wt.%, on the electrochemical and corrosion properties of Pb-Ca-Sn-Al grid alloy in sulphuric acid solutions at room temperature was investigated by potentiodynamic and potentiostatic methods. The introduction of Ag into a common grid alloy of Pb-Ca-Sn-Al confers some important features on the alloy. The addition of Ag refined the grains and enhanced the passivation of the electrode and its corrosion resistance. A decrease in the oxygen evolution overpotential and an increase in the hydrogen evolution overpotential with the additions of Ag were also observed during the experiments.

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