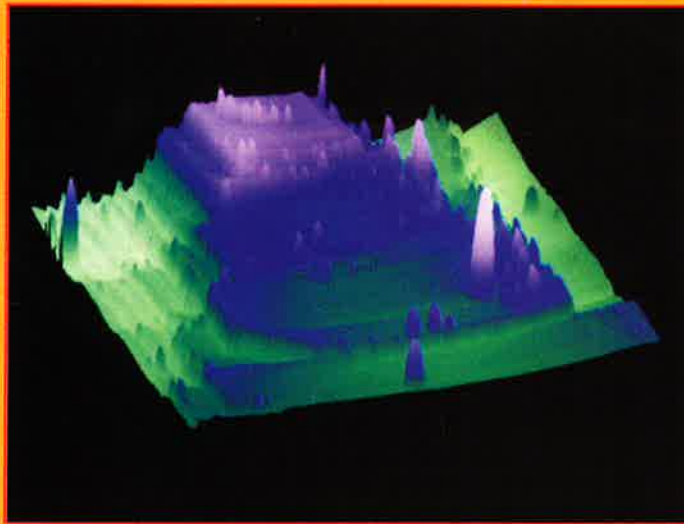




University of Wollongong



INSTITUTE FOR
MATERIALS TECHNOLOGY
AND MANUFACTURING
ANNUAL REPORT
1995 - 1996



INSTITUTE FOR
MATERIALS TECHNOLOGY
& MANUFACTURING
ANNUAL REPORT 1995/96

MICROGRAPH IN COVER PAGE

Atomic Force Microscope Image of Spiral Growth Pattern of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_x$ single crystals. Spiral growth mechanism was observed for the first time in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_x$ single crystals which show an enhanced flux pinning as evidenced by the anomalous peak (Fish tail effect) in magnetisation hysteresis loops between 20K to 45K. (Wang X L, H.K. Liu and S.X. Dou, *Physica C* 273 (1997) 349-354, *Physica C*; Wang X L Yau S T, Liu H K and Dou S X, *Physica C* (in press)).

Table of Contents

1.	Research Staff	3
2.	Research Program for CSEM	6
	2.1 Research Projects for Postgraduate Students in CSEM	15
3.	Research Program for ESMRG	18
	3.1 Research Projects for Postgraduate Students in ESMRG	19
4.	Research Program for RCAMP	22
	4.1 Research Projects for Postgraduate Students of RCAMP	23
5.	Strong International Links	26
6.	Link with Industries	27
7.	Equipment and Facilities	27
8.	Research Grants	29
9.	Staff Profiles	32
10.	Invited Talks and Papers	33
11.	Visiting Scientists who Gave Seminars	35
12.	Finished Thesis	35
13.	Publications for 1995 - 1996	36

The Institute for Materials Technology & Manufacturing

**PROFESSOR S.X. DOU
DIRECTOR**

**INSTITUTE OF MATERIALS TECHNOLOGY AND MANUFACTURING
UNIVERSITY OF WOLLONGONG, WOLLONGONG, NSW 2522**

Telephone: 042-214558

Fax: 042-214577

Email: shi_dou@uow.edu.au

1. RESEARCH STAFF

The Institute consists of two Centres and a Research Group, and is involved with three Faculties and four Departments on campus.

CENTRE FOR SUPERCONDUCTING & ELECTRONIC MATERIALS (CSEM):

Co-ordinator: Shi Xue Dou - ARC Professorial Research Fellow

Mr. M. Ionescu, Assistant Director
Dr. P. Mikheenko, Senior Research Fellow
Dr Y.C. Guo, Research Fellow
Dr J. Horvat, Research Fellow
Dr Q.Y. Hu, Research Fellow
Dr. V.P.S. Awana, Research Fellow
Dr J.N. Li, Research Fellow
Dr. G. Murashova, Visiting Fellow
Mr. R. Zeng, Research Associate
Mr. C. Rossi, Technician
Mr. T. Shaw, Lab Assistant

Associate Members:

A/Professor H.K. Liu, ARC A/Professorial Research Fellow
Professor P. Fisher (Physics)
Dr. C. Zhang (Physics)
Dr. M. Jagdish (Physics)
Professor C. Cook (Electrical Eng.)
Dr. J. Boldman (ANSTO)
Dr D.K. Yu, Research Fellow
Dr. W. Xu, Research Fellow

RESEARCH CENTRE FOR ADVANCED MATERIALS PROCESSING (RCAMP)

Coordinator: Dr. A. Calka, Senior Lecturer

Professor D. Dunne, Head of Department
Dr. Z.X. Chen, Lecturer
Dr D. Wexler, Post Doctoral Fellow
Dr H.J. Li, Research Fellow
Dr N. Alam, Research Fellow

Associate Members:

A/Professor T. Chandra
Dr. S. Nightingale, Senior Lecturer
Dr. G. Brooks, Lecturer
Dr. M. Ferry, Lecturer
Dr. G. Spinks, Senior Lecturer
Dr. Y. Zhang, Research Fellow

ENERGY STORAGE MATERIALS RESEARCH GROUP (ESMRG)

Coordinator: A/Professor H.K. Liu, ARC A/Professorial Research Fellow

Dr. D. Bradhurst, Honorary Professor
Dr. V. Murashov, Senior Research Fellow
Mrs. W.Y. Chen, Research Associate
Mr. L. Sun, Research Associate
Mr. X.Z. Liao, Research Associate
Mrs. J.Z. Wang, Research Associate

Research Postgraduate Students in CSEM in 1994 - 1996:

Student Name	Degree	Commenced	Completed Thesis	PT/FT	Supervisors Name
Peter Bain	PhD	Jan, 95	Jan, 97	FT	Liu/Dou
R. Bhasale	PhD	Jan, 93	Dec, 96	FT	Liu/Dou
Q.Y. Hu	PhD	May, 92	Feb. 95	FT	Dou/Weber
M. Ionescu	PhD	Jan, 92	Feb, 97	FT	Dou/Collings
J.X. Jin	PhD	Jan, 94	Mar, 97	FT	Liu/Dou
W.G. Wang	PhD	Nov, 94	Oct, 97	FT	Dou/Liu
X.L. Wang	PhD	Jan, 96	Mar, 99	FT	Dou/Liu
N.V. Vo	PhD	Jan, 94	April, 97	FT	Dou/Liu
B. Zeimetz	PhD	Jan, 95	Feb, 98	FT	Dou/Liu
M. Yavuz	PhD	Jan, 94	Dec, 96	FT	Dou/Liu
J.M. Xu	PhD	Jan, 94	Jan, 97	FT	Dou/Cadogan

Research Students in RCAMP in 1994-6

Student Name	Degree	Commenced	Completed	PT/FT	Supervisor(s)
K. Aryal	(PhD) (ANU)	1993	(1997)	PT	A. Calka
J. Nikolov	(PhD) (ANU)	1993	1996	FT	A. Calka
G. Wang	(PhD) (ANU)	1993	1996	FT	A. Calka
S. Nightingale	(PhD)	1989	1995	PT	D. Dunne/H. Worner
A. Razaghian	(PhD)	1993	1995	FT	T. Chandra
M. Frewin	(PhD)	1994	(1997)	FT	D. Dunne
A. Abdollahzadeh	(PhD)	1992	1996	FT	D. Dunne
G. Banadkouki	(PhD)	1992	1996	FT	D. Dunne
H. Li	(PhD)	1991	1996	FT/PT	D. Dunne
L. Liu	ME(Hons)	1993	1996 *	FT/PT	D. Dunne
H. Tsuei	(PhD)	1996		FT	D. Dunne
Z. Sterjovski	ME(Hons)	1995	(1997)	FT	D. Dunne
K. Baughn	(PhD)	1994		PT	D. Dunne
F. Fitzgerald	(PhD)	1992		PT	D. Dunne
A. Mosbah	ME(Hons)	1996	(1997)	FT	S. Nightingale
P. Basu	(PhD)	1994	1996*	FT	G. Spinks
S. Smiltnieks	(PhD)	1995		FT	G. Spinks
J. Zhou	ME(Hons)	1996	(1997)	FT	A. Calka

Research Students in ESMRG in 1994 - 1996:

Student Name	Degree	Commenced	Completed PhD Thesis	PT/FT	Supervisors Name
Benli Luan	PhD	1994	Feb, 97	FT	Liu, Dou
Ning Cui	PhD	1994	Feb, 97	FT	Liu, Dou, Bradhurst
Zhong Shi	PhD	1995		FT	Liu, Dou, Kazacos
Jun Chen	PhD	1996		FT	Liu, Dou
Zahiri H. Saden	ME (Hons)	1995	Dec, 96	FT	Liu, Dou
Ying-Shan Wu	ME (Hons)	1995	Feb, 96	FT	Liu, Dou

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

Visitng Scientists:

- Associate Professor S. Kambe, Yamagata University September 1995 - March, 1996.
- Dr. M. Xu, Ames Laboratory, Iowa State University, May - June 1995.
- Mr. J. Ostanson, Ames Laboratory, Iowa State University, August - Sept. 1995.

2. RESEARCH PROGRAM FOR CSEM

The research carried out by this large group covers a wide range of projects from materials aspects to theoretical modelling in HTSC.

"MICROSTRUCTURE, FLUX PINNING AND CRITICAL CURRENT DENSITY OF HIGH TEMPERATURE SUPERCONDUCTORS (HTSC)",

Chief Researcher: S.X. Dou
Position: Australian Research Council (ARC) Professorial Fellow
Sponsor: ARC Fellowship Scheme
Duration: 1993-1997

The aim of the project is to enhance the critical current density and flux pinning strength through the use of powder-in-tube technique to a level suitable for practical applications. The project focuses on improvement of critical current density and magnetic properties of HTS through introduction of pinning centres and development of innovative technology. This project has led to the establishment of a pilot plant production at the Australian Technology Park which will transfer the technology of HTS wire fabrication from the University of Wollongong to MM Ltd for commercialisation. A six million dollar consortium project, "A Plan for Australian Technology of Superconducting Wire", was launched in 1995. This project has also resulted in the establishment of CSEM which consists of 13 full time researchers and 10 postgraduate students.

"FABRICATION OF LONG AG-CLAD HTSC WIRES AND TAPES"

Chief Researcher: H.K. Liu
Position: ARC Senior Research Fellow
Sponsor: ARC Fellowship Scheme
Duration: 1994-1998

Rapid advances in research and development in high-T_c superconductors have been achieved through intensive world efforts. At this stage, the scaling-up problem is of prime importance to the technology transfer from laboratory research to prototype products. The objectives of this project are as follows: to investigate the microstructures, critical current density (J_c), and flux pinning behaviour in the Ag-clad superconducting Bi-based wires in order to improve the J_c to a level suitable for large-scale applications, to fabricate long superconducting wires up to 1000 meters and to develop prototype devices such as current leads, current limiting devices, and magnets for a variety of applications. This team has achieved a J_c of 40,000 A/cm² at 77.3 K in zero field and

300,000 A/cm² at 4.2 K in zero field. tapes and multifilaments, up to 50 meters long, with a J_c over 10,000 A/cm² at 77 K over the entire length, have been fabricated.

"MICROSTRUCTURES AND CRITICAL CURRENT OF HTSC"

Chief Researchers: S.X. Dou, L. Vance, B. Bonwick and N. Savvides
Associate Researchers: H.K. Liu and Y.C. Guo
Sponsor: ARC (Collaborative)
Duration: 1994-1996

The aim of this project is to investigate the effects of phase transformation, grain boundaries, second phases and structural defects on the critical current density in the Bi-based superconductors. The presence of impurities, amorphous phases, compositional variations, solid solutions, intergranular pores, charge distribution and other features at the grain boundaries are known to affect the electrical and magnetic properties. Microstructural studies consist of high-resolution scanning electron microscopy (HRSEM), high-resolution transmission electron microscopy (HRTEM) and proton scattering. Models for interpretation of the mis-orientation of grains and phase transformation will be tested. With precise data obtained from the study on the phase evolution, the processing, microstructures and electromagnetic properties, correlation of these data will lead to optimisation of processing parameters for improving the critical current density to a level suitable for large scale applications.

"THERMOMECHANICAL PROCESSING OF HTS WIRES"

Chief Researcher: H.K. Liu and T. Chandra
Position: Associate Professors
Sponsor: ARC (Collaborative)
Duration: 1994 - 1996

The hot working of the superconducting materials has drawn world wide attention recently and is seriously considered by the Geneva Group to be a commercially viable technique to produce long lengths of superconducting tapes and wires. The aim of this project was to optimise the fabrication parameters to produce Bi-based tapes and wires by thermomechanical processing techniques. High temperature deformation is an effective fabrication method which can produce ideal shape, long and continuous products. Hot working can increase physical density and high level texture structure of the HTS materials and in turn increase critical current density following annealing and is desirable technique for large scale applications.

"High Temperature Superconductor (HTSC) LABORATORY"

Chief Researcher: S.X. Dou, H.K. Liu, I.D.R. MacKinnon, P.J.K. Paterson, N. Savvides, K. Muller, E.R. Vance, M.P. Das, W.J. Bonwick, T. Finlaynson, G.B. Smith, J.M. Bell, D.N. Jamieson, S. Myhra and I.M. Low
Sponsor: ARC (Research Infrastructure Equipment and Facilities)
Duration: 1995 - 1996

This ARC founded project is to upgrade the high temperature superconductor (HTSC) materials laboratory. The mission of the laboratory is to establish a world class cooperative research team to conduct fundamental and applied research in HTSC and to stimulate the technological and commercial development of the Australian HTSC industry.

“MAGNETIC PROPERTY MEASUREMENT SYSTEM (MPMS)”

Chief Researcher: S.X. Dou, H.K. Liu, I.D.R. MacKinnon, E.R. Vance, M.P. Das, S. Myhra, P.D. Killen, C. Zhang and I.M. Low
Sponsor: ARC (Research Infrastructure Equipment and Facilities)
Duration: 1996 - 1997

This ARC founded program is to establish a Magnetic Property Measurement System (MPMS) at University of Wollongong. The MPMS has become an essential tool for this large group of researchers studying magnetic properties of the high temperature superconductors (HTSC) in the fields of physics, chemistry and materials science. The MPMS ensures high sensitivity and reliability, flexible operation and versatile applications and hence is of vital importance for high quality research work.

“DETERMINATION OF CURRENT DISTRIBUTION AND LIMITING FACTORS”

Chief Researcher: S.X. Dou, H.K. Liu, K. Muller and H. Weber
Associate Researchers: J. Horvat, Y.C. Guo, M. Ionescu, J. Li and P. Mikheenko
Sponsor: ARC
Duration: 1997 - 1999

The project will focus on the understanding of current distribution and current limiting factors through the correlation of electromagnetic and transport properties with structure, microstructure and phase composition. **The main questions to be answered are: what is the current limiting mechanism in the real high T_c superconductors? and how can the critical current densities be improved through materials formulation?** A multi-Hall probe technique will be employed to establish the current distribution profile in the transverse direction of the tape. Since the Hall probe technique is non-destructive it may be used for monitoring the variation of current distribution during tape processing. The current distribution profile will be further confirmed using magnetisation and transport measurements on the intact Ag-sheathed tape and on the oxide core. The comparison of these measurement results will provide a clear current flow patterns in various samples. The current distribution profile in both the perpendicular and parallel direction to the tape axis will also be established. The precise current distribution profile will provide important information on the limiting factors for super-current and the current transport models can be developed.

“INVESTIGATION OF WEAK LINKS CHARACTERISTICS IN HTSC”

Chief Researcher: S.X. Dou, H.K. Liu, K. Muller and H. Weber
Associate Researchers: J. Horvat, J. Li and P. Mikheenko
Sponsor: ARC
Duration: 1997 - 1999

This project will focus on understanding the weak links behaviour of the tapes. Through remnant magnetisation measurements of the intact Ag sheathed Bi-based tapes and the severely bent tapes, the inter- and intra-current densities can be separated. The results reveal that the intergrain current density is smaller than intragrain current density in state-of-the art tapes in magnetic fields, suggesting that the overall J_c is limited by the weak links in low fields. Although there are various types of weak links in the HTSC materials, grain boundaries are the major cause of the weak links. Grain boundaries with varying angles will be examined by using an electron diffraction technique to test whether the existing coincidence site lattice model or some modified model is applicable to interpret the mis-orientation in the HTSC materials. A systematic studies on the correlation of grain boundary angles with critical current performance of tape materials as well as bi-crystals will be carried out. With the detailed information on grain boundary structures available, we will be in a position to analyse and assess various current transport mechanisms and to propose means to improve the weak links.

“ARTIFICIAL PINNING CENTRES USING A COMBINATION OF NEUTRON IRRADIATION AND URANIUM DOPING”

Chief Researchers: S.X. Dou, K. Muller (CSIRO) and H. Weber (Vienna)
Associate Researchers: H.K. Liu, J. Horvat and P. Awana
Sponsor: ARC
Duration: 1997 - 1999

In collaboration with Prof. H. Weber at the Atomic Institute, a noticeable enhancement in transport J_c in Ag/Bi-based 2223 tapes has been achieved using fast neutron irradiation. Potential pinning centres will be introduced through uranium doping, followed by thermal neutron irradiation. It is believed that a combination of neutron irradiation and uranium doping would introduce fission tracks throughout the sample which will act as effective pinning centres, leading to substantial increase in critical current density. Defects such as dislocations and other planar defects will also be introduced by mechanical deformation and melt process. Defect densities will be varied, for example, the cascade density can be increased by increasing the fluence of fast neutrons and dislocation density can be varied by controlling the degree of deformation and oxygen vacancy density can be varied by controlling partial oxygen pressure. Defect structure will be correlated to the electromagnetic properties.

"INVESTIGATION OF HTS HIGH GRADIENT MAGNETIC SEPARATOR",

Chief Researchers: S.X. Dou, B. Buckley (New Zealand) and H.K. Liu
Associate Researchers: M. Ionecsu
Sponsor: ARC (Collaborative)
Duration: 1997 - 1999

This programme arises from the rapid maturing of high-Tc superconducting technology and the opportunity to apply this technology to the expanding need for refined products from Australia's mineral industries. The aim of the research is to conduct a collaborative research project on the feasibility of applying high temperature superconductor (HTS) magnet technologies to applications in the mineral separation industry. In particular, the programme will focus on determining the required characteristics of high-gradient magnetic separators and thus the required performance of an HTS magnet and cryogenic system. High-Tc technology offers an attractive alternative in that sufficiently high fields can be generated at reduced power consumption and high efficiency.

"NEW MANUFACTURING PROCESS FOR LONG LENGTH HTSC WIRES

Chief Researcher: Y.C. Guo
Position: Postdoctoral Fellow
Advisor: S.X. Dou
Sponsor: ARC Fellowship Scheme
Duration: 1997 - 2000.

The practical application of Bi-based high temperature superconductors depends on the successful fabrication of long tapes with high current-carrying capacity (J_c) and superb mechanical properties. Although considerable advances in the improvement of J_c have been achieved for short tapes, J_c for long tapes is still too low for most applications. The aim of this project is to improve the J_c and mechanical strength of long-length superconductor tapes to a level suitable for practical application through the implementation of a number of new techniques including 'defined phase balance' precursor powder, silver-alloy sheath materials and a 'Continuous Tube Forming/Filling (CTFF)' procedure.

"A PLAN FOR AUSTRALIAN TECHNOLOGY IN HTS WIRE"

Chief Researchers: S.X. Dou, H.K. Liu, N. Savvides, K. Muller (CSIRO), M. Apperley (MM Cables)
Associate Researchers: M. Ionecsu, P. Mikheenko, J. Horvat, Y.C. Guo, J. Li, P. Awana and V. Murashov
Sponsor: ERDC, DIST, ESAA, Dept of Energy NSW and MM Ltd
Duration: 1995 - 1998

The primary outcomes within the three year project will be:

- establishment of a Plant for manufacture of superconducting tapes in lengths up to 1 km,
- fabrication of a range of superconducting tapes/assemblies, and
- plans for commercialisation of superconducting tape.

The objectives within the three year project are:

1. To transfer current technology from the laboratory to a development plant and scale-up production to provide 1km lengths of HTSC tape with improved properties.
2. To establish statistically the reproducibility of both tape and process.
3. To achieve high critical current density, $J_c > 10,000 \text{ A/cm}^2$, over the full length.
4. To develop a range of single and multifilament tapes.
5. To reduce the cost of tape production.
6. To develop proposals for commercialisation of tape.

"PHASE EVOLUTION AND TRANSFORMATION DURING MATERIALS FORMULATION"

Chief Researchers: S.X. Dou, H.K. Liu, M. Xu and D. Finnemore (Ames Lab, USA)
Associate Researchers: M. Ionescu
Sponsor: Bilateral Program, DIST, NSF(USA)
Duration: 1994 - 1996

The aim of this project is to understand the phase formation and transformation processes at processing temperature and in real time in order to determine the phases that form and the kinetics of growth. The effect of various processing factors such as partial pressure of oxygen, starting stoichiometry and second phases will be studied in detail. An in-situ high temperature X-ray camera is used for the study of melting and freezing processes on these tapes. The results of this study allow the establishment of the correlation between phase transformation and various processing variables, and hence the connection between the microstructure and performance of these materials.

"EFFECT OF SILVER ADDITION AND SHEATH MATERIALS ON PROPERTIES OF BI-BASED HTS WIRES"

Chief Researchers: S.X. Dou and H. Maeda (Japan)
Associate Researchers: Y.C. Guo
Sponsor: Bilateral Program, DIST, STA (Japan)
Duration: 1995 - 1996

Silver-sheathed $(\text{Bi, Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$ (2223) superconducting composite tapes are very promising materials for use in the area of large currents and high magnetic fields. Practical applications of these materials depend on the successful fabrication of superconducting tapes with high current carrying capacity and superb mechanical properties. The aim of this project is to investigate the effect of silver additions and silver-alloy sheath materials on the electrical and mechanical properties of Bi(2223) composite tapes. A precise relationship between the silver addition level, silver-alloy sheath materials, and superconducting and mechanical properties will be established, providing the best materials processing technology for fabrication of high current carrying capacity and highly flexible short and long Bi(2223) superconducting wires and tapes.

“DOPING OF AG-ALLOY SHEATH OF BI-HTS WIRES AND COMPOSITE HTSC”

Chief Researchers: S.X. Dou and H. Togano (Japan)
Associate Researchers: Y.C. Guo
Sponsor: Bilateral Program, DIST, STA (Japan)
Duration: 1995 - 1999

Silver has long been used as a sheath material for Bi-based superconducting tapes. However, mechanical properties of silver are inadequate to withstand the stress occurring upon their production and service. Silver alloys with better mechanical properties can be used to account for this deficiency. Doping of silver alloys with elements like lithium or titanium, for example, was reported to improve the current carrying capabilities of the tapes. However, it is not clear how this improvement occurs. In this project, we will elucidate the mechanisms of this improvement. We will find the optimal doping conditions and assess the upper limits of the improvement. If the doping is capable of substantially enhancing the current carrying capabilities of the tapes, it will be used in industrial production of superconducting tapes since it is a simple and inexpensive method.

“WEAK LINKS AND FLUX PINNING OF HTSC TAPES”

Chief Researchers: S.X. Dou and D. Dew-Hughes (Oxford)
Associate Researchers: J. Horvat
Sponsor: Bilateral Program, DIST
Duration: 1995 - 1996

Superconducting tapes that operate at temperatures of liquid nitrogen are already finding their place in industrial applications. However, the application on a large scale is severely hampered by strong sensitivity of their critical current densities on the magnetic field. The basic processes behind this are poorly understood. The main objective of this project is to identify and elucidate these processes, which will give a new impetus to our major project consisting of developing the manufacturing methods for the production of long, quality tapes.

“PINNING ENERGY OF HTSC”

Chief Researchers: S.X. Dou and E. Babic (Uni of Zagreb)
Associate Researchers: J. Horvat
Sponsor: Bilateral Program, DIST
Duration: 1997 - 1998

Experiments will be carried out to investigate the voltage-current characteristics (V-I curves) on the well characterised samples including single crystals, polycrystals and the Ag-sheathed tapes. From these results one can deduce the effective activation energy (U_0) by assuming that the motion of fluxions is a thermally activated process. Since the U_0 corresponds to the height of the pinning potential the knowledge of U_0 is very important for both theoretical understanding and practical application. By comparing the results derived for various samples prepared from the same HTS compound one could understand whether the U_0 is dependent on the materials processing, and whether and how the effective pinning centres could be introduced into the materials. Furthermore, from these results one can understand the mechanism of the resistance broadening with or without

Lorentz force and factors controlling the broadening. The results of irreversibility measurements will be studied in terms of their implication for the questions of whether the irreversibility line represents a melting or a flux creep phenomena and whether and how the flux pinning strength will affect the irreversibility behaviour of various HTSC compounds and different forms of a particular HTSC compound.

CARRYING CAPACITY IN AG-CLAD HTS WIRES FOR MAGNET

Chief Researchers: H.K. Liu and E.W. Collings (Ohio State Uni)
Associate Researchers: M. Ionescu
Sponsor: Bilateral Program, DIST
Duration: 1996 - 1997

The objective of this collaborative project is to increase the current-carrying capacity for the Ag-clad $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_x$ (Bi-2223) and $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_x$ (Bi-2212) superconducting wires and tapes through investigation of the relationship between the microstructure and flux pinning properties using expertise and facilities in both sides. To promote scientific exchange and collaboration in the high technology area between scientists in the two countries.

“ELECTRONIC PROPERTIES AND DISSIPATION IN HTSC”,

Chief Researchers: P. Mikheenko and C. Zhang
Associate Researchers: J. Horvat
Sponsor: ARC
Duration: 1995 - 1997

The project is to study some important properties of these HTSC materials, including electronic pairing mechanisms and related dissipation phenomena (thermal noise and resistivity broadening). The chief concern is can pairing arise from pure electronic excitation? how do these HTSC materials respond to external conditions such as magnetic field and temperature? and how to make use of the intrinsic electronic properties of the materials in real device design. The project deals the problems from experimental and theoretical point of view. The MPMS will be used extensively for the measurements of magnetic hysteresis loops from which AC loss can be derived.

TRANSPORT MECHANISM OF HTS

Chief Researchers: P. Mikheenko and C. Zhang
Associate Researchers: J. Horvat
Sponsor: ARC, ERDC, DIST, ESAA, Dept of Energy NSW and MM Ltd
Duration: 1995 - 1997

This project will focus on the fundamental transport mechanism in anisotropic low-dimensional superconductors such as HTSC. Several important questions will be addressed in this project such as vortex dynamics and damping, dissipation and energy loss, Kosterlitz-Thouless transition (KTT) and role played by various interlayer coupling. However, the core questions to be answered are

what is the fundamental transport mechanism in anisotropic layered superconductors? and how can structural information of high-T_c superconductors be obtained via transport study? To achieve a microscopic understanding of various transport mechanisms, we shall also study the effect of electron and spin correlation on HTSC using a nonperturbative approach. Our ultimate goal is to obtain a complete picture of the transport mechanism and electronic states in these exotic new materials.

DYNAMIC RESPONSE IN TYPE-II SUPERCONDUCTORS IN A MAGNETIC FIELD AND IN THE PRESENCE OF VORTEX DAMPING

Chief Researchers: C. Zhang
Associate Researchers: J. Horvat and P. Mikheenko
Sponsor: ARC
Duration: 1995 - 1997

A microscopic description of dynamic response in type-II superconductors will be developed by using a fully quantum mechanical approach. Current-current response for the normal state in layered anisotropic systems have been calculated within the framework of thermal Green's functions and a quantum kinetic description. Within these methods, frequency and magnetic field dependent effective quasiparticle mass and transport relaxation time can be calculated. These two important quantities have been so far treated as input parameters in the existing work. However, in order to fully understand the vortex dynamics and magneto-optics observation, a complete knowledge of field and frequency dependent vortex damping (and the quasiparticle mass) is urgently required. The damping can also provide useful information on vortex pinning. By treating, vortex-vortex interaction, vortex-disorder coupling, and vortex pinning on an equal footing, effective mass and vortex damping rate can both be calculated. The result can then be used to analyse the experimentally observed magnetoresistivity. Within the quantum-kinetic description, a complex conductivity tensor will be calculated. The real part of the conductivity then determines the optical absorption. The conductivity obtained within this approach also contains full temperature dependence. To understand the static dissipation due to non-Lorentzian forces, a first principle approach on the thermal noise of a system of multiple or periodic Josephson junctions will be developed.

2.1 RESEARCH PROJECTS FOR POSTGRADUATE STUDENTS IN CSEM

THERMOMECHANICAL PROCESSING OF HIGH TEMPERATURE SUPERCONDUCTING BI-PB-SR-CA-CU-O MATERIALS.

Student: R. Bhasale
Supervisors: H.K. Liu, S.X. Dou
Sponsor: ARC (APA (I))
Duration: 1193 - 1997

The objective of this project is to study the effect of mechanical deformation on the phase formation, microstructure and critical current density of Ag-clad Ag/Bi-2223 wires. It was found that the Bi-2223 formation particle decomposition results in improvement of critical current densities due to the induced precipitation at lower annealing temperatures.

"POWDER PROCESSING AND CHARACTERIZATION OF HTSC",

Student: M. Yavuz (Ph.D candidate)
Supervisors: S.X. Dou and E.R. Vance (ANSTO)
Sponsor: AINSE
Duration: 1996 - 1997

The objective of this project is to develop novel procedures for HTSC powder preparation which has been well established as a critical factor for the quality and final properties of all the HTSC products. The UoW and ANSTO group has jointly developed a solution route using spray drying, co-decomposition or freeze drying processes. This process ensures the homogeneity, reactivity, absence of carbonate and a rapid formation of the Bi-based high T_c phase.

"FAULT CURRENT LIMITER WITH HIGH TEMPERATURE SUPERCONDUCTING COILS

Student: J.X. Jin (Ph.D candidate)
Supervisors: S.X. Dou, H.K. Liu and C. Grantham (UNSW)
Sponsor: Dept of Energy NSW and MM Ltd
Duration: 1994 - 1997

The aim of the project is to test the suitability of high T_c superconductor coils for the use in the operation of the current limiter. In 1993 a small prototype unit with Bi-2223 Ag clad superconducting coils was designed and built using the established principle of a magnetic core saturable reactor. The results from the tests were sufficiently encouraging to demonstrate the principle and potential of a power system fault current limiter with high temperature superconducting coils. Work has now begun on the design and build of a substantially larger prototype which is being designed to handle fault currents of several hundred Amperes and will therefore represent a substantial step forward towards the use of large practical fault current limiters in power system networks.

"DESIGN AND CONSTRUCTION OF HTSC MAGNETS",

Student: N.V. Vo (Ph.D candidate)
Supervisors: S.X. Dou and H.K. Liu
Sponsor: DEET (APA(I))
Duration: 1994 - 1997

The critical current density of HTSC at low temperatures has exceeded those for conventional superconductors in high fields. High field magnets can be fabricated with HTSC. The objective of this project is to design and test HTSC magnet. The magnet of solenoid or pancake type can be made through reaction-winding or winding-reaction processes using HTSC tapes.

"DESIGN AND TESTING OF HTSC CURRENT LEADS"

Student: B. Zeimetz (Ph.D candidate)
Supervisors: S.X. Dou and H.K. Liu
Collaborators: B. Bonwick and B. Chen (Monash Uni.)
Sponsor: ARC
Duration: 1994 - 1997

The objective of this project is design and test current leads constructed by using Ag-clad HTS tapes. Current leads made from HTSC tapes or bulk shape can be used to replace the copper leads in the energy storage from 4.2K to 77K which has already constructed in Monash Uni.

IMPROVEMENT OF HTS PROCESSING

Student: W.G. Wang (Ph.D candidate)
Supervisor: S.X. Dou and H.K. Liu
Sponsor: ARC
Duration: 1995-1997

The objective of this project is to investigate HTS materials processing conditions with the focus of overall parameters optimisation. A sandwich rolling technique was developed to avoid the formation of "Sausaging" during deformation. Lead distribution in the precursor was found to be critical for the 2223 phase formation and critical current density. Total sintering time within 100 hours can be achieved through optimisation of Pb distribution and heat treatment for Ag/Bi-2223 tape fabrication.

INTRINSIC PROPERTIES OF SINGLE CRYSTALS

Chief Researchers: X.L. Wang (Ph.D candidate)
Supervisors: S.X. Dou and H.K. Liu
Sponsor: ARC
Duration: 1994-1997

This project is to study the intrinsic electromagnetic properties through high quality single crystals. Good quality single crystals provide a standard reference for studying the relationship between the chemical composition, structure and the physical properties of the high T_c superconductors. Spiral growth and fine crystallised CuO inclusions were observed for the first time in Bi-2212 crystals. Because of the instability of $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_y$ (Bi-2223), there are no Bi-2223 single crystals available. By using a mixture of component oxides with appropriate amounts of NaCl/KCl, some small size Bi-2223 crystals with dimension of $0.2 \times 0.3 \text{ mm}^2$ have been obtained. With a proper temperature gradient applied during the crystal growth, Bi-2223 single crystals with a millimetre size may be obtained. The crystalline structure, defects and twinning of the irradiated and unirradiated single crystals will be examined at various levels by XRD, SEM, TEM and STM. The magnetic properties and hence the pinning behaviour of the single crystals will be investigated by using a.c. magnetic susceptibility, field- and time-dependent magnetisation and magnetic field dependence of the critical current density. These results will be used to clarify the effect of neutron irradiation on flux pinning and to test the various pinning models which relate to the flux pinning properties including the pinning potential, pinning force density, volume, shape, and distribution of the pinning centres.

3. RESEARCH PROGRAM FOR ESMRG

“INVESTIGATION OF METAL-NICKEL HYDRIDE ALLOYS FOR THE USE OF ENERGY STORAGE”

Chief Researchers: H.K. Liu, S.X. Dou, I. Uehara, T. Sakai (Osaka), Y.S. Zhang (Nankai) and J.S. Wang (Harbin)
Sponsor: DEET, Target Institutional Link Program
Duration: 1996 - 1999

The objective of the project is to investigate nickel-metal hydride alloys for incorporation in rechargeable batteries with high energy density and low cost. These will play an increasingly important role in the energy industry. This will be achieved by bringing together internationally recognised experts in this field from Japan, China and Australia to conduct collaborative research work. The research project described in this proposal is at the forefront of the rapidly developing field of nickel-metal hydride (Ni-MH) materials and will enhance the R&D capacity of the Universities. Its success would significantly contribute to the growth of Ni-MH materials science and technology, enhancing Australian manufacturing capability in metal hydride batteries. These products would be very attractive for applications such as electric vehicles and telecommunications. The Ni-Metal alloys also have great potential to replace Ni-Cd alloys and to prevent the proliferation of Cd in the environment.

“MAGNESIUM-BASED HYDRIDE ALLOYS FOR RECHARGEABLE BATTERIES”

Chief Researchers: H.K.Liu
Associate Researchers: S.X. Dou and S. Kennedy (ANSTO)
Sponsor: ARC
Duration: 1995 - 1996

Magnesium-based hydrogen storage alloys have shown a great promise for the use of electrode for rechargeable batteries which will play an important role in energy industry. The objective of the project is to investigate magnesium-based alloy electrode materials for operation, at ambient temperature and pressure, of the rechargeable batteries with sufficiently high hydrogen storage capacity and low cost.

“MICROSTRUCTURE AND DEFECTS IN NICKEL-METAL HYDRIDE ALLOYS THROUGH NEUTRON DIFFRACTION AND SCATTERING TECHNIQUE”

Chief Researcher: H.K.Liu
Associate Researchers: S.X. Dou and S. Kennedy (ANSTO)
Sponsor: AINSE
Duration: 1996 - 1997

Ti₂Ni type hydrogen storage alloys used for the fabrication of electrodes to manufacture high performance rechargeable Ni-MH batteries is drawing a great deal of attention due to the high feasibility of commercialisation. A project is being implemented under the present applicants supervision and organisation. Achievements completed in the past two years put our group at the forefront of world research in this field. Elemental substitutions such as cobalt, boron, potassium

and aluminium have brought significant improvements to the performance of the electrodes in specific capacity and/or cycle life; Aluminium addition, for instance, was found responsible for the passivation of the alloy which is beneficial for the increase of cycle life; Formation and accumulation of a new phase, $Ti_2NiH_{0.5}$, was discovered for the first time as being responsible for the capacity loss of the electrodes which becomes the third reason for the failure of electrode in addition to the two commonly known reasons of powder disintegration and oxidation. Although the aforementioned work has been done carefully with X-ray diffraction and Auger analysis, it is still of great importance using neutron diffraction to further expand our previous work in order to locate the various atoms (especially H atom), determine their coordinates, quantitatively analyse the phase structure, study the strain and particle size distribution and to confirm or to correct our previous work. Furthermore, in situ studies on the variation of the crystal structure during charge/discharge process are expected to provide some novel information to this field. The in-depth information obtained by neutron diffraction will certainly highly promote our research and further enhance the feasibility of commercialisation.

3.1 RESEARCH PROJECTS FOR POSTGRADUATE STUDENTS OF ESMRG

Phase Formation and Transition in the R-Fe-T Systems

Student: J.M. Xu (Ph.D candidate)
 Supervisors: S.X. Dou and J. Cadogan
 Sponsor: ARC
 Duration: 1993 - 1996

The objective of this project is to investigate the phase stability and phase transition in the R-Fe-T Systems where R represent Nd, Gd, Tb, Dy Er, H_o , T_m and T represents Si, Ti and Zr. Their structure's, structure-relationship and magnetic properties will be systematically studied.

“LEAD-CALCIUM-TIN-ALUMINIUM GRID ALLOYS ON VALVE REGULATED LEAD/ACID BATTERIES”

Student: S. Zhong (Ph.D candidate)
 Supervisors: H.K. Liu, S.X. Dou and M. Skyllas-Kazacos
 Sponsor: URC, ARC
 Duration: 1995 - 1997

For the lead-acid batteries materials project, it has been confirmed that the creep strength and the corrosion resistance of grid alloys can be increased by the addition of silver. Additions of sodium can refine grain sizes and increase the mechanical properties of the grid alloy, but sodium containing grids show a poor creep strength and unsatisfactory corrosion resistance. The project will focus on evaluation of the effect of additives on the performance of rechargeable batteries. For lead-acid battery materials, our aim is to improve the performance of the grid plate alloy materials for Valve Regulated Lead/Acid Batteries. The research plan will be:-

- (1) to investigate sample alloy electrodes, bare grids and pasted grids,
- (2) to investigate the influence of the active materials and electrolyte containing some additives,

- (3) to analyse the microstructure, mechanical properties, corrosion properties, and electrochemical properties of the alloys.

INVESTIGATION OF MG-BASED HYDROGEN STORAGE ALLOYS

Student: N. Cui (Ph.D candidate)
Supervisors: H.K. Liu, S.X. Dou
Sponsor: DEET, ARC, URC
Duration: 1994 - 1997

The objective of the project is to investigate the kinetics of hydriding and dehydriding of the Mg-based hydride. A breakthrough in the research of Mg-based hydrogen storage alloy anodes has been made through this PhD project. We have demonstrated for the first time that the Mg-based hydrogen storage alloys can be used as rechargeable anodes. The capacity of the modified Mg₂Ni-type anode has been increased to 210 mAh/g from the initial value of only 8 mAh/g for an unmodified Mg₂Ni anode. The high-rate discharge capability of the Mg-based anode has also been remarkably improved.

"EFFECTS OF ADDITION ON THE PERFORMANCE OF TITANIUM BASED HYDROGEN STORAGE ALLOY ELECTRODES"

Student: B.L. Luan (Ph.D candidate)
Supervisors: H.K. Liu and S.X. Dou
Sponsor: AIDB, JCSS
Duration: 1994 - 1997

The objective of the project is to study the Nickel-Metal Hydride Materials. The effects of potassium-boron addition on the performance of titanium based hydrogen storage alloy electrodes were studied for the first time in the world. Charge/discharge cycles showed a significant increase of cycle life as well as the specific capacity of the electrodes with potassium-boron addition. The effects of aluminium additions on the performance of Ti₂Ni hydrogen storage alloy electrodes has been studied. The charge/discharge cycles of the electrodes revealed that the cycle life of the Ti₂Ni electrodes greatly increases with increasing addition of aluminium.

AB₅ NICKEL-METAL HYDRIDE MATERIALS,

Student: J. Chen (Ph.D candidate)
Supervisors: H.K. Liu and S.X. Dou
Sponsor: APA and UPA
Duration: 1996 - 1999

The aims of this project are to determine the structure of AN₅ alloy after repeated hydriding and dehydriding using neutron diffraction and scattering techniques, to insert an suitable electrochemical cell into the neutron diffraction system and follow the hydriding and dehydriding for many cycles, and to study the location of hydrogen atoms, quantitative phase analysis, strain and particle size distributions. The phase assemblage, microstructures and defect structures will be examined by

XRD, SEM and TEM. The collaboration will continue with Dr. Kennedy who is a member of neutron scattering group, ANSTO. "In-Situ" Studies on the variation of the crystal structure during charge/discharge process are expected to provide some novel information in the field.

4. RESEARCH PROGRAM FOR RCAMP

RAPID SOLIDIFICATION AND MECHANO-CHEMICAL PROCESSING OF MATERIALS

Chief Researchers: A. Calka and D. Wexler
Sponsor: ARC
Duration: 1994 - 1996

The ARC funded project on Crystallisation of Metallic Glasses has proceeded well during 1996 with major advances in the development of magnetic nanocrystalline materials being achieved through the substitution of certain transition metal elements to improve magnetic permeability. Additional work in this field has included the use of advanced techniques of Magnetic Force Microscopy to image the stray magnetic fields above soft magnetic materials and the investigation of alternative elements to initiate the nucleation of fine nanocrystals. Probing of the interactions between hard and soft magnetic phases in partially crystallised amorphous ribbons resulted in improvements in our understanding of fundamental magnetisation processes in these materials.

PROCESSING AND PROPERTIES OF Nb₃Al FOR HIGH FIELD APPLICATIONS

Researcher: A. Calka, D. Wexler and E.W. Collings (Ohio State University)
Position: Research Fellow
Starting Date: July 1996
Supervisor: A. Calka
Sponsor: ARC

The research will explore a new synthesis route for Nb₃Al superconductors. In spite of their apparent simplicity Nb₃Al superconductors are notoriously difficult to fabricate and conventional synthesis methods have not resulted in development of useful processes. Just recently Nb₃Al superconductors have been synthesised at the Department of Materials Engineering, University of Wollongong using non-conventional magneto-mechano-chemical method. The research will focus on synthesis, stability and properties of Nb₃Al superconductors.

METAL MATRIX COMPOSITES

Researchers: T. Chandra and D. Yu
Sponsor: ARC
Duration: 1994 - 1996

This project has involved joint research with Professor Asanuma from Chiba University, Japan on processing of a new in-situ AlTi/Al composite and interface characterisation of a smart fibre reinforced materials (FRM) by embedding optical fibres. This cooperation is currently continuing and will extend to 1997.

MATERIALS JOINING

Researchers: D. Dunne and G. Spinks
Sponsor: CRC
Duration: 1994 - 1997

A raft of projects on advanced joining techniques for materials, mostly funded by the CRC for Materials Welding and Joining, is underway. A nationally important data-base has been established at the University and valuable research experience has been acquired on adhesive bonding of sheet steel and aluminium alloys. These projects have been directed by Dr Spinks in collaboration with Dr Yang, P. Basu and S. Smiltnieks, and have focussed recently on the importance of the pre-treatment of the metal surface on the strength, durability and integrity of the adhesive joint. Studies of the fatigue performance of adhesively bonded aluminium alloy sheet will also comprise an important component of ongoing activity and, as it is particularly relevant to the aluminium shipbuilding industry, it has the potential for significant industrial funding.

Professor Dunne and Dr Li are involved in projects on FEM modelling of tandem laser welding of coated sheet steels; life assessment of repair welded pressure vessel steels in partnership with ANSTO; and high productivity welding of austenitic, ferritic and duplex stainless steels in collaboration with CSIRO. An ARC sponsored research project on shape memory alloys has led to the development of a new Fe-Mn-Si based alloy with the highest recovery strain so far reported. Commercial possibilities for application as heat shrinkable couplings for joining of tube and pipe are being explored.

MICROWAVE SINTERING OF CERAMICS

Researcher: S. Nightingale
Sponsor: ARC
Duration: 1994 - 1996

A new project on the reaction bonding of silicon carbide refractories has made substantial progress. Major modifications had to be made to the existing microwave sintering equipment to enable use of a controlled atmosphere. The process involves combining silicon metal with SiC grains, and then heating in a nitrogen atmosphere to produce a silicon nitride bonded silicon carbide. In conventional furnaces, it is impossible to completely react all the silicon, as an expansion associated with this reaction blocks the pores, and prevents the nitrogen gas from reaching the interior. By using the microwave heating system nitridation levels of >99% have been achieved at low temperatures after heating cycles much shorter than used in conventional heating. Work is continuing on process optimisation, and product characterisation.

Studies of low temperature microwave sintering of yttria zirconia have also continued. Densities of 99% of the theoretical value have been achieved at temperatures 150°C lower than normally used. The material also has a very fine grain size and good mechanical properties. The arrival of the new 28GHz power supply late in 1996 enables work to be undertaken in 1997 which will study the effects of high frequency on microwave sintering kinetics, by comparing the results with the extensive data already collected at 2.45GHz, and results obtained through collaboration with JWRI

in Osaka (through a Link Program) at 60GHz. Dr. Nightingale will visit Osaka in February of next year to undertake these experiments.

MICROSTRUCTURE AND PROPERTIES OF SOME GAMMA BASED TITANIUM ALUMINIDES

Researcher: Z.Chen
Sponsor: Department of Materials Engineering
Starting date: 1996

The characterisation of transition metal addition gamma TiAl produced via ingot route has progressed well in terms of the understanding of microstructure development and phase relationship. Cooperation's with colleagues inside and outside of the Centre have led to new initiatives in the development of gamma based TiAl intermetallics. They are synthesis of TiAl via the powder metallurgy route (with Calka) and the application of titanium aluminide coatings on steels (with Samandi).

4.1 RESEARCH PROJECTS FOR POSTGRADUATE STUDENTS OF RCAMP:

SYNTHESIS OF ALN USING REACTIVE BALL MILLING

Student: Narelle Steer
Starting Date: March 1996
Supervisor: A. Calka
Sponsor: Department

Aluminium nitride is a wide-band semiconductor which shows high thermal conductivity, low dielectric constant, high mechanical strength and expansion coefficient similar to silicon. Therefore, aluminium nitride is considered as a perfect substrate material for electronic devices. Conventional synthesis routes for aluminium nitride are direct nitridation of metallic aluminium, and carbothermic reaction of alumina, carbon and nitrogen. Direct nitridation involves heating aluminium powder in the presence of N₂ or NH₃ at temperatures above 1200°C. Alternatively, carbothermal reduction involves reacting finely mixed Al₂O₃ and carbon powder in N₂-containing gas at temperatures between 1100-1800°C. Aluminium nitride may also be synthesised by plasma nitridation of aluminium, reaction of aluminium chloride with ammonia and by pyrolytic routes. In all of those processes, the quality of the product powder is limited by the impurity level. This strongly affects the thermal conductivity which is always well below the theoretically predicted value.

We studied formation of AlN compound in ball milled Al powder in ammonia and/or nitrogen. We have shown that using controlled ball milling of Al in ammonia leads to formation of Al based nanostructure. This material transforms into Al-AlN nanocomposite type of structure upon heating below the melting point of Al. By using different atmosphere and/or milling time, a range of nanocomposites with different ratio of AlN to Al matrix can be synthesised.

SYNTHESIS OF Si₃N₄ BY REACTIVE BALL MILLING

Student: Sonya Colburn
Position: PhD Student
Starting Date: July 1993
Supervisor: A. Calka
Sponsor: Department

Using conventional methods, Si₃N₄ nitride can be fabricated by carbothermal reaction of oxides in nitrogen (e.g. SiO₂ in the case of synthesis of Si₃N₄) liquid-phase reduction, vapour-phase reduction, plasma and laser-assisted gas-phase reaction, through organometallic precursors, combustion synthesis and by direct nitridation processes. The direct nitridation method is widely used in industrial practice. However, it involves a series of heating cycles at high temperatures (varying from 1100 to 1400°C) under different nitriding atmospheres. Very often the unwanted, high-temperature form of nitrides (e.g. β-form in the case of Si₃N₄) is always formed in addition to the low temperature forms. Most of these problems can be overcome if the ball milling method is employed. The milling process generates a large number of new, atomically clean, and presumably highly reactive, surfaces which are freshly exposed to nitrogen. The continual creation of such surfaces may substantially enhance the adsorption and reaction of nitrogen. This project was focused on formation of nanostructural Si₃N₄ using reactive ball milling and determination of its sintering and mechanical properties.

SYNTHESIS OF THERMOELECTRIC MATERIALS.

Name: Khamal Aryl
Position: Research Fellow
Starting Date: July 1993
Supervisor: A. Calka
Sponsor: Research School of Physical Sciences, ANU

Si-Ge based alloys are found to have the best properties for the temperature (~1000°C) thermoelectric converter applications. In particular the efficiency of Si-Ge/GaP alloy is outstanding. Even though thermoelectric generators (TEG) have low efficiency, they exhibit many other attractive features such as compactiveness, long life and reliability, safe and silent operation. The research and development is directed to develop a suitable Si-Ge based thermoelectric materials in a cheaper and simpler way using mechanical alloying technology.

SYNTHESIS OF HARD METAL NITRIDES BY REACTIVE BALL MILLING.

Student: J.I. Nikolov
Position: PhD Student
Starting Date: July 1993
Supervisor: A. Calka
Sponsor: Research School of Physical Sciences, ANU

Tungsten and molybdenum nitrides are generally less stable than oxides. When heated to high temperature they lose N₂ or O₂, respectively. Because of the much lower bond energy of the N₂ molecule (941 kJ/mol) compared to O₂ (499kJ/mol) the decomposition of the nitride occurs at much lower temperature. The higher stability of oxides relative to nitrides means not only that nitrides must be prepared at lower temperature, but also that oxygen and water must be completely excluded from the nitriding environment, usually nitrogen gas or ammonia. Using traditional nitriding techniques it is not easy to achieve which leads to lack of activity in this field. However, using mechano-chemical techniques it is quite easy to keep control on the nitriding atmosphere and other process parameters such as milling energy and local milling temperature. This method gives broad opportunity to discover new chemistry and new phenomena in solid state processing of nitrides. In these study we investigated possibility of synthesis of Ti, Zr, W, Mo nitrides by ball milling of elemental metal powder in nitriding atmosphere.

5. STRONG INTERNATIONAL LINKS

IMTM has established an international multidisciplinary collaborative network. This has led to information exchange, co-supervision of PhD students, joint grant proposals and joint publications with about 20 research teams around the world as listed below.

1. CSIRO Division of Applied Physics, N. Savvides, K. Muller
2. ANSTO, ER Vance, J. Boldman and S Kennedy
3. Electron Microscope Unit, University of Sydney, D.J.H. Cockayne
5. UNSW Schools of Physics, Elec. & Chemical Eng., 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
12. Industrial Research lab. NZ, B. Buckley
13. Blackett Lab. Imperial College (A.D. Caplin), London, UK
14. Oxford University, Eng Dept (D. Dew-Hughes)
15. National Research Institute of Metals (H. Maeda, K. Togano)
16. Ames Lab. Iowa State University(D. Finnemore), Iowa, USA.
17. Ohio State University (E.D. Collings), Columbus, OH, USA.
18. University of Zagreb (E. Babic), Zagreb, Croatia.
19. Argonne National Lab (DL Shi, now in Cincinnati Uni), Argonne, IL, USA.
20. Atomic Institute of Austrian Universities (H. Weber), Vienna, Austria.
21. Houston Uni, (R. Weistein), USA
22. Institute of Physics, Academy Science, Beijing, PRC (Z.X. Zhao)
23. Northeastern University, Shenyang, PRC, (Z.T. Sui, G.R. Zhang).
24. National Institute of Standard Technology (J. Ekin), Boulder, USA
25. Institute of Non-ferrous Metals, Beijing, PRC, (R.K Wang).
26. Singapore National Uni (A. Bourdillon)
27. Tokai University, Japan (T. Toyoda)
28. University of Alberta, Canada (Y. Tadashi)

29. Osaka National Research Institute, Japan (I. Uehara and T. Sakai)
30. Northwestern Institute of Non-ferrous Metals (L.Zhou)
31. Nakai Uni (Y.S. Zhang)
32. Harbin Uni. (J.S. Wang)
33. Yamagata University, Japan (S. Kambe)

6. LINK WITH INDUSTRIES

- * Metal Manufactures Ltd
- * BHP
- * Pacific Power
- * Electric Supply Association of Australia
- * Alphatech International Ltd
- * Readings Ltd
- * Aohua Batteries Technology Ltd.
- * Huagong Energy Storage Ltd

MM has been involved with the research with average cash contribution of \$100,000 per annum since 1988. MM established a Chair of Superconductivity which had been held by Professor Dou until 1993. MM sponsored two ARC collaborative projects and three APA(I) in the Institute which formed an integral part of the research and training program. The company has initiated a program "A Plan for Australian Technology of HTSC Wires" to commercialise the UoW group's laboratory achievements by building a pilot plant at the Australian Technology Park. This three year project is a continuation of a collaborative effort and builds on the success to date of work undertaken by a consortium consisting of MM, UoW and CSIRO. Total investment of \$6M from various sectors including MM Ltd, DIST, Energy Research Development Corporation(ERDC), ESAA and the Department of Energy of NSW has been committed to this project.

The UoW group has already provided a formal training programs to four research fellows and engineers from MM who will work on the consortium project. The interaction between UoW team and MM team is on daily or at least weekly base at the present.

Close collaboration exists between BHP Research laboratory and the RCAMP. Research in the areas of joining, interface engineering and materials characterisation. BHP Research Laboratory is currently expanding its operations at Port Kembla and the opportunity exists to further strengthen our links in existing and new project areas.

7. EQUIPMENT AND FACILITIES

The Centre for Superconducting and Electronic Materials is equipped with modern materials processing facilities. Facilities for drawing, swaging, pressing and rolling are available in the Centre. Equipment for powder processing and characterisation have been installed at the Centre, including Attrition Mill, Planetary Mill, Spray Drier, Freeze Drier, Laser Beam Particle Size Analyzer. More than 20 programmable furnaces with varying capabilities are currently used for heat treatment of HTSC. SEM, XRD, TEM, STM, AFS and Optical spectroscopy are available for compositional

and microstructural analysis. A simultaneous DTA and TGA and a DSA for studying thermal properties and Instron machines for testing mechanical properties are also available.

Equipment for testing electrical and magnetic properties is available at the Centre, including 8 Tesla magnet, Physical Property Measurement System by QUANTUM DESIGN operated from 4K to 300K, 0T to 9T, 12T Oxford VSM, Computerised four probe DC resistivity measurement system, AC susceptibility equipment, large current DC/AC power supply up to 800A and closed cycle cryogenic system are available in our laboratory. A number of multimeters including high precision nanovoltmeter for I-V measurements, high precision power supplies, lock-in amplifiers, flux meter, oscilloscopes, and software and interfaces have been installed for physical characterisation.

8. RESEARCH GRANTS

- [1] S.X. Dou, ARC Professorial Fellowship on HTSC Processing, 1993-97 (\$520,000).
- [2] H.K. Liu, ARC Senior Research Fellowship on Long Wires of HTSC, 1994-98 (\$410,000).
- [3] S.X. Dou, L. Vance, B. Bonwick and N. Savvides, "Microstructures and Critical Current of HTSC", ARC Collaborative, 1994-6 (\$383,000).
- [4] S.X. Dou, H.K. Liu, I.D.R. MacKinnon, P.J.K. Paterson, N. Savvides, K. Muller, E.R. Vance, M.P. Das, W.J. Bonwick, T. Finlayson, G.B. Smith, J.M. Bell, D.N. Jamieson, S. Myhra, I.M. Low and D.Y. Li from 11 Institutions, "HTSC Laboratory", ARC RIEF, 1995 (\$300,000 from ARC, \$120,000 from UoW).
- [5] S.X. Dou, H.K. Liu, I.D.R. MacKinnon, E.R. Vance, M.P. Das, S. Myhra, I.M. Low, P.D. Killen and C. Zhang from 7 institutions, "PPMS", ARC RIEF, 1996 (\$250,000 from ARC, \$72,000 from UoW).
- [6] H.K. Liu and T. Chandra, "Thermomechanical processing of HTSC", ARC Collaborative, 1995-1997 (\$273,000).
- [7] S.X. Dou and H.K. Liu, "Fabrication and Application of HTS Wires and Tapes", Energy Office of NSW, 1996-98 (\$382,728).
- [8] S.X. Dou, N. Savvides, M. Apperley, "A Plan for Australian Technology in HTS Wire", ERDC, 1995-8 (\$1,600,000).
- [9] S.X. Dou and H.K. Liu, "Technology and Applications of HTSC Wires", MM Ltd. 1993-96 (\$275,000).
- [10] S.X. Dou and H.K. Liu, "Fabrication and Application of HTS Wires and Tapes", ESAA Grant, 1994-96 (\$160,000).
- [11] S.X. Dou, H.K. Liu and C.C. Sorrell, "Targeted Institutional Link program with Northeastern Uni and Institute of Physics of PRC on HTSC", DEET, 1992-94 (\$162,000).
- [12] S.X. Dou, H.K. Liu, N. Savvides and K. Muller, " A Plan for Australian Technology of HTSC Wires", DIST, 1996-98 (\$500,000).
- [13] S.X. Dou, K.H. Muller, H.W. Webber, "Microstructure and Critical Current in Bi-HTS", ARC, (\$180,000), 1997/99).
- [14] S.X. Dou, R.G. Buckley and H.K. Liu, "Investigation of HTS High Gradient Magnetic Separator", ARC - Collaborative, (\$380,000), 1997/99.
- [15] Y.C. Guo, "Doping of Silver-Alloy Sheath of Bi-HTS Wires", ARC-Fellowship, (\$200,000), 1997/99.

- [16] S.X. Dou, H.K. Liu, "Investigation of Metal-Nickel Hydride Alloys for the use of Energy Storage", TIL, DEET, (\$191,000 from DEET), (\$70,000 from UoW), 1197/99).
- [17] H.K. Liu, " Nickel-Metal Hydride Alloy", ARC, 1995 (\$6,000).
- [18] S.X. Dou and D. Finnemore (Ames), " Bilateral Program on HTSC Wires", DIST (\$5,500) and D. Finnemore, NSF (USA, \$23,000) 1994.
- [19] S.X. Dou, Y.C. Guo, and H. Maeda (NRIM), "Bilateral Program of Composite HTSC", DIST (AUS.), \$8,000, STA (JAPAN), \$5,000, 1995-96.
- [20] H.K. Liu, M. Ionescu and E.W. Collings (Ohio), "Bilateral Program of 2212 HTSC Wires", DIST (\$4,600) 1996.
- [21] S.X. Dou, J. Horvat and D. Dew-Hughes (Oxford), "Bilateral Program of Critical Current and Flux Pinning of HTSC", DIST (\$4,100).
- [22] S. Kambe (Yamagata Uni) and S.X. Dou, " Japanese-Australian Exchange Program on HTSC", Australian Academy of Science (\$14,000), 1995-6.
- [23] S.X. Dou and H.K. Liu, Two APA (I) on HTSC, DEET (\$140,000), 1993-96.
- [24] H.K. Liu and S. Kennedy (ANSTO), "Neutron Diffraction of Metal Hydride", AINSE (\$9,000), 1995/6.
- [25] S.X. Dou and H.K. Liu, " HTSC Lab", UoW (\$200,000), 1994-6.
- [26] S.X. Dou, Centre for Superconducting Materials, UoW, \$44,730, 1995.
- [27] H.K. Liu, Group of Energy Storage Materials, UoW, \$11,140, 1995.
- [28] S.X. Dou, Institute of Materials Technology and Manufacturing, UoW (\$210,000), 1996-98.
- [29] 7 OPRS, DEET (\$315,000), 1994-8.
- [30] 5 UPA and APA, DEET (\$225,000), 1994-98.
- [31] AINSE supplement scholarship of HTSC powder processing with Dr. ER Vance in ANSTO, 1994-96 (\$45,000).
- [32] S.X. Dou, J. Horvat and E. Babic (Zagreb Uni), "Links in HTS Tapes", DIST, (\$82,000), 1997/98.
- [33] S.X. Dou, Y.C. Guo and R. Togano(Japan), "Doping of Ag-Alloy Sheath of Bi-HTS Wires", DIST, (\$24,000), 1997/99.
- [34] X.L. Wang, UPRS & UPA, (\$92,000), 1996/98.
- [35] S.X. Dou, Centre of CSEM, (\$47,300). URC, 1996.

- [36] S.X. Dou, Institute of Materials Technology and Manufacturing”, (\$75,000), URC, 1996.
- [37] G. Spinks, CRC Materials Welding and Joining, Adhesive bonding of coated steels, 1994-96 (\$126,800).
- [38] G. Spinks, CRC Materials Welding and Joining, Adhesives for hostile environments, 1994-96 (\$120,000).
- [39] D. Dunne, CRC Materials Welding and Joining, Laser Welding of coated steels, 1994-96 (\$76,000).
- [40] D. Dunne, CRC Materials Welding and Joining, High Productivity Welding of Stainless Steels, 1995-96 (\$78,000).
- [41] D. Dunne and Z. Chen, CRC Materials Welding and Joining, Life Assessment of Pressure Vessel Steels, 1994-96 (\$168,000).
- [42] T. Chandra, University of Wollongong, Metal Matrix Composites, 1994 (\$10,000).
- [43] T. Chandra, Iranian Govt., Metal Matrix Composites, 1995-96 (\$27,500).
- [44] G. Spinks and D. Dunne, RIEF, Scanning Probe Microscope, 1995 (\$277,000).
- [45] S. Nightingale, ARC-Small, MW Processing of Reaction Bonded Refractories, 1994 (\$9,900).
- [46] D. Dunne, ARC-Large, Development of Iron Based Shape Memory Alloys, 1996 (\$61,700).
- [47] A. Calka, ARC-Small, Processing and Properties of Nb₃Al for High Field Applications, 1996 (\$8,500).
- [48] D. Dunne, RIBG Pool 2, Optical Microscope, 1995 (\$48,000).
- [49] Z. Chen and D. Dunne, RIBG Pool 2, EDS for TEM, 1996 (\$57,000).

9. STAFF PROFILES

Professor Shi Xue Dou

Honours/Awards

- Fellow of Australian Academy of Technological Science and Engineering.
- Fellow of International Academy of Electrotechnical Sciences.
- President of Aus-China Scholar Association.

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. Physics C, Superconductor Science and Technology.

Professor Druce Dunne

Editorial Roles

- Editor - Australasian Welding Journal Research Supplement.
- Editorial Board - The Science and Technology of Welding, Institute of Materials, United Kingdom.

Committees

- International Organising Committee - International Conference on Martensitic Transformations (ICOMAT).
- Wollongong Branch Committee - Institute for Metals and Materials, Australasia.
- Organising Committee - Materials '98 IMMA Conference, Wollongong.
- Organising Committee - International Conference THERMEC 97.

Honours/Awards

- Visiting Professor - Universitat de les Illes Balears, Palma, Spain, 1995.
- Visiting Scholar - Dept. of Metallurgy and Materials Science, University of Cambridge, 1995.
- Life Associate Member - Clare College, Cambridge.

Dr. Andrej Calka

Committees

- Elected Member of the Advisory Committee of the International Conference on Rapidly Quenched Metals.
- Member of the International Committee of the 2nd International Conference on Structural Applications of Mechanical Alloying.
- Member of the International Committee of the International Symposium on Metastable, Mechanically Alloyed and Nanocrystalline Materials.
- Member of the International Committee of the International Symposium on Mechanochemistry.

Editorial Committees (International Journals):

- International Journal on Mechano-Chemistry.

Associate Professor Hua Kun Liu

- Member of Organising Committee of Thermec '97.

10. INVITED TALKS and PAPERS

Professor Shi Xue Dou

12-16 Feb, 1995, "Sandwich rolling, J_c and pinning energy in Ag-sheathed BPSCCO superconducting tapes", Symposium of Synthesis, processing, and large scale applications of HTSC, 1995 TMS Annual Meeting in Las Vegas, Nevada, USA

20-22 Feb 1995, "Critical current and pinning energy in Ag/BPSCCO tapes", International Conference on Advances in High Magnetic Field (AHMF'95), Tsukuba, Japan

18-21 June 1995, "Crystal growth and critical current of HTSC", International Workshop on Superconductivity co-sponsored by MRS/ISTEC, Maui, Hawaii, USA

27/Nov-1/Dec. 1995, "Effect of defects on properties of HTSC", Symposium F of HTSC for MRS Fall Meeting, Boston, MA, USA

13-15 Dec. 1995, JIM/TMS/ASM joint Fall Meeting, Honolulu, Hawaii, USA

4-8 Feb 1996, Symposium of Synthesis, Processing and Large scale applications of HTSC, TMS Annual Meeting, Anaheim, CA, USA

27-29 May 1996, "Fabrication of HTS Wires with High J_c " 8th IWCC in superconductors, Kitakyushu, Japan

6-8 May, 1997, International Workshop on Critical Currents in Superconductors for Practical Applications.

31 Oct - 8th November 1996, 2nd Brazillian Conference on Superconductivity.

October 1996, 10th Anniversary Reviewed Paper for Superconductor Science and Technology.

March 1997, Royal Chemical Society Annual Report on High Temperature Superconductivity.

Associate Professor Hua Kun Liu

4 - 9th May 1997, 91st Meeting of Electrochemical Society Montreal, Quebec, Canada.

RCAMP

T. Chandra and D. Yu, "Thermomechanical Processing of Discontinuous Particle Reinforced Aluminium Based Metal Matrix Composite", **Proceeding of 4th Japan Inter. SAMPE Sympo.**, 25-28th Sept, 1995, Japan, p.507-516.

H. Asanuma, H. Do, K. Ichikawa, T. Kishi, T. Chandra and D. Yu, "Development of a Smart FRM by Embedding Optical Fiber", **Advanced Composites'96**, 1996, Bangalore, India.

A.Calka "*Formation of nanostructures by Magneto-Mechano Ball Milling: Applications in Materials Processing*". **Fourth International Workshop on Non-Crystalline Solids, 20-23 September 1994, Madrid, Spain,**

A.Calka "THE DYNAMICS OF MAGNETO-BALL MILLING AND ITS EFFECT ON PHASE TRANSFORMATIONS DURING MECHANICAL ALLOYING" (**keynote**) International Symposium on metastable, Mechanically Alloyed and Nanocrystalline Materials, European Meeting on Disorder and Amorphization, June 27- July 1, 1994, Grenoble, France

I. Ashcroft, M. Sopher and D. Wexler, "*Active Metal Brazing of Copper and Alumina*", Proc. Int. Conf on Materials Welding and Joining, Adelaide, Australia, Inst. Metals and Materials, Australasia, 23 and 24 August 1995.

D. Wexler, C. Harland and M. Emr, "*Magnetic Force Microscopy of amorphous, partially crystalline and nanocrystalline soft magnetic ribbons*", SMP 1996, Scanning Probe Microscopy Conference held at The Esplanade Hotel, Newcastle, Australia, 7-9 July, 1996 (University of Newcastle) (1996).

X. Li, M. Smandi and Z. Chen, "*Characterisation of Nanocrystalline Structures By Nano-Beam Electron Diffraction*", Presented at 14th Australia Cof. on Electron Microscopy, Feb. 1996 Sydney

H. Li, D Dunne and Z. Chen, "*The effect of Thermomechanical Training on the Structure and Crystallography of Stress Induced Martensite in Fe-Mn-Si-Cr-Cu shape Memory Alloys*", Presented at 14th Australia Cof. on Electron Microscopy, Feb. 1996 Sydney

D.Dunne, "*Research Initiatives at the University of Wollongong in Materials Engineering*", Materials Research 96, Brisbane, IMMA Conference Proceedings, Vol. II, pp 15-16, July 1996.

11. VISITING SCIENTISTS TO GIVE SEMINARS

Prof. H. Weber, Atomic Institute, University of Vienna, Austria, Feb. 1994, 96
Dr. E.W. Collings, Ohio State Uni., Columbus, OH, USA, Feb. 1994, 95, 96
Dr. M.P. Das, ANU, Canberra, June 1994, May 1995
Dr. J.C. Macfarlane, Uni of Strathclyde, UK, Feb 1995
Dr. G. Samadi, Atomic Institute of the Austrian Universities, Feb 1995
Prof. A. Bourdillon, National Uni of Singapore, March 1995
Prof. E. Babic, Uni of Zagreb, Croatia, April 1995
Prof. S.E. Hsu, UNSW, June 1995
Dr. D. Dew-Hughes, Oxford Uni, UK, Jan 1996
Dr. H. Maeda, National Research Institute of Metals, Japan, Jan 1996
Associate Professor S. Kambe, Yamagata University, Japan, Dec 1995.
Dr. P. Ellis, BHP, Melbourne Laboratories, November, 1996.
Dr. D. Cookson, BHP, Melbourne Laboratories, November, 1996.
Professor W.G. Lu, MacMaster University, Canada, October, 1996.
Dr. M. Xu, Ames Laboratory Iowa State University, May, 1995.
Professor H. Asanuma, Chiba University, Japan, February, 1996.

12. FINISHED THESIS

J.X. Jin, MSc, "HTSC Ceramics and Their Application in The Design and Construction of Electrical Fault Current Limiters", March, 1995.

Q.Y. Hu, PhD, "Fabrication and Enhancement of Critical Currents of Silver-Sheathed Bi-2223 Tapes", December, 1995.

13. PUBLICATIONS FOR 1995 - 1996

- H.K. Liu, S.X. Dou, M. Ionescu, Z.B. Shao, K.R. Liu and L.Q. Liu, "Equilibrium phase diagrams in the system CuO-PbO-Ag", *J. Mater. Res.*, 10, 29337 (1995)
- B. Luan, N. Cui, H.K. Liu, H.J. Zhao and S.X. Dou, "Low-temperature Surface Micro-encapsulation of Ti₂Ni Hydrogen-storage Alloy Powders", *J. Power Sources*, 52 (2), 295-9 (1994)
- N. Cui, B. Luan, H.K. Liu, H. Zhao and S.X. Dou, "Characteristics of Magnesium-based Hydrogen Storage Alloy Electrodes", *J. Power Sources*, 55, 263-7 (1995).
- N. Cui, B. Luan, H.K. Liu, H. Zhao and S.X. Dou, "Characteristics of Magnesium-based Hydrogen Storage Alloy Electrodes", *J. Power Sources*, 55, 263-7 (1995).
- B. Luan, N. Cui, H. Zhao, H.K. Liu and S.X. Dou, "Early Capacity Loss Mechanism of Ti₂Ni Hydrogen Storage Alloy Electrode", *J. Power Source*, 53. (1995)
- B. Luan, N. Cui, H.K. Liu, H. Zhao and S.X. Dou, "Effects of Cobalt Addition on the Performance of Ti-Based Hydrogen Storage Electrodes", *J. Power Sources*, 55, 197-203 (1995).
- B. Luan, N. Cui, H.K. Liu, H. Zhao and S.X. Dou, "Effects of Cobalt Addition on the Performance of Ti-Based Hydrogen Storage Electrodes", *J. Power Sources*, 55, 197-203 (1995).
- E. Babic, I. Kusevic, K. Zabro, I. Ivkov, Z. Maroenic, D. Drobac, M. Prester, H.K. Liu, S.X. Dou, D. Todorovic-Marinic and A. Kurumovic, "Superconductivity in Bi-2223 compound: Physics and Applications", *Fizika A* 4549-560 (1995).
- M.N. Cuthbert, M. Dhalle, J. Thamas, A.D. Caplin, S.X. Dou, Y.C. Guo, H.K. Liu, "Transport and Magnetisation Measurements of Bi2223/Ag Tapes and The Role of Granularity on Critical Current Limitation", *IEEE Transactions on Applied Superconductivity*, 5, 1391-4 (1995).
- M. Dhalle, M.N. Cuthbert, L.F. Cohen, G.K. Perkins, A.D. Caplin, M. Yang, C.R.M. Grovenor, S.X. Dou, H.K. Liu, Q.Y. Hu, E.L. Wolf, F. Lu and A. Chang, "Field, Temperature and Angle Dependence of the Critical Current Density in Bi₂Sr₂Ca₂Cu₃O₁₀/Ag Ribbons", *J. Supercond.* 8, 37-42 (1995).
- S.X. Dou, M. Ionescu, W.G. Wang, H.K. Liu, E. Babic and I. Kusevic, "Sandwich Rolling, J_c and Pinning Energy in Ag/Bi-based Superconducting tapes", *J. Electronic Materials*, 24, 1801-4 (1995).
- S.X. Dou, Y.C. Guo, R.K. Wang, M. Ionescu, H.K. Liu, E. Babic, and I. Kusevic, "Effect of Silver on Phase Formation and Superconducting Properties of Bi-2223/Ag Tapes", *IEEE Transactions on Applied Superconductivity*, 5, 1830-3 (1995).
- J. Horvat and S.X. Dou, "Depinning Current for Flux Lines in Ag/BSCCO Superconducting Tapes", *Supercond. Sci Technol.* 8, 904-8 (1995).
- Q.Y. Hu, R.M. Schalk, H.W. Weber, H.K. Liu, R.K. Wang, C. Czurda and S.X. Dou, "Anisotropy of The Critical Current in Silver Sheathed (Bi,Pb)₂Sr₂Ca₂Cu₃O₁₀ Tapes", *J. Appl. Phys.* 78(2), 1123-30 (1995)
- Q.Y. Hu, H. Weber, H.K. Liu and S.X. Dou, "Angular Dependence of The Critical Current And Grain Misalignment of Ag Clad (Bi,Pb)₂Sr₂Ca₂Cu₃O₁₀ Tape", *Physica C*, 252, 211-220 (1995).
- Q.Y. Hu, H.K. Liu and S.X. Dou, "Formation Mechanism of High T_c Phase and Critical Current in (Bi,Pb)₂Sr₂Ca₂Cu₃O₁₀/Ag Tape", *Physica C*, 250, 7-14 (1995).
- I. Kusevic, E. Babic, H.K. Liu and S.X. Dou, "Vortex and Flux Pinning in Bi-2223/Ag tape", *Solid State Commun.* 95, 515-8 (1995)
- J.X. Jin, H.K. Liu, C. Grantham, and S.X. Dou, "The Application of High T_c Superconducting Coils for prototype Fault Current Limiter", *IEEE Transactions on Applied Superconductivity*, 5, 1051-4 (1995).

- H.K. Liu, M. Ionescu, Y.C. Guo, R. Bhasale, Q.Y. Hu, S.X. Dou, N. Savvides, M. Apperley, G. Secrett and E.W. Collings, "Fabrication of Ag-Sheathed Bi-2223 Tapes and Coils", IEEE Transactions on Applied Superconductivity, 5, 1267-70 (1995).
- H.K. Liu, S.X. Dou, M. Ionescu, Z.B. Shao, K.R. Liu, "Equilibrium Phase Diagram in Ag-CuO-PbO Systems", J. Mater. Res. 10, 2933-7 (1995).
- N. Vo, S.X. Dou and H.K. Liu, "The Effect of Initial Packing Density of the OPIT Method on the Phase Formation, Electrical Transport and Mechanical Properties of BiPbSrCaCuO Monocore Superconducting Tapes", Physica C, 250, 139-52 (1995)
- W.G. Wang, H.K. Liu, Y.C. Guo, P. Bain and S.X. Dou, "Mechanism of Deformation and 'Sandwich' Rolling Process in Ag-clad Bi-based Composite Tapes", Appl. Supercond.
- R.K. Wang, H.K. Liu and S.X. Dou, "Study on Interfaces and Microstructural Defects in Ag-Clad (Bi,Pb)₂Sr₂Ca₂Cu₃O_{10+y} Tapes", Supercond. Sci. Technol., 8[3] 168-173 (1995).
- J.A. Xia, P.R. Munroe, R.K. Wang, H.T. Ren, Y. Zhao and S.X. Dou, "A Study on the Microstructural Defects Along a-b Plane in the Melt Textured YBa₂Cu₃O_y Superconductor", Physica C, 241 142-150 (1995).
- B. Zeimetz, A. Pan and S.X. Dou, "Effect of Deformation of Parameters on the interface Morphology of Silver-sheathed High Temperature Superconductor tapes", Physica C, 250, 170-5 (1995)
- J. Berezovsky, H.K. Liu and S.X. Dou, "Conductivity and Phase Stability of Bismuth Oxide Based Electrolytes", Proceedings of Eighth Cimtec, Advances in Science and Technology (3D), Ceramics: Charting the Future pp 2649 - 2654, ed. by P. Vincezini (1995).
- S.X. Dou, H.K. Liu, Q.Y. Hu, R. Bhasale and N. Savvides, "Long Ag-Clad Bi-based Superconducting tapes and Coils", Advances in Science and Technology (8), Superconductivity and Superconducting Materials Technologies, pp 287-92, ed. by P. Vincezini (1995).
- C. Grantham, J.X. Jin, S.X. Dou, and H.K. Liu, "Novel Electronic High Voltage Generator with High Temperature Superconducting Coils", Proceedings of IPEC, pp 234-8, 27 February-1 March 1995, Singapore.
- Y.C. Guo, P. Bain, H.K. Liu, S.X. Dou and E.W. Collings, "Continuous Filling and Forming Process for fabrication of Ag-Bi-based Superconducting Tapes", Proceedings of European Appl. Supercond. Conference, July 1-5 1995, Edinburgh, UK.
- M. Ionescu, S.X. Dou, E. Babic, I. Kusevic and E.W. Collings, "Controlled Process and Critical Current of Bi-2212 Superconducting tapes", Proceedings of 1995 International Workshop on Superconductivity by ISTE and MRS, pp 44-7, June 18-21 1995, Maui, Hawaii.
- M. Ionescu, S.X. Dou, E. Babic, I. Kusevic and E.W. Collings, "Controlled Process and Critical Current of Bi-2212 Superconducting tapes", Proceedings of European Appl. Supercond. Conference, July 1-5 1995, Edinburgh, UK.
- I. Kusevic, E. Babic, M. Prester, H.K. Liu, Q.Y. Hu, and S.X. Dou, "Critical Currents in (Bi,Pb)₂Sr₂Ca₂Cu₃O_x Ceramic and Ag-clad wires", Advances in Science and Technology (8), Superconductivity and Superconducting Materials Technologies, pp 121-8, ed. by P. Vincezini (1995).
- I. Kusevic, E. Babic, Z. Marohnic, H.K. Liu and S.X. Dou, "The Current path and Anisotropy in High J_c, Ag-clad (Bi,Pb)₂Sr₂Ca₂Cu₃O_x Tapes", Fourth EURO CERAMICS, Vol 7 High T_c Superconductors, pp 175-82 (1995).
- J.X. Jin, S.X. Dou, H.K. Liu, and C. Grantham, "Design Considerations of Current Limiting Devices with High T_c Superconductors, Proceedings of IPEC, pp 170-5, 27 February-1 March 1995, Singapore.

- J.X. Jin, H.K. Liu, C. Grantham, and S.X. Dou, "Prototype Fault Current Limiter With High T_c Superconducting Coil", *Advances in Science and Technology* (8), Superconductivity and Superconducting Materials Technologies, pp 755-62, ed. by P. Vincezini (1995).
- H.K. Liu, R. Bhasale, P. Bain, J.X. Jin, Y.C. Guo and S.X. Dou, "Critical Current Density of Variable Angle Joining of Ag-Sheathed Bi-based Superconducting Tapes", *Proceedings of 1995 International Workshop on Superconductivity by ISTEK and MRS*, pp 375-6, June 18-21 1995, Maui, Hawaii.
- H.K. Liu, S.X. Dou and E.W. Collings, "Microstructure Development and Phase Transformation of Ag-sheathed Bi-2223 Tapes", *Advances in Science and Technology* (8), Superconductivity and Superconducting Materials Technologies, pp 110-6, ed. by P. Vincezini (1995).
- K.H. Muller, C. Andrikidis, H.K. Liu and S.X. Dou, "Intergranular and Intergranular Currents in Silver-Sheathed Bi-Pb-Sr-Ca-Cu-O Tapes", *Proceedings of 1995 International Workshop on Superconductivity by ISTEK and MRS*, pp 381-2, June 18-21 1995, Maui, Hawaii.
- W.G. Wang, H.K. Liu and S.X. Dou, "Control of "Sausaging" Formation by Sandwich Rolling Process in Ag-clad Bi-Based Composite tapes", *Proceedings of 1995 International Workshop on Superconductivity by ISTEK and MRS*, pp 377-8, June 18-21 1995, Maui, Hawaii.
- S.X. Dou, H.K. Liu, M. Ionescu, W.G. Wang, E. Babic and I. Kusevic, "Critical current density and pinning energy in Ag-clad BPSCCO tapes", *Physica B*, 216, pp 225-257, 1996.
- N.V. Vo, H.K. Liu and S.X. Dou, "Effect of Sintering Periods on the Pinning Force, Activation Energy and Microstructure of High T_c Superconducting Bi-(Pb)-Sr-Ca-Cu-O Tapes", *Supercond. Sci. Technol.* 9, pp 104-112, 1996.
- I. Kusevic, E. Babic, M. Ionescu, H.K. Liu and S.X. Dou, "Flux Pinning in High- J_c Bi2212/Ag Tape", *Solid State Communications*, Vol. 97, No. 5, pp. 339-343, 1996.
- W.G. Wang, H.K. Liu, Y.C. Guo, P. Bain and S.X. Dou, "Mechanism of Deformation and "Sandwich" Rolling Process in Ag-Clad Bi-Based Composite Tapes", *Applied Superconductivity* Vol. 2, No. 7/8, pp. 1-7, 1996.
- H.K. Liu, J. Horvat, Q.Y. Hu, D.K. Yu and S.X. Dou, "Effect of Hot Pressing on the Weak Link Behaviour of Ag Clad Bi Based Superconducting Tapes", *Physica C*, 259, pp 187-192, 1996.
- N.V. Vo, H.K. Liu and S.X. Dou, "Effect of Sintering Periods on the Microstructure and Electrical Transport Properties of High- T_c Superconducting Bi-(Pb)-Sr-Ca-Cu-O Tapes", *J. Mater. Res.*, Vol. 11, No. 5, pp 1101-1107, 1996.
- I. Kusevic, E. Babic, M. Ionescu, H.K. Liu and S.X. Dou, "Flux Pinning in High- J_c Bi2212/Ag Tape", *Solid State Communications*, Vol. 97, No. 5, pp. 339-343, 1996.
- Q.Y. Hu, H.K. Liu and S.X. Dou, "Effect of Mechanical Deformation on the Mass Density of Ag-Clad $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10}$ Wire and Tape", *Applied Superconductivity*, Vol. No. 4, No. 1/2 pp. 17-24, 1996.
- K.-H. Muller, N. Savvides, A. Katsaros, Y.C. Guo and S.X. Dou, "AC loss from susceptibility measurements in Bi-2223/Ag superconducting tapes", *Czechoslovak Journal of Physics*, Vol. 46, pp. 1297-1298, 1996.
- P.N. Mikheenko, S.X. Dou, S.J. Lewandowski and I.S. Abaliosheva, "Quasi-2D behaviour of HTSCs: the consequence of the small effective thickness of superconducting layers", *Supercond. Sci. Technol.* Vol. 9, pp 1-10, 1996.
- N.V. Vo, S.X. Dou and Hua Kun Liu, "Development of Bi(Pb)-2223/Ag Pancake-Shaped and Solenoidal Coils", *IEEE Transactions on Applied Superconductivity*. Vol 6 No. 2, pp. 102-105, 1996.

- K.-H. Muller, C. Andrikidis, H.K. Liu and S.X. Dou, "Critical current and hysteretic AC loss in monofilamentary Bi-2223/Ag tapes", *Inst. Phys. Conf. Ser. No. 148*, IOP Publishing, pp, 439-442, 1996.
- J. Everett, M.D. Johnston, M. Dhalle, H.K. Liu, S.X. Dou, and A.D. Caplin, "Influence of superconducting layer thickness on the dissipation in monofilamentary BSCCO/Ag 2223 tapes", *Inst. Phys. Conf. Ser. No. 148*, IOP Publishing, pp, 355-358, 1996.
- M. Dhalle, M.N. Cuthbert, J. Thomas, J. Everett, M.D. Johnston, H.K. Liu, S.X. Dou, G. Grasso, R. Flukiger, J. Kessler, W. Goldacker, M. Yang, C. Govenor and A.D. Caplin, "Limits on the critical current of BSCCO/Ag conductors", *Inst. Phys. Conf. Ser. No. 148*, IOP Publishing, pp, 419-422, 1996.
- I. Kusevic, P. Simuadic and E. Babic, M. Ionescu, H.K. Liu and S.X. Dou, "Scaling of J_c -B Curves in BSCCO/Ag Tapes, *Sol. State Commun.* 100 (96) 187.
- P.N. Mikheenko, I.S. Abaliosheva and S.J. Lewandowski, "Two-dimensional behaviour of bulk high temperature superconductors", *Low Temp. Phys. (Fiz. Nizk. Temp.)*, Vol. 22, No. 4, pp. 364-374, 1996.
- P.N. Mikheenko, "Evidence of angstrom thickness in the isolated superconducting layers of HTSC", *Sov. Phys. Low. Temp. Phys.*, Vol. 22, No. 4, 1996.
- I. Kusevic, P. Simundic, E. Babic, J. Ivkov, Z. Marohnic, M. Ionescu, H.K. Liu and S.X. Dou, " J_c -B-T Surface of high- J_c Bi₂Sr₂CaCu₂O_{8-x}/Ag Tape", *Superconductor Science and Technology*, pp. 1 - 12, 1996.
- Y.P. Sun, G.Y. Xu, J.J. Du, Y.R. Zhou, R. Zheng, and X.K. Fu, et al., "Observation of a three-dimensional Vortex-line Liquid in a highly c-axis-oriented (Bi, Pb)₂Sr₂Ca₂Cu₃O_x Silver-Sheathed tape", *Phy. Rev. B*. Vol. 53, No. 22, pp. 53-56 (163), 1996.
- G.Y. Xu, Y.P. Sun, J.J. Du, Y.R. Zhou, R. Zeng and X.K. Fu et al., "Micro-Current Path in (Bi, Pb)₂Sr₂Ca₂Cu₃O_x/Ag tapes", *J. of Low temperature Physics*, Vol. 18, April, pp. 362-364, 1996.
- Y.P. Sun, G.Y. Xu, J.J. Du, Y.R. Zhou, R. Zheng and X.K. Fu, "Dissipation of a High C-axis-oriented Bi(2223)/Ag in the 3d Vortex line liquid", *J. of Low temperature Physics*, Vol. 18, April, pp. 350-352, 1996.
- L. Du, P.C. Sun, Y.G. Zhao, S.Q. Guo and R. Zeng, "Fabricated Bi(2223)/Ag Thick Film Using Net-Print-Method", *J. of Low Temperature Physics*, Vol. 18, April, pp. 68-72, 1996.
- R. Zeng, Y.R. Zhou, P.W. Hua and X.K. Fu, "The analysis of fabricated technique of long Bi(2223)/Ag tapes", *Rare Metals*, Vol. 20, No. 1, 57-59, 1996.
- R. Zeng, Y.R. Zhou, P.W. Hua and X.K. Fu, "Fabricated and Properties of Bi-2223 High Tc Superconducting Magnet", *J. of Low temperature Physics*, Vol. 8, April, 344-348, 1996.
- B. Zeimetz, S.X. Dou, and H.K. Liu, "Improved critical current of superconducting Bi2223-Ag tapes for current lead application by addition of 'large' silver particles", *Supercond. Sci. Technol.* Vol. 9, pp. 888-892, 1996.
- W.G. Wang, P. Bain, J. Horvat, B. Zeimetz, Y.C. Guo, H.K. Liu and S.X. Dou, "Preparation of Ag/Bi-2223 tape by controlling the phase evolution prior to sintering", *Supercond. Sci. Technol.* 9, pp. 881-887, 1996.
- W.G. Wang, J. Horvat, H.K. Liu and S.X. Dou, "The effect of mechanical deformation on silver-core interface and critical current density in Ag-Bi-2223 single-and multifilament tapes", *Supercond. Sci. Technol.* 9, pp. 875-880, 1996.
- J. Horvat, S.X. Dou, H.K. Liu and R. Bhasale, "Critical currents through strong links in Ag/Bi-Sr-Ca-Cu-0 superconducting Tapes", *Elsevier Science, Physica C* 271, 1996.

- A. Konopka, S.J. Lewandowski, P.N. Mikheenko and R. Monaco, "Equilibrium States in Multi-Junction Superconducting Quantum Interferometers", *J. Appl. Phys.*, 1996.
- Z. Janu, R. Tichy and X.L. Wang, "Flux Dynamics in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ Single Crystal", *Czechoslovak Journal of Physics*, Vol 46, Suppl. S3, pp. 1735-6, 1996.
- Z. Janu, R. Tichy, M. Novak, V. Gregor and X.L. Wang, "Flux noise in YBaCuO Thin Film and BiSrCaCuO Single Crystal", *Czechoslovak Journal of Physics*, Vol 46, Suppl S3, pp. 1737-8, 1996.
- X.L. Wang, J. Horvat, H.K. Liu and S.X. Dou, "Enhanced Flux Pinning from CuO Inclusions in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_y$ Crystals", *J. Appl. Phys.* 80 (12), pp. 1-3, 1996.
- P.N. Mikheenko, S.X. Dou, S.J. Lewandowski and I.S. Abaliosheva, "Quasi-2D behaviour of HTSC: consequence of small effective thickness of superconducting layers", *Supercond. Sci. Technol.*, 9, pp. 942-951, 1996.
- Q.Y. Hu, D. Yu, H.K. Liu, T. Chandra and S.X. Dou, "Hot-Pressing of Bi-2223 Bulks and Formation of the Bi-2223 Phase", *HTS: Synthesis, Processing and large Scale Applications*, ed U. Balachandra et al, pp. 105 - 112, 1996.
- J.X. Jin, S.X. Dou, C. Grantham and H.K. Liu, "A High T_c Superconductor High Voltage Generator", *HTS: Synthesis, Processing and large Scale Applications*, ed U. Balachandra et al, pp. 233 - 239, 1996.
- Q.Y. Hu, H.K. Liu, D. Yu and S.X. Dou, "Deformation and Densification of the Core of $(\text{Bi, Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}/\text{Ag}$ Wire and Tape", *HTS: Synthesis, Processing and large Scale Applications*, ed U. Balachandra et al, pp. 81 - 87, 1996.
- N.V. Vo, S.X. Dou and H.K. Liu, "Phase Development and Microstructural Effect of Sintering Periods on Uniaxially Pressed High- T_c $\text{Bi}(\text{Pb})$ -2223/ Ag Tapes", *HTS: Synthesis, Processing and large Scale Applications*, ed U. Balachandra et al, pp. 53 - 60, 1996.
- S. Zhong, H.K. Liu, S.X. Dou and M. Skyllas-Kazacos, "Evaluation of lead-calcium-tin-aluminium grid alloys for valve-regulated lead/acid batteries", *Journal of Power Sources*, 59, pp. 123 - 129, 1996.
- K. Zadro, E. Babic, H.K. Liu and S.X. Dou, "Irreversible Magnetisation and Critical Currents in Silver-Sheathed $(\text{Bi, Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+y}$ Tape", *Phys. Stat. Sol.*, 157, pp. 427 - 437, 1996.
- J.X. Jin, H.K. Liu, C. Grantham and S.X. Dou, "Using Bi-2223 Ag Clad Tape as a Liquid Nitrogen Level Sensor", *Advances in Cryogenic Eng.*, Vol 41, pp. 1813 - 1816, 1996.
- J.X. Jin, S.X. Dou, C. Grantham, R. Bhasale and H.K. Liu, "Preparing A $(\text{Bi, Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+x}$ Ag Clad HTS Wire for a Fault Current Limiter Prototype", *Advances in Cryogenic Eng.*, Vol 41, pp. 1825 - 1828, 1996.
- J.X. Jin, S.X. Dou, R. Bhasale, H.K. Liu, C. Grantham, N. Savvides and M. Ionescu, "Consideration of Using HTS Coils as a Magnetic Core Bias Winding", *Advances in Cryogenic Eng.*, Vol 41, pp. 427 - 432, 1996.
- J.X. Jin, C. Grantham, H.K. Liu, M. Apperley and S.X. Dou, "Electronic High Voltage Generator with a High Temperature Superconducting Coil", *Advances in Cryogenic Eng.*, Vol 41, pp. 991 - 996, 1996
- A. Calka and J.I. Nikolov "The Dynamics of Magneto-Ball Milling and Its Effect on Phase Transformations During Mechanical Alloying" *Materials Science Forum*, vol. 179-181, pp. 333-338, 1995
- G.M. Wang, A. Calka, S.J. Campbell and W.A. Kaczmarek, "Carburization of Iron by Ball-Milling Fe50-C50" - *Materials Science Forum*, vol. 179-181, pp. 201-206, 1995
- G.M. Wang, P. Millet, A. Calka and S.J. Campbell "The Mechano-synthesis of Tungsten Carbide" - *Materials Science Forum*, vol. 179-181, pp. 183-188, 1995

A. Calka, J.I. Nikolov, Z.L. Li and J.S. Williams, "Structure and Thermal Properties of Tungsten and Molybdenum Milled in Nitriding Environment: Effect of Milling Time and Atmosphere" *Materials Science Forum*, vol. 179-181, pp. 295-300, 1995

P. Millet and A. Calka "Ball Milling of Soft Metals: The Formation of Gallium Nitride" *Materials Science Forum*, vol. 179-181, pp. 321-324, 1995

J.I. Nikolov, A. Calka and J.S. Williams "The Effect of Milling Condition on Micro/Macrostructural Transformations During Milling of B and Si in Nitriding Environment: Formation of BN and Si₃N₄." *Nanostructured Materials*, vol.6, pp. 401-404, 1995

A. Calka and J.I. Nikolov "Direct Synthesis of AlN and Al-AlN Composites by Room Temperature Magneto Ball Milling: The Effect of Milling Condition on Formation of Nanostructures", *Nanostructured Materials*, vol.6, pp. 409-412, 1995

A. Calka, "Magneto-ball Milling for Materials Processing", *Nanostructured Materials*, vol.6, pp. 401-404, 1995

G.M. Wang, S.J. Campbell, A. Calka and W.A. Kaczmarek, "Ball Milling of Fe-C Mixtures (20-65%Fe)" *Nanostructured Materials*, vol. 6, pp. 389-392, 1995

L.M. Di, A. Calka, Z.L. Li and J.S. Williams, "The Formation of Ternary Compound Fe₃Mo₃C by Ball Milling", *Journal of Applied Physics*, vol. 78, pp. 4118-4122, 1995

A. Calka, J.I. Nikolov and J.S. Williams, "Formation, Structure and Stability of Iron Nitrides Made by Reactive Ball Milling", *Materials Science Forum*, vol. 225-227, pp. 527-532, 1996

D.Dunne, J. Chevis and A. Cabello, "*The Microstructures and Properties of Low Carbon Copper Bearing Steels*", *Proceedings of International Conference on Microstructures LCS'94*, Tokyo, November 1994, pp 53-56.

A. Abdollah-Zadeh and D.Dunne, '*Recovery and Recrystallization in a Hot Deformed Austenitic Fe-Ni-C Alloy*', *Proceedings of Riso Conference*, Denmark, Sept. 1995, pp 247-252.

A. Abdollah-Zadeh and D.Dunne, '*The Effect of Niobium on the Recovery Deformed Austenitic*', *Proceedings of Int. Symp. on Recovery and Recrystallisation in Steel*, Hamilton, Ontario, Canada, 1995 37th MWSP Conf. *Proceedings ISS XXXIII*, 1996, p.689-694.

A. Abdollah-Zadeh and D.Dunne, "*Effect of Niobium on Static Recrystallization of Hot Deformed Austenitic HSLA Steel Analogue Alloy*", *Proceedings of HSLA Steels '95 Conference*, Beijing, Oct. 1995, pp 157-162.

D.Dunne, "*Weldable Copper Strengthened Low Carbon Steels*", *Proceedings of HSLA Steels '95 Conference*, Beijing, Oct. 1995, pp 90-98.

D.Dunne and H. Li, "*The Mechanism of Thermomechanical Training of Fe-Mn-Si-Cr-Cu Shape Memory Alloys*", *Proceedings of ICOMAT '95*, Lausanne, Switzerland, Aug, 1995.

N. Kennon, D.Dunne and J. H. Zhu, "*Effect of Precipitation on Martensitic Transformations and Shape Memory Behaviour in Rapidly Solidified Ni Al Alloys*", *Proceedings of ICOMAT '95*, Lausanne, Switzerland, Aug, 1995.

B.S. Ghasemi, D. Yu and D.Dunne, "*Age Hardening in a Cu-bearing High Strength Low Alloy Steel*", *ISI Japan International*, 1996, Vol. 36, pp 61-67.

D.Dunne, B.S. Ghasemi and D. Yu, "*Isothermal Transformation Products in a Cu-bearing HSLA Steel*", *ISI Japan International*, 1996, Vol. 36, pp 324-333.

H. Li, Z. Chen and D.Dunne, "*The Effect of Thermomechanical training on the Structure and Crystallography of Stress Induced Martensite in Fe-Mn-Si-Cr-Cu*", *14th Australian Conference on Electron Microscopy*, Sydney, Feb. 1996.

H. Li and D.Dunne, "The Effect of Copper on the Shape Memory Effect and Corrosion Resistance of Fe-Mn-Si based Shape Memory Alloys", Materials Research 96, Brisbane, IMMA Conference Proceedings, Vol. I, pp 117-12, July, 1996.

F.T. Ciacchi, S.A.Nightingale, and S.P.S. Badwal, "Ionic Conductivity of Microwave Sintered Zirconia-Yttria Electrolytes" Austceram 94 Proceedings, pp. 420-425

F.T.Ciacchi, S.A. Nightingale and S.P.S. Badwal, "Microwave Sintering of Zirconia-Yttria Electrolytes and Measurement of Their Ionic Conductivity", Solid State Ionics, 10thSSI, Singapore, Dec 1995.

S.A.Nightingale, H.K.Worner and D.P.Dunne, "Grain Growth in $Y_2O_3-ZrO_2$ Ceramics Heated in a Microwave Field", Intl. Scientific and Industrial RF & Microwave Applications Conference, Melbourne, Australia, July, 1996.

D. Yu and T. Chandra, "A Study of Microstructural Development in Particulate Reinforced 6061Al Metal Matrix Composite During High Temperature Deformation", 16th Riso Inter. Sympo., 4-8 Sept, 1995, Denmark.

C. Huang, Z. Chen, T. A. Dean and M.H. Loretto, "The effect of post forging heat treatment on the microstructure and room temperature tensile properties in Ti-25Al-10Nb-3V-1Mo (Super α_2)", Materials Science and Engineering, A174, pp 23-35(1994).

Z. Chen, I.P. Jones, N. Saunders and C.A. Small, "Characterisation of Phases in Ti-42Al-8Nb Alloy at 1200°C", Scripta Metallurgica et Materialia, 30, 1994, pp1403-1408.

Z. Chen, I.P. Jones, "Sublattice Occupancy in Three Ti-Al-Mo B2 Phases", Scripta Metallurgica et Materialia, 32, 1995 pp 553-558.

F. Herrouin, Z. Chen and I.P.Jones, "Effect of Heat treatment on the microstructure of Ti-Al-Nb" presented at EMAG'95, Birmingham UK.

N Jiang, Z Chen and I P Jones, "Sublattice ordering in TiAl-Mo: an experimental (ALCHEMI) and theoretical investigation", Presented at EMAG'95 Birmingham UK.

Z Chen, I P Jones and C J Small, "Laves Phase in Ti-42Al-10Mn Alloy", Scripta Metallurgica et Materialia, 35, 1996 pp23-27.

D. Wexler and G. Christie, "Temperature Sensitive Device for Fresh Produce", Proc. 1st Int. Conf on Shape Memory and Superelastic Technologies, Monterey, Calif., Mar 6-10 1994.

D. Wexler, G.W. Delamore, N.V. Brown, C. Harland and B. Tate, "Magnetic Properties and Microstructure of Nanocrystalline $Fe_{79}Si_{10}B_{10}Cu_1$ ", ISMANAM 95, Proc. Int. Symp. on Metastable, Mechanically Alloyed and Nanocrystalline Materials, Quebec, July 1995.

A.K.Shaikh, D. Wexler and G.W. Delamore, "Effect of Annealing on the Magnetic Properties and Microstructure of Amorphous $Co_{75}Si_{10}B_{15}$ ", Journal of Magnetism and Magnetic Materials, 152 pp. 345-352.

X. Li, M. Samandi, D. Dunne, D. Wexler and G. Collins, "Microstructural Evolution in High Temperature Nitrogen Implanted Stainless Steel", ISMANAM-95, Proc. Int. Symp. on Metastable, Mechanically Alloyed and Nanocrystalline Materials, Quebec, July 1995.

A.Calka, J.I.Nikolov and G.H.J.Wantenaar, "Low Temperature Synthesis of Al-AlN Composites from Nanostructure Made by Controlled Magneto-Ball Milling of Al in Ammonia", Journal of Applied Physics, vol 75 (10), p.4953, 1994.

P.Millet and A.Calka, "Amorphization of Silicon and Germanium by Mechanical Grinding: Influence of the Conditions and Atmosphere of Milling", **Materials Science and Engineering**, vol., A181/A182, 1994, pp.1222-1226.

P.Millet, A.Calka and B.W.Ninham, "Reduction of Ilmenite by Surfactant Assisted Mechanochemical Treatment", **Journal of Materials Science Letters**, vol 13, p.1428, 1994.

W.A.Kaczmarek, A.Calka and B.W.Ninham, "Evaluation of Fe Contamination in Ball Milling of Nonmagnetic Materials by VSM", **Physica Status Solidi**, vol (a) 141 (2) 1994, p.K123-126.

W.A.Kaczmarek, A.Calka and B.W.Ninham, "Preparation of Co_{70.3} Si₁₅B₁₀Fe_{4.7} Amorphous Powders from Crystalline Ribbons by Surfactant Assisted Ball Milling", **Physica Status Solidi**, vol (a) 141 (1) 1994, p.K1-5.

P.Millet and A.Calka, "Amorphization of Silicon and Germanium by Mechanical Grinding: Effect of Atmosphere and Milling Conditions".**Materials Science and Engineering**, vol., A181/A182, 1994, pp.1222-1226.

A.Calka and J.I.Nikolov "The Dynamics of Magneto-Ball Milling and Its Effect on Phase Transformations During Mechanical Alloying", **Materials Science Forum**, vol.179-181, pp.333-338, 1995.

G.M.Wang, A.Calka, S.J.Campbell and W.A.Kaczmarek, "Carburization of Iron by Ball-Milling Fe₅₀-C₅₀" **Materials Science Forum**, vol.179-181, pp.201-206, 1995.

G.M.Wang, P. Millet, A.Calka and S.J.Campbell, "Mechanosynthesis of Tungsten Carbide" - **Materials Science Forum**, vol.179-181, pp.183-188, 1995.

A.Calka, J.I.Nikolov, Z.L.Li and J.S.Williams, "Structure and Thermal Properties of Tungsten and Molybdenum Milled in Nitriding Environment: Effect of Milling Time and Atmosphere", **Materials Science Forum**, vol.179-181, pp.295-300, 1995.

P.Millet and A.Calka, "Ball Milling of Soft Metals: The Formation of Gallium Nitride", **Materials Science Forum**, vol.179-181, pp.321-324, 1995.

A.Calka, "Mechanical Alloying - A Method for Processing and Creating of New Materials", **Nukleonika**, vol.39, pp. 41-46, 1994.

A.Calka, "Formation of nanostructures by Magneto-Mechano Ball Milling: Applications in Materials Processing", **Proceedings of the Fourth International Workshop on Non-Crystalline Solids**, 20-23 September 1994, Madrid, Spain, Ed. M.Vazquez and A. Hernando, World Scientific Publications, - p.25.

J.I.Nikolov, A.Calka and J.S.Williams, "The Effect of Milling Condition on Micro/Macrostructural Transformations During Milling of B and Si in Nitriding Environment: Formation of BN and Si₃N₄". **Nanostructured Materials**, vol. 6, pp.401-404, 1995.

A.Calka and J.I.Nikolov, "Direct Synthesis of AlN and Al-AlN Composites by Room Temperature Magneto Ball Milling: The Effect of Milling Condition on Formation of Nanostructures" **Nanostructured Materials**, vol. 6, pp.409-412, 1995.

G.M.Wang, S.J.Campbell, A.Calka and W.A.Kaczmarek, "Ball Milling of Fe-C Mixtures (20-65%Fe) **Nanostructured Materials**, vol. 6, pp.389-392, 1995.

L.M.Di, A.Calka, Z.L.Li and J.S.Williams, "The Formation of Ternary Compound Fe₃Mo₃C by Ball Milling", **Journal of Apply Physics**, vol. 78, pp. 4118-4122, 1995.

For further information contact:

**Professor Shi Xue Dou
Director,
Institute for Materials Technology and Manufacturing
Centre for Superconducting and Electronic Materials
University of Wollongong
Wollongong, NSW 2522
Australia**

Telephone: 61 42 21 5730 or 21 4558

Facsimile: 61 42 21 5731

Email: shi_dou@uow.edu.au

