RESEAU FRANÇAIS DE MECANOSYNTHESE

Lettre N°59

Février 2000

169 (+1) Groupes de Recherche

(dont 97 (+1) à l'étranger / 35 Pays)

Bureau : E. Gaffet (Président), G. Le Caër (Secrétaire Général), A.R. Yavari (Trésorier)

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1 Nouvelle Adhésion
Dr. S.-I. Orimo - Faculty of Integrated Arts and Sceinces - Higashi - Hiroshima -**Japon**
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Le site web du RFM est :
http:://www.bls.fr/amatech
Rubrique Pages Sciences et Techniques pour l'Ingénieur (Rubrique Sciences)
vous y trouverez les anciennes lettres du RFM (accessible par Adobe Acrobat)
les statuts du RFM ainsi que les annonces concernant les JRFM'99 et quelques éléments mis a jour régulièrement concernant les derniers résultats dans ce domaine.

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Web Sites

• Pour ceux intéressés par le devenir du Rayonnement Synchrotron en France / Europe, un site intéressant et particulièrement actif ces dernières semaines

• People interested by the Synchrotron Radiation Development in France / Europe

Website : http://www.Lure.u-psud.fr/actus/avenir
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Corresp. : Eric.Gaffet@utbm.fr

The First International Conference on Advanced Materials Processing

19-23 November, 2000 - Rotorua, New Zealand
SECOND CIRCULAR AND CALL FOR PAPERS

Scope of The 1st International Conference on Advanced Materials Processing

In the last few decades of 20th century, research on advanced materials processing has made a tremendous contribution to the development of new materials processing technology and novel, high performance and low cost materials. Without any doubt, in the new millenium, advanced materials processing will continue to be one of the most active research areas in materials science and engineering. To celebrate the achievements of scientists and engineers in this crucially important area, we are organising The 1st International Conference on Advanced Materials Processing (ICAMP) in the very first year of the new millenium.

This conference will provide a forum for international researchers to exchange their recent research findings and views in the area of advanced materials processing. Internationally renowned experts in this area will be invited to give keynote lectures to the conference. During the conference, a workshop will also be organised to discuss opportunities for international cooperation in research on advanced materials processing.

The theme of the conference will focus on the following areas:

New Materials Processing Technology

- · Powder Processing: e.g. mechanical alloying, high energy milling, mechanochemical processing, atomisation and chemical processes.
- · Powder Consolidation: e.g. injection moulding, extrusion, slip casting, sintering and hot isostatic pressing.
- · Composite Processing: e.g. pultrusion, joining and filament winding.
- · Semiconductor fabrication.
- · Other Innovative Material Processing Technology.

Synthesis and Development of New Materials

- · Composite Materials: e.g. metal matrix composites, ceramic matrix composites and polymer matrix composites.
- · Electronic and Ionic Materials: e.g. high temperature superconductors, materials for fuel cells.
- · Advanced Polymers: e.g. conductive polymers, scavenging polymers.
- · Advanced ceramics and intermetallics.
- · Smart Materials.

Call for Papers : Intending authors are invited to submit an abstract of approximately 200-300 words by mail, fax or e-mail (preferred) before March 31, 2000. The abstract should contain the title of the paper, the author's name(s) and full mailing addresses, the fax number and e-mail address of the corresponding author, and indication of the preferred type of presentation (oral or poster). It should be noted that the papers are accepted based on the understanding that one or more of the authors will personally attend the conference and present their work. Guidelines for the final manuscript will be sent out on acceptance of the abstracts.

Abstracts should be sent to:

Dr. D. Zhang - Co-Chair, ICAMP 2000 - Department of Materials and Process Engineering The University of Waikato
Private Bag 3105 - Hamilton, New Zealand - Fax: 64-7-838 4835 - e-mail: d.zhang@waikato.ac.nz

Key Dates

Abstract Due:March 31, 2000
Notice of Acceptance: April 30, 2000
Third Circular: April 30, 2000
Full Paper Due: June 15, 2000
Early Bird Registration: October 1, 2000
Standard Registration: October 31, 2000

Registration Fees

Early Bird Registration NZ$750
Standard Registration NZ$850
Full Time Student Registration NZ$450
(All registration fees include 12.5% Goods and Services Tax (GST))
The registration fees include admission to all technical sessions and the workshop, one copy of the conference proceedings, the reception, lunches, coffees and teas, and the conference dinner.

Conference Location and Accommodation

Rotorua is a city in the central North Island and holds many attractions, including the world famous thermally active reserves. It takes about 2.5 hours by bus or 0.5 hour by flight to go to Rotorua from Auckland International Airport. The temperature in mid-November is in the mid-20s, with little rain. The evenings can, however, be a little cooler.
The rate of a hotel or motel room in Rotorua is in the range of NZ$100-180 (US$50-90, Inc. GST). Inexpensive accommodation is also available. The contact details of the hotels and motels will be listed in the third circular.

Conference Co-sponsors

· Institute of Materials, UK
· The Minerals, Metals and Materials Society (TMS), USA · Department of Materials and Process Engineering, The University of Waikato, NZ

Local Organising Committee

Professor N. M. Sammes (Chair), Dr. D. Zhang (Co-Chair), Dr. M. Brown (Treasurer), Dr. K. L. Pickering

(Secretary)
Dr. G. Tompsett

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ANNONCE DE CONGRES ET / OU ECOLES
CONGRESS AND SCHOOL ANNOUNCEMENTS

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Sintering 2000
7th International Conference on Sintering
Sintering Science and Technology beyond 2000AD
22 - 25 Février 2000 - New Delhi - Inde
E_Mail : gsu@iitk.ac.in

Ultrafine Grained Materials
Strengthening, Fracture and Creep of Nanostructured Materials Symposia
12 - 16 Mars - TMS Annual Meeting - Nashvile TN - USA
Contact : RSMIOSHRA@ucdavis.edu

Nanomatériaux :
Vers les Applications Industrielles
Nanomaterials :
Towards Engineering Applications
Colloque : France - Etats Unis - Canada
17-19 Mai 2000 - Montréal, Canada
Contacts : Champion@glvt-cnrs.fr et/ou Eric.Gaffet@utbm.fr

JRFM'2000
23 - 24 Mai 2000 - Bordeaux France
Wbesite : http:://www.bls.fr/amatech

III European Conference on Fluidization
29 - 31 Mai 2000 - Toulouse - France
E_Mail : Progep@ensigct.fr

PM2 TEC2000
2000 International Conference on Powder Metallurgy & Particulate Materials
31 Mai - 3 Juin 2000 - New York - USA
Contact : MPIF

4th EUROMECH
26 - 30 Juin 2000 - Metz - France
E_Mail : euromech@lpmm.univ-metz.fr
WebSite : http://www.lpmm.univ-metz.fr/euromech

ISMANAM 2000
International Symposium on Metastable Mechanically Alloyed and Nanocrystalline Materials
9 - 14 Juillet 2000 - St Catherines College - Oxford UK
E_Mail :
ismanam2000@materials.ox.ac.uk
website : http://www.materials.ox.ac.uk/Materials/OCAMAC/ISMANAM/ISMANAM2000.html

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NCM8
8th International Conference on the Structure of Non - Crystalline Solid
6 - 11 Aout 2000
Website : http://www.sgt.org

XIVth International Symposium on the Reactivity of Solids
Budapest, Hungary through 27-31 August 2000
http://www.jate.u-szeged.hu/~isrs14.

Solid State Chemistry 2000
Prague, Czech Republic, September 3 - 8,2000
and
3rd INCOME
International Conference on Mechanochemistry and Mechanical Alloying
Prague, Czech Republic, September 4 - 8,2000
Organised by the Institute of Inorganic Chemistry (UACH), Czech Republic
WebSite : http:://www.iic.cas.cz/INCOME.htm

PM 2000
Powder Metallurgy World Congress& Exhibition
12 - 16 Novembre 2000 Kyoto - Japon

Contact : Fax : 81 - 3 - 3423 - 1600

The 1st International Conference on Advanced Materials Processing
Rotorua, New Zealand, 19-23 November 2000.

Secretary, ICAMP 2000,
Department of Materials and Process Engineering The University of Waikato
Private Bag 3105, Hamilton, New Zealand
Fax: 64-7-838 4835, e-mail: d.zhang@waikato.ac.nz
Or visit the conference web site:
http://mape.waikato.ac.nz/conferences/amp.htm

PM2 TEC2001
2001 International Conference on Powder Metallurgy & Particulate Materials
13 - 17 May 2001 - New Orleans - USA
Contact : MPIF

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SOUTENANCE DE THESE
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Cyril Lenain

APPLICATION DE LA MECANOCHIMIE A LA PREPARATION D'ALLIAGES HYDRURABLES NANOCRISTALLINS AB5, MG-NI, AB2 (M) ET DE COMPOSITES M-C, M-Cu : ETUDE DE LEURS PROPRIETES ELECTROCHIMIQUES.

THESE DE DOCTORAT

Specialite: sciences des materiaux presentee a l'Universite de Picardie Jules Verne

Jury :

M. le Prof. J. Etourneau (Universite Bordeaux) M. D. Fruchart (DR, Lab. Cristallographie, Grenoble) Mme A. Percheron - Guegan (DR, LCMTR, Thiais) M. le Prof. L. Schlapbach (Universite de Fribourg) M. le Prof. J-M. Tarascon (Universite de Picardie) M. L. Aymard (Universite de Picardie)

L'objectif de ce travail presentait deux aspects. L'un, fondamental, visait a etablir l'influence du broyage sur les proprietes electrochimiques des alliages de type AB5, et plus particulierement de distinguer les roles respectifs des etats de surface et de la structure du materiau sur sa capacite de stockage de l'hydrogene. Le second point a consiste a mettre en evidence l'interet de la mecanochimie, en tant que methode de synthese ou de traitement de surface, afin d'optimiser les performances de materiaux peu electroactifs et/ou presentant une mauvaise tenue au cyclage.

Cette double approche a d'abord ete appliquee aux alliages de type AB5. Nous avons pu synthetiser avec reussite des alliages ternaires, LaNi4M (M = Al, Mn, Co, Cu) et polysubstitues, La0.67Ce0.16Pr0.1Nd0.07Ni3.6Al0.35Mn0.25Co0.8, dont les capacites electrochimiques apres recuit (274mAh/g) etaient equivalentes a celles des alliages prepares par fusion. La faible capacite des alliages directement issus du broyage fut attribuee a l'oxydation de la surface des grains constituant les particules agglomerees.

L'influence des etats de surface sur les proprietes des materiaux broyes a ensuite ete demontree par le broyage simultane des poudres d'AB5 et de graphite. Ainsi, l'utilisation des connaissances acquises au LRCS dans le domaine du broyage des materiaux carbones a permis d'obtenir un effet benefique sur les capacites des composites (alliages + carbone) et de demontrer ainsi la reactivite du carbone broye, pour non seulement reduire les oxydes de surface mais aussi pour proteger l'alliage de l'oxydation.

L'augmentation de la pression d'equilibre d'hydruration des alliages AB5 est une autre consequence de la modification des proprietes structurales et surfaciques des materiaux broyes qui a ete mise en evidence lors de ce travail. Ce phenomene a ete utilise avec succes afin de destabiliser les hydrures des alliages du systeme Mg-Ni et de rendre leur pression d'equilibre compatible avec l'application electrochimique, rendant ainsi leur utilisation possibles dans les accumulateurs Ni-MH. Des alliages binaires cristallises (Mg2Ni) ou amorphes (MgNi) presentant des capacites massiques importantes, respectivement 270 et 500 mAh/g, ont ete synthetises par broyage mecanique. Cependant, la mauvaise tenue au cyclage de ces materiaux en milieu alcalin, due a la formation d'hydroxyde de magnesium, nous a conduits a preparer des alliages ternaires de formule Mg1-xNiTx (T = Al, Ti, V, Y, Zr) et MgNi1-xTx (T = Cr, Mn, Fe, Co) dans le but de modifier la resistance a la corrosion de l'electrode. Ainsi, une nette amelioration de la tenue au cyclage a ete observee dans le cas des alliages MgNi0.85Fe0.15 et Mg0.9Y0.1Ni, cependant celle-ci n'etait pas suffisante.

Une autre voie a alors ete exploree : le traitement de surface par broyage en presence de graphite ou cuivre. La formation d'electrodes composites MgNi-C a permis d'obtenir une amelioration substantielle de la tenue au cyclage. Concernant le traitement de surface de l'alliage ZrNi1.14Mn0.49Cr0.18V0.1, nous avons constate que le broyage en presence de graphite ameliore la cinetique d'activation et permet d'augmenter de 40% la capacite electrochimique apres stabilisation. En revance, la capacite maximale a pu etre atteinte des le premier cycle lors du traitement mecanique avec le cuivre et une augmentation de 20% de celle-ci a ete obtenue, demontrant clairement l'effet benefique d'un depot controle de cuivre sur l'activation de cet alliage.

F.Charlot

Etude et compréhension des réactions auto-entretenues activées mécaniquement. Elaboration du composé FeAl nanostructuré.

6 Déc. 1999 - Université de Technologie de Belfort - Montbéliard

Nanomatériaux : Elaboration et Transitions de Phases Hors Equilibre, UPR 806 CNRS, UTBM - Sévenans.
Matériaux à Grains Fins, LRSS UMR 5613 CNRS-Université de Bourgogne.

Jury (Provisoire) :

G. Bertrand, G.LeCaer (Rapp.) , F.Thévenot (Rapp.) , F.Bernard (Co - Dir.), E.Gaffet (Co - Dir.), J.C.Gachon, M.Bessière, M.Gailhanou

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Frédéric BERNARD

25 Novembre 1999 - Amphi de l'ESIREM - Dijon

De l'introduction de " mécanique " dans l'élaboration de la poudre au massif nanométrique vers la maîtrise des propriétés thermomécaniques.

Jury :

D.LOUER, Directeur de Recherches CNRS(Université de Rennes II) rapporteur
H. VAN DAMME, Professeur (Université d'Orléans) rapporteur
J.C. TEDENAC, Professeur (Université de Montpellier II) Rapporteur
J. FOCT, Professeur (Université de Lille)
G. LE CAER , Directeur de recherches CNRS (Ecole des Mines, Nancy)

G. BERTRAND, Professeur (Université de Bourgogne)
A. NONAT, Directeur de Recherches CNRS (Université de Bourgogne)
J.C. NIEPCE, Professeur (Université de Bourgogne) Date et lieu :

Frédérique PERROT-SIPPLE

17 Novembre 1999 - Université de Bourgogne - Dijon

Maitrise de la taille de nanograins d'oxydes de structure perovskite pour applications électrocéramiques:
- Synthèse par chimie douce,- Broyage par attrition.

Rapporteurs:

M. J.-M. HAUSSONNE Professeur, Ecole d'Ingénieurs de Cherbourg
M. A. ROUSSET Professeur, Université de Toulouse

Examinateurs

M BEAUGER Alain Ingénieur de Recherche et Développement TPC Saint Apollinaire
M. BERTRAND Gilles Professeur, Université de Bourgogne
M. CHARTIER Thierry Chargé de Recherche, ENSCI de Limoges
M. HUGENTOBLER Denis Directeur Stratégie et Développement ligne céramique, TPC Saint Apollinaire
M. MUTIN Jean-Claude Directeur de Recherche, Université de Bourgogne
Mme RIEUX Nadine Ingénieur de Recherche Alstom-PERT, Massy

Directeurs de thèse:

M. D. AYMES Maître de Conférences, Université de Bourgogne M. P. PERRIAT Professeur, INSA de Lyon

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H. SOUHA

Thèse de Doctorat d'Etat Marocaine

Lieu : Faculté des Sciences Dahr El Mehraz Fes.

Elaboration par recuit et par réaction de combustion du composé Cu3Si à partir d'un mélange de poudres activées mécaniquement. Réactivité du composé Cu3Si vis à vis du chlorure cuivreux.`

Jury :

B. Gillot, G. Bertrand, F. Bernard (Co - Dir.), E. Gaffet (Co - Dir.)

O. Held

"Etude des réactions de combustions solide-solide ou solide liquide auto-entretenues pour différents intermétalliques du système Al-Ni-Ti.
Elaboration de ces mêmes intermétalliques par broyage mécanique et étude de leur cinétique de cristallisation

Nancy, Faculté des Sciences, le 5/11/99.

Jury : J. L. Jorda, J. M. Moreau, P. Satre, J. C. Gachon, F. A. Kuhnast, F. Bernard, J. F. Bérar, M. Bessière.

D. Cracco

"Recherche de Nouveaux Alliages Hydrurables de Forte Capacité Massique Utilisable comme Matériaux d'Électrode Négative d'Accumulateur Ni - MH"

CNRS - Thiais - France - 25 Juin 1999

Jury : B. Darriet, L. Schlapbach, B. Knosp, R. Portier, A. Percheron - Guégan

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A. Gentil - Sagot

Amélioration de la tenue au fluage d'un alliage d'argent (AIC) par introduction d'une dispersion d'oxydes.
Elaboration par Métallurgie des Poudres

Ecole des Mines - Paris - 17 Juin 1999

Jury : M. Grosbras, L. Charrin, S. Kleine, D. Havart, J. - L. Strudel, Y. Bienvenu

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Cooperative Research on Related Areas

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COREE du SUD (19/01/2000)

From Professor Soon H. Hong
Dept. of Materials Science and Engineering - Korea Advanced Institute of Science and Technology
373-1 Kusung-dong, Yusung-gu - Taejon, 305-701, Korea
E-mail : HYPERLINK mailto:shhong@sorak.kaist.ac.kr shhong@sorak.kaist.ac.kr
Fax. : 82-42-869-3310 - Tel. : 82-42-869-3327
We are currently working on the mechanical alloying processes and the characterization of mechanical & thermal properties of nanocrystalline materials and composite materials, such as SiC/Al, WC/Co and W/Cu for structural or thermal management applications. We are very pleased to discuss for international cooperative research on related topics with Members of Mechanosynthese Group.

COREE du SUD (6 May 1999)

From Professor Soon B. Hong
Department of Materials Science and Engineering
Korea Advanced Institute of Science and Technology
373 - 1 Kusung - dong, Yusung - gu
Taejon 305 - 701 Korea
One research topic is entitled "Mechanical Behavior and Wear Resistance of Nanocrystalline WC - Co alloy". We are investigating the fabrication process, sintering and mechanical & wear properties of nanocrystalline WC - Co hard materials. The other research topic is titled "Fabrication Process and Mechanical Properties of Mechanically Alloyed Tungsten Heavy Alloys". We are investigating the mechanical alloying process, sintering behavior and mechanical properties of MA tungsten heavy alloys.
We are very pleased to discuss for international cooperative research on above research topics with Member of Mecanosynthese Group
E_Mail : ShHong@Sorak.kaist.ac.kr

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Ph D Position and Post Doc Position Requests - Proposals

COREE du SUD (10/01/2000)

From Professor Soon H. Hong
Dept. of Materials Science and Engineering - Korea Advanced Institute of Science and Technology
373-1 Kusung-dong, Yusung-gu - Taejon, 305-701, Korea
E-mail : HYPERLINK mailto:shhong@sorak.kaist.ac.kr shhong@sorak.kaist.ac.kr
Fax. : 82-42-869-3310 - Tel. : 82-42-869-3327
The Composite Materials Laboratory at Korea Advanced Institute of Science and Technology is looking for a postdoctoral position. The postdoctoral contract will be one year on the field of modeling and simulation of mechanical & thermal properties of composite materials or on the field of fabrication process of nano-composite materials. Applicant should be within three years of receipt of Ph.D. degree on related field. For more information, please contact :

*** Postdoctoral Position Available for a Ph.D Physicist (13th October 1999)

The High-Pressure (HP) group of the School of Physics & Astronomy at Tel Aviv University has a one year position available. This position could be extended to two years.
The HP group is known worldwide as one of the leading groups in experimental HP physics and is on the frontier of HP and diamond-anvil-cells based methodology. The main methods used are:
Mössbauer spectroscopy
X-ray diffraction with synchrotron radiation (ESRF, Grenoble) resistivity
Applicants must be between the final stage of dissertation and within three years of receipt of Ph.D diploma.
For more information, please contact:
Dr. Moshe P. Pasternak
School of Physics and Astronomy
Tel Aviv University
69978 Tel Aviv, ISRAEL
email: hh136@ccsg.tau.ac.il

*** Looking for Job Position (6th July 1999)

I have a Ph.D. in Physics (Mechanical Alloying by Ball Milling) from the Australian National University (Canberra) and extensive experience (more than 17 years and more than 40 publications) in the area of Materials Sciences,

Mechanical Engineering and Electronics. The topic of my Ph.D. was Production of Hard Materials by Mechanical Alloying (under the guidance of Dr. A. Calka). I have worked on the productin of hard compounds by ball milling such as nitrides, carbides and special alloys. I have completed a post-doctoral fellowship program in Japan (Tokyo University of Technology and The Photon Factory at Tzukuba) and I am currently working as a X-ray Diffraction Officer at CSIRO in Melbourne (Australia). My contract expires and I am looking for a new position.
For more information please contact: ph./fax +61-3-95433002 or email: Jonian.Nikolov@Minerals.CSIRO.au

**** Proposals

FRANCE (2/07/99)

Joindre Pascal Viel , tél 01 69 08 41 47 CEA SRSIM Bt 461, 91191 Gif sur yvette
Proposition de post doc qui débuterait idéalement en septembre 99. Le financement du post doc est acquis (1 an) Le lieu de travail est le centre de Saclay (DSM/DRECAM/SRSIM) Le sujet concerne une étude très appliquée sur la dépollution des eaux de rejets industriels : Mise au point et étude d'un procédé d'élimination des métaux lourds basé sur la fabrication d'un filtre actif (complexation-décomplexation) utilisant la modification de surfaces métalliques par des films polymères électrogreffés en couches minces.
Conditions: avoir sa thèse depuis moins d'un an, ne pas avoir été salarié depuis sauf pour un an de postdoc à l'étranger et avoir moins de 30 ans

FRANCE (6/06/99)

P. Bracconi (Univ. Dijon) propose une position de Post Doc en Métallurgie des Poudres, de nationalité autre que française (Poste Fléché CNRS)
Contact : pbrac@u-bourgogne.fr

GRECE (11/06/99)

The PEML (Photonics and Electronics Materials Lab) at FORTH, Herklion Crete, Greece, offers two postions available for European Post and Pre Docs, to work within the framework of two TMR networks (HAFAM and MICROSYNC) concerning microfabrication and microassembling"
Contact : Porf. G. Kiriakidis : Kiriakid@iesl.forth.gr

Bibliographie Récente

Livres ou "Special Issues"

NOUVEAU (15/11/99)
"Mechanical Alloying : Fundamentals and Applications"
Prof. P.R. Soni (1999) - Cambridge International Science Publishing
web site : http://www.demon.co.uk/cambsi/book52.htm

"Non Equilibrium Processing of Materials"
R.W. Cahn - Elsevier Science - Volume 2 in the Pergamon Materials Series

A large number of technical papers have been published in reviews, monographs and conference proceedings, but have almost always been devoted to a single processing technique. This book, however, covers all the non equlibrium processing methods and their effects in a single volume.

web site : www.elsevier.nl/locate/isbn/0080426972

Bulk Amorphous Alloys : Preparation and Fundamental Characteristics
A. Inoue
Materials Science Foundation Vol. 4 - Trans Tech Publications : http ://www.ttp.net
Interest in bulk amorphous alloys has increased rapidly throughout the workd and these materials have now gained a position of great importance in basic science and engineering materials technology. Bulk amorphous alloys based upon the Zr - Al - Ni - Cu, Zr (Tin,Nb) - Al - Ni - Cu and Zr - Ti - Ni - Cu - Be systems have already achieved wide commercial success as components of various technical accessories ranging from sporting goods to optical instruments.
Here is a state of the art reviews on this new group of materials, covering all areas of interest, ranging from the synthesis of these special alloys and their fundamental properties, to their engineering characteristics and applications.
This work will therefore be of equal interest to those who wish to become fully acquainted with the subject, and to those who are already actively engaged in the field.

DISPERSION-STRENGTHENED ALUMINIUM PREPARED BY MECHANICAL ALLOYING
Michal Besterci, Institute of Materials Research, Slovak Academy of Sciences, Kosice
In the book, the author describes the theoretical and technological fundamentals of mechanical alloying the Al-C system. Special attention is given to material characteristics, the kinetics and mechanism of mechanical alloying, methods of mixture compaction and heat treatment of compacted parts. Models of dispersoid spatial arrangement, dispersoid evaluation and optimisation and experimental possibilities are discussed. The interpretation of the static and dynamic mechanical properties, especially strength and ductility properties at 20 °C, mechanical properties at elevated temperatures are discussed, with emphasis on the effect of interface, superplasticity, creep and creep-fatigue characteristics. Content
Introduction
1. Characteristics of dispersion-strengthened systems
2. Mechanical alloying (kinetics and mechanism of preparation of the Al-C system by mechanical alloying; compaction of powders and heat treatment of compacts;
3. Microstructure and quantitative evaluation of parameters of dispersion-strengthened materials (definition and properties of interparticle distance; experimental possibilities of determination of structural objects; models of heterogeneous structures and their evaluation; simulation of model structures; analysis of the spatial distribution of particles in the Al-Al4C3 material) 4. Static and dynamic mechanical properties (mechanical properties at elevated temperatures; mechanical properties at 20°C; effect of interface on the mechanical properties; superplastic
properties of the system; thermal stability of the system; creep characteristics; creep-fatigue characteristics)
References
Index
ISBN 189832655X, 80 pages, 234 **156 mm, soft laminated cover,** £22.00, January 1999
Cambridge International Science Publishing 7 Meadow Walk, Great Abington, Cambridge CB1 6AZ, England Fax +44 1223 894539; Tel +44 1223 893295 Email: cisp@cisp.demon.co.uk
http://www.demon.co.uk/cambsci/homepage.htm

"Mechanical Alloying"
Auteurs : Li Lü & Man On Lai(National University of Singapore)
Kluwer Academic Publishers
Contents : Preface - Introduction to Mechanical Alloying - Experimental Set - Up - The Mechanical Alloying Process - Formation of New Materials - Characterization of Powders - Densification - Mechanical Properties - Mechanisms of Mechanical Alloying - Modeling of Mechanical Alloying - Index

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"Surface-Controlled Nanoscale Materials for High-Added-Value Applications"

Editors: Kenneth E. Gonsalves, Marie-Isabelle Baraton, Rajiv Singh, Heinrich Hofmann, Jerry X. Chen, and Joseph A. Akkara.
Materials Research Society, Symposium Proceedings Volume 501, 1998
MRS, Warrendale, Pennsylvania, USA (website: http://www.mrs.org/)

"Nanomatériaux"

Auteurs : E. Gaffet, S. Begin - Colin, O. Tillement
Editeur : Innovation 128 - 24 Rue du Quatre Septembre - 75002 Paris - France - Fax : 33 1 42 65 47 76
Les dernières années ont vu apparaître dans le monde des matériaux avancés le préfixe "nano" (nanostructuré, nanocristallins, nanophase ou nanométrique) ; les conférences et les forums sur Internet se multiplient où s'échangent des informations sur les avancées scientifiques et technologiques dans ce domaine des matériaux nanostructurés qui se distinguent des matériaux polycristallins conventionnels par la dimension des cristallites les composant ou par la dimension des hétérostructures présentes : ces dimensions sont de quelques dizaines d'angströms, voire de quelques nanomètres. A ces dimensions, les propriétés des matériaux changent radicalement.
Au début des années 90, les japonais ont été les premiers a lancé d'ambitieux programmes de R & D puisque le MITI a consacré aux nanomatériaux près de 200 millions de dollars pour la période 1990 - 2000 et que la Science & Technology Foundation a investi presque la même somme pour co - financer des projets de laboratoires publics et privés. Les Etats Unis puis les pays européens ont investi plus tardivement mais déjà ont obtenu des résultats prometteurs (••••••) Certaines applications existent déjà au niveau international, quelque 400 sociétés se partagent aujourd'hui un marché voisin de 1 milliard de dollars mais qui devrait tripler, voire quintupler à l'horizon 2001.(••••••)
(•••) Pour aider les industriels concernés à imaginer les applications qu'ils pourraient s'approprier et identifier les acteurs internationaux, la présente étude dresse un état de l'art complet des nanomatériaux en décrivant leurs procédés d'élaboration actuels ou envisagés et en détaillant leurs différentes propriétés physico - chimiques et les géométries que l'on peut obtenir.
Enfin l'étude permet de cerner les applications actuelles et potentielles•••

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Proceedings of 2d International Conference on Mechanochemistry
(INCOME-2), which was held in Novosibirsk in 1997.

Contact : Prof. • N.Z. Lyakhov, Inst. Sol. State Chem.- Russian Acad Sci. - Kutaleladze, 18 - Novosibirsk - 630128 Russia - The Proceedings will be available by the price 80 USD.

Mechanochemistry of Materials
Cambridge International Science Publishing

Emmanuel Gutman - Materials Eng. Dpt - Ben Gurion University - Beer Sheva - Israel

Considerable advances have been made in mechanochemistry in the last couple of decades. Training of experts in this fied with a background in materials science, chemical and mechanical engineering, etc. requires study of the fundamentals of mechanochemistry. There is a need for a textbook in the general and compressed form which would cover many aspects and would be used as a basis for understanding the fundamental principles to control mechanochemical phenomena. This textbook is based on lectures given by Prof. Gutman in a graduate course in the mechanochemistry of materials at the Ben - Gurion University of the Negev. The book contains examples of experimental results to illustrate the mechanochemical phenomena and technologies.

BIBLIOGRAPHY ON MECHANICAL ALLOYING AND MILLING

Suryanarayana (Inst for Materials and Advanced Processes, University of Idaho, USA)

The present bibliography covers information on mechanical alloying and milling of materials starting from 1970 (when it was recognized that MA has become a commercial/viable material processing technique instead of just a grinding method) to 1996. All the available references will be presented in a chronological fashion. Under each year, (•••••)
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Proceeding du Congrès "Mechanically Alloyed, Metastable and Nancrystalline Materials"- Barcelone (1997)
Editor : M.D. Baro, S. Surinach - Materials Science Forum 269 - 272 (1998)

PERIODIQUES

(Rubrique réalisée grâce aux moyens de la bibliothèque de
l'Université de Technologie de Belfort - Montbéliard / UTBM)

[62] TWO DIMENSIONS COMMINUTION OF KAOLINITE CLAY PARTICLES

Baudet G. Perrotel V. Seron A. Stellatelli M. - Powder Technology. 105(1-3):125-134, 1999

Comminution of kaolin clay samples, using attrition-milling in a stirred bead mill and high energy kneading in a pug-mill, was investigated at laboratory scale. Attrition-milling was shown to provide predominant delamination within the first minutes, prolonged treatment resulted in more marked transverse breakage of clay flakes. Pug-milling caused simultaneous delamination and breakage of clay platelets with dominant production of ultra-fine particles in the -0.5 mu m size range. When compared with feed and attrition-milled materials, pug-milled clays exhibit lower viscosity in relation with finer size distributions and lower aspect ratios (AR).

[61] SYNTHESIS OF THERMOELECTRIC MATERIALS BY MECHANICAL ALLOYING IN PLANETARY BALL MILLS

Schilz J. Riffel M. Pixius K. Meyer HJ. - Powder Technology. 105(1-3):149-154, 1999

We report on the influence of the planetary ball mill setting parameters on the evolution of alloy formation on the thermoelectric semiconductor systems, Si-Ge, Mg2Si, and Mg-2(Si,Sn). From a macroscopical viewpoint, it turned out that the geometry of the mill and the ratio of the angular velocities of the planetary and the system wheel play the,crucial role in milling performance. In the case of the brittle-brittle system Si-Ge, the frequency ratio has to be set to achieve the maximum normal impact energy (i.e., to a value of -2.5), whereas for the brittle-ductile Mg2Si system even a higher frequency ratio is desirable. Regarding the microscopic alloy formation, the alloy constitution for the Si-Ge system occurs via a solid state diffusion process. In the case of Mg2Si and Mg-2(Si,Sn), alloying proceeds on the surface of the Mg bulk particles. Additionally, we observed that a successful development of an Mg-2(Si,Sn) solid solution is always accompanied by a temporary high temperature Mg2Sn phase.

[60] MECHANOCHEMICAL SYNTHESIS OF CATIO3 FROM A CAO-TIO2 MIXTURE AND ITS HR-TEM OBSERVATION

Mi GM. Murakami Y. Shindo D. Saito F. - Powder Technology. 105(1-3):162-166, 1999

Anatase (TiO2) is transformed into rutile via brookite within 1 h by room temperature grinding using a planetary ball mill. This polymorphic transformation of anatase leads to the mechanochemical synthesis of the crystalline CaTiO3 from the mixture with CaO easier than from the CaO and rutile mixture. The amount of CaTiO3 in the ground product increases with improving its crystallinity as the grinding progresses. They reach a 20-nm size by about 5 h of grinding, and the grain boundary and lattice fringe appear clearly as the grinding progresses.

[59] THE MODELING OF DRY GRINDING OF QUARTZ IN TUMBLING MEDIA MILLS

Yildirim K. Cho HC. Austin LG. - Powder Technology. 105(1-3):210-221, 1999

The grinding of quartz sand to produce high purity silica flour was studied using ceramic balls, ceramic cylinders or flint pebbles in a laboratory mill and three full-scale closed circuit mills of 2.2, 2.3 and 2.8 m internal diameter. The primary breakage distribution determined in laboratory tests was the same for the three media types but the characteristic slope (gamma) was changed from 1.05 to 0.95 to fit the full-scale results. An approximate correction was used for non-first order breakage kinetics. Simulation models were developed for the air separator and the mills. Simulations indicated that a mill lining of smooth ceramic gave media slip and was less efficient than flint linings. Higher circulating loads reduced specific grinding energy even though the recycle of fine mill product to mill feed increased. Ceramic balls gave the lowest grinding energy, wear rate and cost per ton of product.

[58] MODEL-BASED EVALUATION OF GRINDING EXPERIMENTS

Muller F. Polke R. Schafer M. - Powder Technology. 105(1-3):243-249, 1999

A grinding simulation has been developed based on the population balance model. In the chemical industry, it is usual that a range of products is milled in the same grinding facility. Performing experiments with narrow fractions or tracers to obtain grinding coefficients for each product would be very cost-intensive. Here, a method is used to determine grinding coefficients using algorithms based on only a few laboratory experiments. The data are approximated with equations for the selection function and the breakage function, which allows the milling conditions to be calculated for a desired particle size distribution. Grinding experiments with a stirred ball mill show that the method provides a good approximation in practice.

[57] ECCENTRIC VIBRATORY MILLS - THEORY AND PRACTICE

Gock E. Kurrer KE. - Powder Technology. 105(1-3):302-310, 1999

A new single-pipe vibratory mill, the eccentric vibratory mill, is introduced. It is the result of a joint development project between the Institute for Processing and Disposal Technology at the Clausthal University of Technology and Siebtechnik, Mulheim, Germany. The eccentric vibratory mill is excited on one side by means of an unbalanced-weight drive flanged directly to the grinding pipe. Unlike conventional vibratory mills with homogeneous circular vibrations, this layout causes elliptical, circular and linear vibrations. Due to a major increase of the acceleration of the individual grinding media, the throughput is increased by the factor 2. The decrease of the ratio between kerb mass and payload and the reduction of power losses due to the bearing load leads to a power consumption reduction of 50% for eccentric vibratory mills. In order to adapt the mill to specific grinding problems, the modular design was introduced. Apart from the constructive details, a mechanical analysis for an optimum dimensioning of the eccentric vibratory mill is presented. The industrial introduction is proven by examples from the fields of mineral processing, the chemical and pigment industry as well as from the field of recycling especially milling of cemented carbides.

[56] OBJECT COMPONENTS FOR COMMINUTION SYSTEM SOFTSENSOR DESIGN

Herbst JA. Pate WT. - Powder Technology. 105(1-3):424-429, 1999

Over the last decade or so, a new "softsensor" technology has been evolving which permits previously inaccessible process variables Is a piece of software which processes inputs from instruments that provide information related to the to be estimated. The "softsensor" unknown variables and interprets these in the context of an on-line model to

arrive at the "best available" estimate of the unknown variable(s). Using as a starting point some early work conducted at the University of Utah and GS Industries, the authors describe in the current paper a general object-oriented approach to the design of softsensors for comminution systems. A generic softsensor, ComMINSens, is shown to be integrable with a variety of models in the form of object components. Applications are presented for SAG milling and ball milling circuits.

[55] STRUCTURAL AND MAGNETIC STUDY OF MECHANICALLY ALLOYED FE-NI

Pekala M. Oleszak D. Jartych E. Zurawicz JK. - Nanostructured Materials. 11(6):789-796, 1999

The FexNi100-x (x = 50, 65 and 80) alloys were synthesized in a conventional horizontal low energy bah mill. The X-ray diffraction was used to identify and characterise Various phases during the milling process of the Fe80Ni20 alloy exhibiting a bcc structure whereas for x = 65 and 50 the fee structures are found. The steady state grain size is about 10 nm. Magnetisation measurements after various milling periods allow to monitor a rate at which Ni atoms dissolve in the iron lattice. The room temperature values of the effective magnetic moment raise with the increasing milling period. All the alloys studied exhibit the ferromagnetic ordering. The magnitude of the magnetic interactions is moderately suppressed at prolonged milling as revealed by the Curie temperatures reduced down to 950 K. Such variations are caused by the deviations in the interatomic arrangements of atoms especially in the intergrain regions. The Moessbauer spectroscopy confirmed the ferromagnetic ordering and was used to calculate the distribution of hyperfine magnetic fields. The mean hyperfine fields are 33.8 T for Fe80Ni20 and correspond to the one to two Ni atoms in nearest neighbourhood. In the remaining alloys, at most, five Ni atoms are located in a neighbourhood of the Fe atom.

[54] NITROGEN SORPTION TESTS, SEM-WINDOWLESS EDS AND XRD ANALYSIS OF MECHANICALLY ALLOYED NANOCRYSTALLINE GETTER MATERIALS

Valdre G. Zacchini D. Berti R. Costa A. Alessandrini A. Zucchetti P. Valdre U. - Nanostructured Materials. 11(6):821-829, 1999

Gas absorbing materials (getters) find several applications in modem vacuum technology; in particular to maintain required vacuum levels in evacuated and sealed enclosures. The gas absorbing properties of these getters depend on the physico-chemical nature of their surfaces. The aim of this work is to study the absorption properties of commercial Zr-based alloys (non-evaporable getters) after mechanical alloying by means of a high vacuum planetary ball milling equipped with an in-situ compaction facility. The main aim was to refine the grain size and to develop particular defect structures to enhance the getter properties. The results have shown an improvement of the specific pumping speed of the ball milled commercial Zr-Zr(V,Fe)(2) alloy with respect to the starting microcrystalline material. In particular, under our experimental conditions, the specific pumping speed vs absorbed gas curve presents a maximum after 2 hours of milling; prolonged milling reduced the pumping speed of the alloyed material. This behaviour is explained in terms of two opposing simultaneous chemical and structural effects.

[53] AQUEOUS SOLUBILIZATION OF CRYSTALLINE FULLERENES BY SUPRAMOLECULAR AMPLEXATION WITH G-CYCLODEXTRIN AND SULFOCALIX[8]ARENE UNDER MECHANOCHEMICAL HIGH-SPEED VIBRATION MILLING [HUNGARIAN]

Koichi K. Koichi F. Yasuhiro M. Tibor B. - Magyar Kemiai Folyoirat. 105(10):383-390, 1999

The solid-state supramolecular complexation of fullerenes C-60 and C-70 as well as of some derivatives of C-60 was attained with gamma-cyclodextrin by the use of mechanochemical high-speed vibration milling. Similarly C-60 and the fullerene dimer C-120 were complexed with sulfocalix[8]arene. The produced complexes were found to be soluble in water, and the solubility was examined by UV-vis spectroscopy.

[52] STRUCTURE AND MAGNETIC PROPERTIES OF (ND, PR)-FE-B-TI ALLOYS PREPARED BY MECHANICAL ALLOYING

Liu W. Zhang ZD. Liu JP. Sun XK. Zhao XG. Cui BZ. - Journal of Physics D-Applied Physics. 32(22):2846-2850, 1999

With the purpose of finding promising nanostructured hard magnetic materials, the structure and magnetic properties of PrxFey2-xB8, Pr10Fe82-y,TiryB8, and Pr10-DNdDFe76B8-zTi6+z alloys prepared by mechanical alloying and subsequent annealing have been studied. The best values of 4 pi M-r = 0.8 kGs, H-i(c) = 18.8 kOe and (BH)(max) = 13.9 MGOe, are obtained for the series of PrxFe92-xB8 With x = 16, which are similar to the results reported previously for the Nd-containing counterpart. It has been found that the ratio M-r/M-s notably decreases with increasing mean grain size of the sample with x = 10, whereas the coercivity increases slightly. Far the series of Pr10Fe82-yTiyB8 and Pr10Fe76B8-zTi6+z, when O less than or equal to y less than or equal to 2, the Pr2Fe14B phase can be formed, accompanied by some alpha-(Fe, Ti), a trace of Pr2O3 and Pr-rich phases similar to Nd-rich phases in the Nd-Fe-Ti-B alloys. When y greater than or equal to 4, besides the phases mentioned above, the Pr(Fe, Ti)(7) phase with the TbCu7 structure is also observed. When z greater than or equal to 2, with increasing Ti content, the Curie temperature of the Pr(Fe, Ti)(7) phase increases, while the Curie temperature of Pr2Fe14B decreases and the magnetic properties of the series degrade. In the series of Pr10-DNdDFe76B4Ti10 it is found that the substitution of Nd for Pr leads to a gradual disappearance of the 1:7 phase with the TbCu7 structure. A nearly single phase Nd2Fe14B is formed for D greater than or equal to 8. The coercivity of the samples is drastically enhanced by Nd substitution.

[51] STRUCTURAL EVOLUTION DURING MECHANICAL ALLOYING AND ANNEALING OF A NB-25AT%AL ALLOY

Kim HS. Kum D. Hanada S. - Journal of Materials Science. 35(1):235-239, 2000

Mixtures of pure elemental Al and Nb powders of Nb-25at%Al composition was mechanically alloyed, and structural evolution during high energy ball milling has been examined. Al dissolved in Nb from the early stage of the ball milling, and amorphization became noticeable after longer than five hours of milling. However the dissolution of Al in Nb was not completed before the amorphization. No intermetallic phase formed during the mechanical alloying. Before complete amorphization, metastable nitride of Nb4.62N2.14 (i.e., beta-NbN) with hexagonal structure has formed in nanocrystalline size through nitrogen incorporation from ambient environment. The lattice parameter of Nb

increased significantly (up to 3.3433 Angstrom after 5 hours of milling) during the milling. Upon annealing above 950 degrees C, Nb2Al became the dominant feature with the beta-NbN, and Nb3Al did not form from the samples milled at ambient environment. Nb3Al appeared only from a sample milled at Ar environment. Structural evolution during mechanical alloying of the Nb-Al system is critically dependent the upon milling environment.

[50] SYNTHESIS OF TITANIUM DIBORIDE TIB2 AND TI-AL-B METAL MATRIX COMPOSITES

Lu L. Lai MO. Wang HY. - Journal of Materials Science. 35(1):241-248, 2000

Titanium diboride TiB2 and TiAl aluminide composites reinforced with in situ borites have been synthesized from the elemental powders of Ti and B, and Ti, Al and B respectively using mechanical alloying technique. No progressive diffusion between Ti and B was observed. The formation of TiB2 was found to be governed by strong and fast exothermic heat release. This indicates that the formation of TiB2 compound in local area of mechanically alloyed powder generated high energy which in turn ignited and promoted the formation of new compound in the rest of the area. Because of the presence of Al in Ti-Al-B system, the concentration of Ti or B was diluted. The exothermic reaction between Ti and B was consequently delayed. However, grain refinement of Ti and Al in this system down to nanometer scale is faster than that in Ti-Al system due to the contribution of B. Using X-ray analysis, strong but broad TiAl, and weak TiB and TiB2 peaks had been detected at 50 h of mechanical alloying indicating the formation of nano TiAl composite reinforced by TiB and TiB2. However, TiB was, however, not a stable phase; it later was transformed into equilibrium phase of TiB2 after annealing at 800 degrees C.

[49] HYDRATION OF ALKALI-ACTIVATED GROUND GRANULATED BLAST FURNACE SLAG

Song S. Sohn D. Jennings HM. Mason TO.- Journal of Materials Science. 35(1):249-257, 2000

The hydration of ground granulated blast furnace slag (GGBFS) at 25 degrees C in controlled pH environments was investigated during 28 days of hydration. GGBFS was activated by NaOH, and it was found that the rate of reaction depends on the pH of the starting solution. The main product was identified as C-S-H, and, in the pastes with high pH, hydrotalcite was observed at later stages of hydration. The pH of the mixing solution should be higher than pH 11.5 to effectively activate the hydration of GGBFS. As deduced from very low electrical conductivity measurements, GGBFS pastes had very tortuous and disconnected pores. The effect of the pH of the aqueous solution on the composition, microstructure and properties of alkali-activated GGBFS pastes are also discussed.

[48] MAGNETIC DISORDER IN CUPRIC OXIDE

Stewart SJ. Borzi RA. Mercader RC. - Hyperfine Interactions. 122(1-2):47-57, 1999

Investigations of the abnormal magnetic properties of cupric oxide reveal discrepancies between both experimental results and theoretical explanations. Through iron-doping cupric oxide by ball-milling and thermal treatments we have been able to obtain Mossbauer results that are an experimental evidence of semi-disorder. The magnetic hyperfine field of the Cu0.995Fe0.005O solid solution displays a spin-glass-like thermal dependence that undergoes two transitions, one at about 150 K, that can be assigned to the long-range ordering of the cupric oxide spins, and the second one at some temperature between 4.2 and 15 K, that exposes either the freezing of the Fe3+ spins into a local canted state or of magnetic clusters in the CuO matrix.

[47] MOSSBAUER COMPARATIVE STUDY OF FE-SI (3.5 WT%) ALLOYS PRODUCED BY MELTING AND BY MECHANICAL ALLOYING

Sthepa HS. Fajardo M. Alcazar GAP. - Hyperfine Interactions. 122(1-2):115-120, 1999

Mossbauer spectroscopy and X-ray diffraction measurements were done on Fe-Si (3.5 wt%) alloys produced by melting and by mechanical alloying during 15, 30, 50 and 75 milling hours from over 99% purity powders. The Mossbauer spectra were fitted using hyperfine field distribution and it was obtained for all the samples in three ferromagnetic sites with fields of 27, 30 and 33 T for the mechanical alloyed samples and 26.8, 30.13 and 32.83 T for the commercial sample. These three sites are attributed to the pure Fe, Fe with one Si in the next near neighbor (nnn) and Fe with two Si in the nnn. As the milling time increases, the mean field increases too. X-ray diffraction measurement shows that all the samples are BCC, with a lattice parameter that increases with the milling time. These lattice parameters are bigger than that of the commercial alloy.

[46] MAGNETIC PROPERTIES OF THE MECHANICALLY ALLOYED FE0.9-XMN0.1ALX SYSTEM

Restrepo J. Alcazar GAP. Gonzalez JM. - Hyperfine Interactions. 122(1-2):189-199, 1999

Samples of nominal composition Fe0.9-xMn0.1Alx (0.1 less than or equal to x less than or equal to 0.5) were prepared by mechanical alloying starting from pure elements. Milling times of 24, 72 and 144 h were considered. The magnetic properties of the samples were studied by using Fe-57 Mossbauer spectroscopy, vibrating sample magnetometry and magnetic susceptibility measurements. The phase distribution was determined from X-ray diffractometry. The so obtained results evidence a strong dependence on the milling time and Al concentration of the room-temperature hyperfine field distributions and coercive forces. The susceptibility measurements in the range of temperature between 10 K and 180 K suggest the occurrence of different types of transitions as the temperature is increased: (a) from a ferromagnetic to a paramagnetic phase, (b) from a reentrant spin-glass phase to a ferromagnetic one and (c) from spin-glass to a paramagnetic phase. These transitions are also strongly influenced by the milling time and the Al concentration.

[45] MECHANO-CHEMICAL PREPARATION OF NOVEL CELLULOSE-POLY(ETHYLENE GLYCOL) COMPOSITE

Endo T. Kitagawa R. Zhang F. Hirotsu T. Hosokawa J. - Chemistry Letters. (11):1155-1156, 1999

A new type of cellulose composite was mechano-chemically prepared by ball-milling mixtures of cellulose and poly (ethylene glycol) (PEG). The composites are probably formed by insertion of PEG molecules among cellulose crystalline molecular-chains, and accordingly the compatibilization of cellulose and PEG through the formation of hydrogen-bonds, exhibiting a different mode of orientation of cellulose from that of similar blends from solution systems.

[44] MECHANICAL ACTIVATION CONDITIONS OF THE FE2O3 AND V2O3 MIXTURE POWDERS IN ORDER TO OBTAIN A NANOMETRIC VANADIUM SPINEL FERRITE

Nivoix V. Bernard F. Gaffet E. Perriat P. Gillot B. - Powder Technology. 105(1-3):155-161, 1999

Co-milling of iron and vanadium oxides allows to obtain an intimate oxides mixture at a nanoscale, similar to a coprecipitate elaborated by soft chemistry. Reduction of such a mixture in the same temperature and oxygen partial pressure conditions (500 degrees C and 10(-25) Pa) as the soft chemistry products leads to a nanometric vanadium ferrite with the only spinel phase. The characterization of the powders is achieved by X-ray diffraction (XRD), scanning electron microscopy, infrared (IR) spectrometry, thermogravimetry and calorimetry. Homogeneity of grain size and chemical composition is reached if the initial oxides have similar grain size.

[43] STRUCTURE AND PROPERTIES OF POWDER METALLURGY PHOSPHOROUS STEELS

Antsiferov VN. Shatsov AA. Oglezneva SA. - Powder Metallurgy & Metal Ceramics. 38(3-4):162-165, 1999

The effect of structure on the Properties of powder metallurgy steels alloyed with phosphorus was investigated Initial mixtures were prepared by the traditional method and by mechanical alloying. Mechanical alloying decreased the sintering temperature, increased the density, and improved the properties thanks to the formation of dispersed phases, a high-density cellular dislocation distribution, and the frapping of phosphorus atoms by the dislocation atmosphere, which prevented coagulation of the phosphides. If was established that when closed porosity is formed, the changes in mechanical properties and fracture resistance do not agree

[42] THE MAGNETISM AND MICROSTRUCTURE OF PULVERIZED TITANOMAGNETITE, FE2.4TI0.6O4: THE EFFECT OF ANNEALING, MAGHEMITIZATION AND INVERSION

Brown AP. O'Reilly W. - Physics of the Earth & Planetary Interiors. 116(1-4):19-30, 1999

Titanomagnetite, Fe2.4Ti0.6O4, pulverized in a ball-mill to make the material readily maghemitize on the laboratory time scale, has been used as an analogue for the magnetic mineral of submarine basalts. The ball-milling, in addition to reducing particle site, produces an internal nanocrystalline structure. Annealing at high enough temperature (600 degrees C-800 degrees C) removes the nanocrystalline structure but the titanomagnetite crystals carry a relic of ball-milling induced non-stoichiometry which contributes to magnetic strain anisotropy. Despite this complication, the coercive force of the annealed material is close to the average coercive force of pillow basalts and should provide an improved synthetic analogue for laboratory studies inspired by the magnetism and mineralogy of the submarine crust. The nanocrystalline structure persists in maghemitized pulverized titanomagnetite, and the magnetization process parameters are consistent with an increasing importance of thermal fluctuations as maghemitization proceeds. In the transformations produced by annealing, maghemitization and inversion, the spinel component immediately post-transformation has composition and/or concentration inherited from the pre-transformation spinel, and does not correspond to equilibrium. Later re-equilibration of the coexisting phases, accelerated in the laboratory by elevated temperature, leads to diminution of the spinel component in favour of more stable phases. Unlike the inversion of maghemite to haematite, the inversion product of titanomaghemite is not a unique assemblage of phases.

[41] SYNTHESIS AND ANODE BEHAVIOR OF LITHIUM STORAGE INTERMETALLIC COMPOUNDS WITH VARIOUS CRYSTALLINITIES

Sakaguchi H. Honda H. Esaka T. - Journal of Power Sources. 82:229-232, 1999

An anode active material, Mg2.0Ge, was synthesized using mechanical alloying (MA). Electrochemical performance of the compounds having different crystallinities was examined. It was found that the first discharge capacity of the Mg2.0Ge with a 90% crystallinity (MA treatment for 25 h) was ca. 320 mA h g(-1). The lattice expansion at the insertion of Li was decreased with decreasing crystallinity, suggesting the prolongation of cycle life. On the other hand, the discharge capacity of Mg2.0Ge with the lower crystallinity (MA treatment for 100 h) showed an insignificant value, being ca. 25 mA h g(-1), but the cycle dependence of capacities was favorable.

[40] PHYSICAL CHARACTERIZATION OF CARBONACEOUS MATERIALS PREPARED BY MECHANICAL GRINDING

Salver-Disma F. Du Pasquier A. Tarascon JM. Lassegues JC. Rouzaud JN. - Journal of Power Sources. 82:291-295, 1999

By means of mechanical grinding, we recently reported the ability to prepare tailor-made carbon materials able to reversibly intercalate two lithiums per six carbons (e.g., Li2C6) while having irreversible capacities of 320 mA h/g. A schematic model involving two different types of surface area was previously proposed to account for the reversible and irreversible capacities measured vs. Li with these powders. We experimentally verified this model by means of differential scanning calorimetry (DSC) measurements. Transmission Electronic Microscopy (TEM), which is a powerful tool for the direct imaging of poorly organized materials at the atomic scale has been used, together with Raman Spectroscopy, to follow the disorganization generated by mechanical grinding.

[39] ELECTROCHEMICAL STUDY OF LI4TI5O12 AS NEGATIVE ELECTRODE FOR LI-ION POLYMER RECHARGEABLE BATTERIES

Zaghib K. Simoneau M. Armand M. Gauthier M. - Journal of Power Sources. 82:300-305, 1999

Li4Ti5O12 a zero-strain insertion material was prepared by conventional method and by high energy ball milling (HEBM) of precursor to form nanocrystalline phases. The electrochemical performance of solid-state negative electrode was carried out using a solvent-free solid polymer electrolyte at 60 degrees C and 80 degrees C. A Li4Ti5O12 vs. lithium cell discharged at C/12 delivered 155 mA h g(-1) for the conventional method and 157 mA h g(-1) for the method using high ball energy milling, corresponding respectively to 97% and 96% first-cycle coulombic efficiency. The chemical diffusion coefficient of Li4Ti5O12 spinel-type compound is about 2 x 10(-8) cm(2) s(-1). This is one order of magnitude higher than that of carbonaceous negative electrodes. Li4Ti5O12, which is a zero-strain insertion material, offers advantage for the SPE cell including safety, long life, and reliability.

[38] ON THE CHOICE OF GRAPHITE FOR LITHIUM ION BATTERIES

Simon B. Flandrois S. Guerin K. Fevrier-Bouvier A. Teulat I. Biensan P. - Journal of Power Sources. 82:312-316, 1999

Graphites as active materials for negative electrode in lithium batteries are particularly attractive because of their large capacity of lithium intercalation and their low average voltage. In some conditions, they are known to suffer from low reversibility of the initial intercalation process. This phenomenon is shown to be unambiguously related to an exfoliation of graphene layers, that can occur even in EC based electrolytes. Occurrence of a clear correlation

between the extent of irreversible behaviour and rhombohedral phase content of graphites is discussed. Milling or thermal treatment of pristine graphites are also shown to influence electrochemical properties.

[37] MECHANICAL AND THERMAL SPREADING OF ANTIMONY OXIDES ON THE TIO2 SURFACE: DISPERSION AND PROPERTIES OF SURFACE ANTIMONY OXIDE SPECIES

Pillep B. Behrens P. Schubert UA. Spengler J. Knozinger H. - Journal of Physical Chemistry B. 103(44):9595-9603, 1999

Mixed metal oxides are important industrial catalysts for the selective oxidation and ammoxidation of aromatics and alkenes and often contain Sb oxides as a component. For the preparation of a catalytically relevant system on the basis of monolayer-type catalysts; an alternative route as compared to the conventional impregnation was chosen by milling the dry compounds in a planetary mill. To get a closer insight into the spreading and oxidation properties of antimony oxide on titania, only the binary oxidic compounds Sb oxide and TiO2 as support were investigated in the present study, Photoelectron spectroscopy (XPS) investigations for surface analysis and X-ray absorption spectroscopy (XANES) for bulk phase analysis were applied. The various Sb oxides (Sb2O3, Sb2O4, and Sb2O5) show totally different spreading behavior, Only with the Sb(III) oxide on titania a significant increase of dispersion was detectable by means of XPS and temperature programmed reduction (TPR), The temperature of oxidation of the supported Sb(III) oxide in air was 100 degrees C lower as compared to the bulk phase oxidation, The final formula after oxidation of Sb(III) oxide can be calculated from XANES results as Sb6O13 and does not end up at a stoichiometry of Sb2O4.

[36] SYSTEMATIC B-METAL SUBSTITUTION IN CANI5

Jensen JO. Bjerrum NJ. - Journal of Alloys & Compounds. 295:185-189, 1999

The aim of this work has been to study the effect of B metal substitutions in CaNi5 (AB(5)) which is known to suffer from poor cycling stability as a hydride electrode material. Systematic monosubstitutions of nickel with the most common other B metals (i.e. Al, Cr, Mn, Fe, Co, Cu, Zn and Sn) and Mg were performed. The overall composition was in all cases CaNi5-xMx (x=0.5 or 1) where M is the substituting element. The alloys were prepared by mechanical alloying. The hydrogen storage capacity was measured electrochemically ranging from 39 to 390 mAh/g, but none of the substitutions increased the cycling stability to any significant extend compared to pure CaNi5. X-ray diffraction patterns of the alloys revealed that only in a few cases the hexagonal CaCu5 structure of a true AB(5) alloy was preserved. In most cases diffraction patterns matching Ca2Ni7, CaNi3 or CaNi2 were seen. It can be concluded that CaNi5 is much less tolerant towards B-metal substitution than LaNi5. This fact makes it less possible that the problem with cycling stability of Ca-based hydride electrodes can be solved by substitutions.

[35] CATALYSED REACTIVE MILLING

Tessier P. Akiba E. - Journal of Alloys & Compounds. 295:400-402, 1999

Magnesium is mechanically activated in a high-energy planetary hail mill. It is found that the yield of magnesium hydride is considerably increased by the addition of a small amount of nickel.

[34] THE EFFECT OF NOVEL PROCESSING ON HYDROGEN UPTAKE IN FETI- AND MAGNESIUM-BASED ALLOYS

Morris S. Dodd SB. Hall PJ. Mackinnon AJ. Berlouis LEA. - Journal of Alloys & Compounds. 295:458-462, 1999

This paper discusses the production and initial evaluation of hydrogen storage alloys produced by physical vapour deposition (PVD) and mechanical alloying (MA). PVD is usually associated with the production of thin films and coatings. However, DERA Farnborough have developed a high rate vapour condensation process to produce bulk deposits, in some cases up to 44 mm thick. Vapour condensation using electron beam evaporation produces the ultimate in cooling rates with extended solid solubility and refinement of microstructure, which produce enhanced physical and mechanical properties. MA is a complimentary technique for processing hydrogen storage materials which has been developed within DERA over the past 3 years. These techniques have been applied to Mg and FeTi alloy systems and it is shown that both methods greatly enhance the amount of hydrogen uptake and the ease of activation.

[33] STRUCTURAL STUDY AND HYDROGEN SORPTION KINETICS OF BALL-MILLED MAGNESIUM HYDRIDE

Huot J. Liang G. Boily S. Van Neste A. Schulz R. - Journal of Alloys & Compounds. 295:495-500, 1999

It has recently been discovered that energetic ball milling of hydrides can improve their hydrogen sorption properties significantly. In this work, we present a systematic study of structural modifications and hydrogen absorption-desorption kinetics of ball-milled magnesium hydride. Structural investigations showed that after only 2 h of milling, a metastable orthorhombic (gamma) magnesium hydride phase is formed. A Rietveld analysis of the X-ray diffraction spectrum of the 20 h milled sample gave a proportion of 74 wt.% MgH2, 18 wt.% gamma MgH2 and 8 wt.% MgO. The hydrogen capacity and sorption kinetics were measured before and after milling. We found that the sorption kinetics are much faster for the milled sample compared to the unmilled one. This explains the fact that the hydrogen desorption temperature of the ball-milled sample as measured by pressured differential scanning calorimetry (PDSC), is reduced by 64 K compared to the unmilled sample. There is no significant change of the storage capacity upon milling and the absorption plateau pressure does not change. From the desorption curves, the activation energy was deduced. The milling also increased the specific surface area. This was confirmed by SEM micrographs and BET measurements. Possible mechanisms explaining the improved kinetics are presented.

[32] STRUCTURAL INVESTIGATION AND SOLID-II, REACTION OF MG2NI RICH NANOCOMPOSITE MATERIALS ELABORATED BY MECHANICAL ALLOYING

Abdellaoui M. Cracco D. Percheron-Guegan A. - Journal of Alloys & Compounds. 295:501-507, 1999

Using a planetary ball mill and starting from a mixture of Mg and Ni with an atomic ration of 2:1, we have successfully elaborated a nanocomposite material formed by the Mg,Ni phase in high proportion, same residual Ni and an amorphous phase. The synthesis of this composite proceeded at milling intensities 7 and 10, corresponding respectively to 3.5 and 10 W g(-1) shock power, respectively after 18 and 4 h. The best hydrogen absorption capacity reported, 3.75 H mole(-1) (3.53 wt.%), is for the composite synthesized for 24 h at 3.5 W g(-1) shock power.

[31] MICROSTRUCTURE AND HYDROGEN ABSORPTION PROPERTIES OF NANO-PHASE COMPOSITE

PREPARED BY MECHANICAL ALLOYING OF MMNI(5-X)(COALMN)(X) AND MG
Zhu M. Zhu WH. Chung CY. Che ZX. Li ZX. - Journal of Alloys & Compounds. 295:531-535, 1999
In this work high energy ball milling was used to prepare composite hydrogen storage alloy in the MmNi(5-x)M(x)-Mg system. X-ray diffraction and TEM analysis were used to characterise the microstructure of the composite alloy obtained by ball milling. It has been shown that the grain size of MmNi(5-x)M(x) and Mg components were reduced to nanometre range after about 20 h of milling. Besides, a Mm(2)Mg(17) phase of nanometre size was also formed in the milling process. Thus, a composite alloy, referred to as nano-phase composite here, composed of MmNi(5-x)M(x), Mg and Mm(2)Mg(17) phase of nanometre size was obtained. Hydrogen storage behaviour of the nano-phase composite was compared with that of conventional MmNi(5-x)M(x) alloy by measuring PCT and kinetics. It showed that the hydrogen absorption properties were improved.

[30] MG2NI HYDRIDE ELECTRODES PREPARED BY SINTERING AND SUBSEQUENT BALL MILLING WITH NI POWDERS
Sun L. Yao P. Liu HK. Bradhurst DH. Dou SX. - Journal of Alloys & Compounds. 295:536-540, 1999
Mg2Ni alloy electrodes were manufactured by a powder metallurgical technique followed by ball milling with Ni powders. The discharge capacities of the electrodes were significantly improved by ball milling. An amorphous structure is a key factor in order to achieve high discharge capacities. Other effective methods include increasing the ball milling time and changing the ratio of ball to sample weight.

[29] SYNTHESIS AND HYDRIDING/DEHYDRING PROPERTIES OF AMORPHOUS MG2NI1.0M0.1 ALLOYS MECHANICALLY ALLOYED FROM MG2NI0.9M0.1 (M=NONE, NI, CA, LA, Y, AL, SI, CU AND MN) AND NI POWDER
Terashita N. Takahashi M. Kobayashi K. Sasai T. Akiba E. - Journal of Alloys & Compounds. 295:541-545, 1999
Amorphous Mg2Ni1.9M0.1 (M=none, Ni, Ca, La, Y, Al, Si, Cu and Mn) alloys were prepared by mechanical alloying of pseudo-binary Mg2Ni0.9M0.1 intermetallic compounds and Ni powder. The crystal structures, thermal stabilities and hydriding/dehydriding properties of those alloys were characterized by powder X-ray diffraction, thermal analysis and conventional measurement of pressure composition isotherms. In spite of the difference in M element, all specimens formed amorphous structures by mechanical alloying. Owing to the substitution of Ca the amount of desorbed hydrogen increased from 1.8 mass% for M=none to 2.1 mass% for M=Ca by measurement of thermogravimetry. The dehydriding reactions occurred at temperatures below about 400 K in both alloys.

[28] HYDRIDING PROPERTIES OF THE HEAT-TREATED MGNI ALLOYS WITH NANOSTRUCTURAL DESIGNED MULTIPHASE
Yamamoto K. Orimo S. Fujii H. Kitano Y. - Journal of Alloys & Compounds. 295:546-551, 1999
The structural and hydriding properties have been investigated for the heat-treated MgNi alloys with nanoscale structure which consists of the Mg2Ni and MgNi2 phases. The alloys were fabricated by mechanical alloying (MA) and heat treatment (HT), the so called MA/HT method. For the as-alloyed amorphous MgNi (a-MgNi) alloy, the maximum hydrogen content reaches 1.72 mass% at 473 K. The hydride, however, gradually decomposes into Mg2NiH4 and MgNi2 phases during measurement of pressure-composition isotherm. In the case of nanoscaled crystalline Mg2Ni (c-Mg2Ni)+amorphous MgNi2 (a-MgNi2) multiphase alloy, the maximum hydrogen content reaches only 0.35 mass% at 473 K. No plateau-like behavior is observed in the desorption process. In the case of nanoscaled c-Mg2Ni+crystalline MgNi2 (c-MgNi2) multiphase alloy, the maximum hydrogen content reaches 1.45 mass% at 473 K. A well-defined plateau region is observed of nearly 0.012 MPa at 473 K in the desorption process. Therefore, it is concluded that the hydriding properties of the nanoscaled MgNi multiphase alloy will. be strongly affected by not only the structural properties of the matrix surrounding the c-Mg2Ni grains precipitated but also by the accumulation/release of internal stress on the precipitation process.

[27] ELECTROCHEMICAL AND STRUCTURAL CHARACTERISTICS OF AMORPHOUS MGNIX (X >= 1) ALLOYS PREPARED BY MECHANICAL ALLOYING
Zhang SG. Hara Y. Morikawa T. Inoue H. Iwakura C. - Journal of Alloys & Compounds. 295:552-555, 1999
The hydriding and structural characteristics of amorphous MgNix alloys prepared by mechanical alloying have been investigated with charge-discharge tests and X-ray photoelectron spectroscopy (XPS)in combination with X-ray excited Anger electron spectroscopy (XAES). It was found that the increase in Ni content lead to a significantly enhancement in cycle performance of MgNix alloys. XPS and XAES investigations indicated the existence of a significantly thicker Ni enriched layer for the MgNi1.5 and MgNi2.0 alloys than that for the MgNi alloy. These results reveal that excess of Ni in MgNix alloys may improve the cycle performance of alloy electrodes by suppressing the segregation of Mg during electrochemical cycling.

[26] ELECTROCHEMICAL CHARACTERISTICS OF NANOCRYSTALLINE ZRCR2 AND MG2NI TYPE METAL HYDRIDES PREPARED BY MECHANICAL ALLOYING
Woo JH. Jung CB. Lee JH. Lee KS. - Journal of Alloys & Compounds. 295:556-563, 1999
The mechanical alloying process (MA) has been introduced to produce nanocrystalline ZrCr2 and Mg2Ni type metal hydride. MA has recently emerged as a novel technique for producing alloy powders whose structures are nanocrystalline. The Zr-Cr-Ni and Mg-Ni systems were prepared using a planetary hall mill, starting from mixtures of elemental powders. Tn the Zr-Cr-Ni system, nanocrystalline C14 structure could not be obtained after ball-milling but could be obtained fi-om heat-treatment of ball-milled powders. The heat-treated Zr-Cr-Ni powders showed a similar discharge capacity to the arc-melted alloy, but the activation was much easier. In contrast to Zr-Cr-Ni system, nanocrystalline Mg2Ni alloy could be formed by ball-milling. In comparison with the polycrystalline one, nanocrystalline Mg3Ni showed a lower temperature for hydrogenation and a much higher discharge capacity at 30 degrees C. The partial substitution of Zr for Mg resulted in a microstructure different from mechanically alloyed Mg,Ni and greatly improved the discharge capacity at 30 degrees C. The discharge capacity of 120 h-milled 1.8Mg-0.2Zr-Ni electrode was 465 mAh g(-1).

[25] HYDROGEN-ABSORBING MAGNESIUM COMPOSITES PREPARED BY MECHANICAL GRINDING WITH GRAPHITE: EFFECTS OF ADDITIVES ON COMPOSITE STRUCTURES AND HYDRIDING PROPERTIES

Imamura H. Takesue Y. Akimoto T. Tabata S. - Journal of Alloys & Compounds. 295:564-568, 1999
Novel Mg/G composites were prepared by mechanical grinding of magnesium (Mg) and graphite (G) with benzene as an additive. The addition of benzene was very important in determining the composite structures and hydriding properties. The composites prepared without benzene (designated hereafter as (Mg/G)(none)) showed negligible activity for hydriding, whereas the use of benzene during grinding led to drastic changes in composite structures, leading to much improved hydriding. Transmission electron microscopy (TEM), X-ray diffraction (XRD) and Raman spectroscopy were used to characterize the structures of the Mg/G composites, especially for the mode of degradation of graphite structure during grinding. In the course of the composite formation in the presence of benzene (referred to as (Mg/G)(BN)), the graphite structure was predominantly degraded by cleavages along graphite layers, while the graphite for (Mg/G)(none) was broken irregularly and disorderly, leading to rapid amorphization. Moreover, the additive for the composite formation plays an important role in promoting synergetic actions induced during the mechanical grinding of magnesium and graphite, in which the flaked graphite formed by fracture along graphite layers interacts with divided magnesium with charge-transfer. X-ray photoelectron spectroscopy (XPS) of (Mg/G)(BN) proved the charge-transfer from magnesium to graphite carbons.

[24] ELECTROCHEMICAL PROPERTIES OF MECHANICALLY GROUND MG2NI ALLOY
Kohno T. Yamamoto M. Kanda M. - Journal of Alloys & Compounds. 295:643-647, 1999
The electrochemical properties of Mg2Ni type alloy powder prepared with a mechanical grinding (MG) of Mg2Ni and Ni or Pd powders were investigated. This alloy powder was found to be mainly changed to an amorphous-like matrix with dispersed nano-size Ni or Pd particles by the MG treatment. As a result, the negative electrode of the mechanically ground Mg2Ni alloy with Ni showed a large discharge capacity (830 mAh/g) which is 2.5 times larger than that of AB, type alloys. In the mechanically ground Mg2Ni alloy with Pd, the cycle life of the alloy electrode was considerably improved. The effect of partial substitution on the hydrogen storage properties of Mg2Ni was also investigated. It was found that the hydrogen reversibility of the mechanically ground Mg1.9M0.1Ni (M=Al, B, C, Ag) alloy electrode was remarkably improved by the substitution of Mg with more electronegative elements.

[23] A NEW ELECTRODE MATERIAL FOR NICKEL-METAL HYDRIDE BATTERIES: MGNI-GRAPHITE COMPOSITES PREPARED BY BALL-MILLING
Iwakura C. Inoue H. Zhang SG. Nohara S. - Journal of Alloys & Compounds. 295:653-657, 1999
MgNi-graphite composites prepared by ball-milling were found to show greatly enhanced charge-discharge characteristics with respect to the original MgNi alloy. There was an optimal ball-milling time for the preparation of the MgNi graphite composite with enhanced electrode performance, when the modification with graphite was limited to the surface layer of MgNi alloy. Raman and XPS investigations on the composites indicated a decline in the pi-electron character of graphite and changes in the chemical states of the constituents on alloy surface, suggesting the possibility of charge transfer between graphite and MgNi alloy during ball-milling, which resulted in an increase in the surface Ni/Mg ratio.

[22] MODIFICATION OF A RAPIDLY SOLIDIFIED HYDROGEN STORAGE ELECTRODE ALLOY BY BALL-MILLING WITH CO3MO
Yang K. Chen DM. Chen LA. Zhang HF. Sun WS. Li YY. - Journal of Alloys & Compounds. 295:670-674, 1999
Rapidly solidified hydrogen storage alloys were reported to have good cycle life, but they are very difficult to activate, especially for AB(2) type alloys. In this study, a Zr0.9Ti0.1 (Ni0.57V0.1Mn0.28Co0.05)(2.1) alloy was prepared by melt-spinning followed by ball-milling with Co3Mo additive in order to improve its kinetic characteristics. The experimental results showed that the alloy exhibited a much improved activation performance as well as electrochemical capacity after 2 hours milling. Cyclic voltammetry and electrochemical impedance experiments also showed that ball-milling of the alloy with Co3Mo could improve the surface activation property to a great extent. This can be attributed to the catalytic effect of Co3Mo, which had a much closer contact to the alloy powders after ball-milling, on the hydrogen oxidation. However, long time milling could decrease the capacity gradually due to the further amorphization of the ahoy.

[21] MG2NI-BASED HYDROGEN STORAGE ALLOYS FOR METAL HYDRIDE ELECTRODES
Chen J. Yao P. Bradhurst DH. Dou SX. Liu HK. - Journal of Alloys & Compounds. 295:675-679, 1999
Mg2-xMxNi (M=Ti, Ce; X=0, 0.1, 0.2) and MgNi1-yNy (N=Mn, Co; y=0, 0.1, 0.2) were prepared by a powder metallurgical sintering technique. The effects of the element substitutions and the ball-milling of the alloy, with or without nickel powder, on the alloy properties were investigated by X-ray diffraction, transmission electron microscopy and the Malvern particle size analyser. Three types of alloys, un-ball-milled, ball-milled without nickel powders and ball-milled with the addition of nickel powders, were used as the active material of metal hydride electrodes. Electrochemical measurements show that ball-milling the alloy with or without nickel powders is an effective method for increasing the discharge capacity and cycle life of the alloy electrode because of the changed phase structure and surface behaviour.

[20] IMPROVEMENT OF THE ELECTROCHEMICAL PROPERTIES OF ZR-BASED AB(2) ALLOYS BY AN ADVANCED FLUORINATION TECHNIQUE
Liu BH. Li ZP. Higuchi E. Suda S. - Journal of Alloys & Compounds. 295:702-706, 1999
An advanced fluorination technique has been developed for improving the electrochemical, performances of Zr-based AB(2) alloys. During the procedure, alloys were ball milled in a complex fluoride solution. It was found that the electrode of the treated alloy exhibited excellent electrochemical performance. Its activation property and high-rate discharge capability were found to be satisfactory compared with the conventional AB(5)-based electrodes. The electrode demonstrated a significant decrease of the reaction resistance measured by an impedance spectrometric method. The F-treated alloy was found to give a larger specific surface area and to form a highly Ni-covered surface.

[19] PROPERTIES OF ZR0.5TI0.5V0.75NI1.25 ALLOY BALL-MILLED WITH NANOCRYSTALLINE LANI5 POWDER
Chen ZH. Huang KL. Huang PY. - Journal of Alloys & Compounds. 295:712-715, 1999
A type of composite powder was prepared by ball-milling Zr0.5Ti0.5V0.75Ni1.25 alloy with a small amount of (2.

wt%) nanocrystalline LaNi5 which was synthesized by mechanical alloying. SEM and EDX results show that the surface of Zr0.5Ti0.5V0.75Ni1.25 alloy was coated with fine nanocrystalline LaNi5 particles after ball-milling. Electrochemical measurement revealed that electrochemical activity of this composite powder was higher than that of as-cast Zr0.5Ti0.5V0.75Ni1.25 powder. The mechanism of this improvement was also discussed.

[18] PHASE TRANSFORMATION AND MAGNETIC PROPERTIES OF ND8FE84TI8 ALLOY DURING HDDR PROCESS

Cui BZ. Sun XK. Geng DY. Liu W. Zhao XG. Zhang HD. Sui YC. Liu JW. - Journal of Alloys & Compounds. 295:868-871, 1999

The effects of the hydrogenation-disproportionation-desorption-recombination (HDDR) process on the structure and the magnetic properties of the Nd8Fe84Ti8 alloy prepared by mechanical alloying (MA) and its nitride counterpart have been studied in detail. It has been found that Nd(Fe,Ti)(12)H-x is formed from. 300 degrees C to 550 degrees C. The disproportionation starts at 550 degrees C and is completed at 960 degrees C. The desorption and the recombination are almost synchronized. Nd(Fe,Ti)(7) is formed at 750 degrees C during the HDDR treatment. With increasing temperature of HDDR process, the metastable structure of TbCu7 type is gradually transformed into the structure of ThMn12 type. The intrinsic coercivity increases with increasing the temperature of HDDR process.

[17] REHBINDER'S PREDICTIONS AND ADVANCES IN MECHANOCHEMISTRY

Butyagin P. - Colloids & Surfaces A-Physicochemical & Engineering Aspects. 160(2):107-115, 1999

The results of studying the effect of mechanical action on reactivities of mixtures of powdered monoatomic crystals have been analyzed. The following idea has been discussed: when the dose of mechanical energy absorbed is commensurable with crystal energy, a dynamic equilibrium between disordering and spontaneous regeneration of crystalline structure is established. Under these conditions, amorphous and nanocrystalline structures are formed in individual substances and in their mixtures deformational mixing occurs and metastable products of synthesis are produced. The energy consumption in the syntheses amounts to hundreds of KJ mol(-1) to tens of MJ mol(-1). Both chemical and mechanical factors determine the energy input and the synthesis kinetics in mixtures of solids. The Rehbinder effect and the energy released significantly decrease the energy expenditure. Mechanical properties of components of a mixture manifest themselves in dissolution of a hard component in a soft one and in mutual dissolution of components similar in the properties.

[16] TRANSMISSION ELECTRON MICROSCOPY STUDIES ON CARBON MATERIALS PREPARED BY MECHANICAL MILLING

Salver-Disma F. Tarascon JM. Clinard C. Rouzaud JN. - Carbon. 37(12):1941-1959, 1999

The effects of mechanical milling on the multiscale organization (structure and microtexture) of various carbon materials were investigated by means of Transmission Electron Microscopy. We show that mechanical grinding generates an increasing amount of disordered carbon at a rate depending on the type of grinding mode used (shear- or shock-type grinding). When the shock-type grinding is used, the triperiodic structure and the lamellar microtexture of the graphite completely break down to give microporous and turbostratic carbons made of misoriented nanometric Basic Structural Units (BSUs). Graphite grinding permits the elaboration of disordered carbons. The involved mechanism is different from a simple reverse graphitization, since not only structure but also microtexture are strongly modified by the grinding. After heat treatment at 2800 degrees C, the graphite organization is not recovered, and a mesoporous turbostratic carbon is mainly obtained. All the carbon precursors studied, submitted to strong grinding, leads to similar microporous carbons. Shear grinding is less effective since remnants of graphitic carbon are still present within the disordered carbon.

[15] "CRYOMILLING OF AL / ALN POWDERS"

C. Goujon, P. Goeuriot, M. Chedru, J. Vicens, JL Chermant, F. bernard, JC Niepce, P. Verdier, Y. Laurent - Powder Technology 105 (1999) 328 - 336

Elemental powders of 80 vol% 5000 Al - alloy (3 wt% Mg) and 20 vol. % AlN were milled in different mechanical conditions and at three different temperature (in liquid nitrogen (cryomilling), low temperature (about - 50°C) and room temperature). The effects of these parameters on the milling efficiency of Al and AlN and on the mechanical alloying were investigated. The cryomilling of both Al and AlN resulted in a rapide decrease in size of the coherently diffracting domains (< 50 nm). However, a good homogeneity of the mixture was obtained only after 6 h of milling. The differential scanning calorimeter (DSC) measurements and the EDS analyses have shown that mechanical alloying of the Al - 3 wt% Mg alloy had occured. The absence of variation of the Al lattice parameter, measured by X - ray diffraction (XRD) , is interpreted as a conscquence of Fe diffusion from the milling balls into the Al matrix.

[14] IN-SITU EXPLOSIVE FORMATION OF NBSI2-BASED NANOCOMPOSITES BY MECHANICAL ALLOYING

Fan GJ. Quan MX. Hu ZQ. Eckert J. Schultz L. - Scripta Materialia. 41(11):1147-1151, 1999

[13] IN-SITU TIME RESOLVED X-RAY DIFFRACTION STUDY OF THE FORMATION OF THE NANOCRYSTALLINE NBAL3 PHASE BY MECHANICALLY ACTIVATED SELF-PROPAGATING HIGH-TEMPERATURE SYNTHESIS REACTION

Gauthier V. Bernard F. Gaffet E. Josse C. Larpin JP. - Materials Science & Engineering A-Structural Materials Properties Microstructure & Processing. 272(2):334-341, 1999

The mechanically activated self-propagating high-temperature synthesis (MASHS) technique was used to produce a NbAl3 intermetallic compound. This process results from the combination of two steps: a mechanical activation of the Nb + 3Al powder mixture which is followed by a self-propagating high-temperature synthesis (SHS) reaction, induced by the exothermal character of the reaction Nb + 3Al. An original experiment was designed to study in-situ the formation of the NbAl3 phase in the combustion front: time-resolved X-ray diffraction coupled with an infrared imaging technique and a thermocouple measurement were performed to monitor the structural and thermal evolution during the SHS reaction. Owing to the temporal resolution of 100 ms between two consecutive diffraction patterns, it was possible to observe several steps before obtaining the niobium aluminide compound. Indeed, the phase transformations corresponding to the aluminum melting plateau, the subsequent temperature increase to the ignition temperature, and the fast reaction between niobium and molten aluminum at such a temperature were well-identified.

The NbAl3 intermetallic compound resulting from the MASHS process is nanostructured.

[12] MECHANOCHEMICAL SYNTHESES OF TITANIUM CARBIDE, DIBORIDE AND NITRIDE

Kudaka K. Iizumi K. Sasaki T. - Nippon Seramikkusu Kyokai Gakujutsu Ronbunshi-Journal of the Ceramic Society of Japan. 107(11):1019-1024, 1999

TiC and TiB2 powders were mechanochemically synthesized from powder mixtures of elemental Ti-C (atomic ratio 1 : 1) and Ti-B (1 : 2) in 34 h 45 min and 15 h 10 min, respectively, in a planetary ball mill using tungsten carbide balls. TiN powder was also mechanically synthesized from titanium powder for 60 h in a high-energy horizontal rotary ball mill (steel balls) equipped with a nitrogen gas how system. The as-milled mixed powders have been characterized as a function of the milling time by means of X-ray diffraction, scanning electron microscopy and X-ray fluorescence spectroscopy. The reaction processes for TiC and TiB2 formation were initiated by mechanically induced solid-state diffusion in the induction period when carbon or boron atoms diffused into titanium, and a small amount of TiC or TiB2 was formed by solid-state diffusion until a mechanically induced self-propagating reaction occurred. The reaction process for TiN formation proceeded via the surface reaction of titanium particles with molecular nitrogen and the mechanically induced solid-state diffusion of nitrogen atoms into titanium. The lattice parameters obtained for TiC, TiB2 and TiN agree with previously reported measurements.

[11] PROTON TRANSFER IN SOLID STATE: MECHANOCHEMICAL REACTIONS OF IMIDAZOLE WITH METALLIC OXIDES

Fernandez-Bertran J. Castellanos-Serra L. Yee-Madeira H. Reguera E. - Journal of Solid State Chemistry. 147(2):561-564, 1999

Mechanochemical reactions of crystalline imidazole with 23 metallic oxides have been studied by milling in a mortar and in ball mill vibrators of low and high mechanical intensity. The reactions were monitored by Fourier transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD) techniques. ZnO, HgO, Ag2O, and Cu2O react rather readily in the mortar, forming the corresponding imidazolates but CdO, Ga2O3, and In2O3 require intense mechanical milling to transform. CuO and NiO do not react immediately but turn bluish after a few months of aging. The oxides of Mg(II), Ca(II), Be(II), Al(III), Fe(II), Co(II), Co(III), Pb(II), Eu(III), Ce(III), Bi(III), Ti(IV), Zr(IV), and Sn(IV) are inert to imidazole even on strong milling for several hours.

[10] SOLID-STATE MECHANOCHEMICAL SYNTHESIS OF FERROCENE

Makhaev VD. Borisov AP. Petrova LA. - Journal of Organometallic Chemistry. 590(2):222-226, 1999

Solid-state mechanochemical reactions of iron(II) chloride with cyclopentadienides of alkaline metals or thallium? which lead to the formation of ferrocene, were studied. The dependence of the yield of the product on the parameters of mechanical loading for the reaction with cyclopentadienylthallium was determined.

[9] MECHANOCHEMICALLY SYNTHESIZED NBC CERMETS: PART. I. SYNTHESIS AND STRUCTURAL DEVELOPMENT

Murphy BR. Courtney TH. - Journal of Materials Research. 14(11):4274-4284, 1999

The mechanochemical synthesis of NbC-based cermets is described. Nanocrystalline NbC is synthesized by room-temperature milling of Nb and graphite (or hexane) mixtures. While some structural coarsening occurs during powder consolidation to full density, a nanoscale structure is maintained. Grinding media wear occurs during milling, and milled powders contain Fe from this abrasion. This phase, homogeneously distributed in milled powders, segregates during consolidation and heat treatment, and a cermetlike microstructure results. Copper added to the powder charge yields NbC-Cu or NbC-Cu-Fe cermets. Copper-containing materials have different phase morphologies. In particular, relatively large NbC particles are dispersed in a matrix containing finer NbC and metal particles. Higher Cu-content materials also develop a pure Cu constituent on heat treatment. A companion paper, "Mechanochemically synthesized NbC cermets: Part II. Mechanical properties," addresses aspects of the mechanical behavior of these materials.

[8] FABRICATION OF (BA,PB)TIO3-BASED TAPES WITH POSITIVE TEMPERATURE COEFFICIENTS OF RESISTIVITY BY THE OXIDATION OF MALLEABLE, METAL-BEARING PRECURSORS (THE VOLUME IDENTICAL METAL OXIDATION PROCESS)

Allameh SM. Sandhage KH. - Journal of Materials Research. 14(11):4319-4328, 1999

The feasibility of producing (Ba,Pb)TiO3-based thermistor tapes by the oxidation of malleable, metal-bearing precursors has been demonstrated. Intimate Ba-Pb-Ti-TiO2-bearing powder mixtures, produced by high-energy vibratory milling, were packed within a fugitive metal can and then compacted and formed into tapes of uniform thickness by cold drawing and rolling. The tape-shaped precursors were oxidized and converted into (Ba,Pb)TiO3-based tapes with a series of heat treatments at less than or equal to 1120 degrees C. With proper control of thermal treatments and chemical additions (Sb2O3 + MnO2 dopants), positive-temperature-coefficient-of-resistivity thermistors were produced that exhibited significant increases in resistivity commencing at temperatures greater than or equal to 350 degrees C.

[7] NEUTRON AND IN SITU X-RAY INVESTIGATION OF HYDROGEN INTAKE IN TITANIUM-BASED CUBIC ALLOYS

Blouin M. Schulz R. Bonneau ME. Bercier A. Roue L. Guay D. Swainson IP. - Chemistry of Materials. 11(11):3220-3226, 1999

The structure of nanocrystalline Ti:Ru:Fe (2 - gamma:(1 + gamma)/2:(1 + y)/2) obtained by high-energy ball milling has been studied by X-ray and neutron diffraction as a function of the Ti content, for gamma varying from 0.00 to 1.00 by step of 0.25, using Rietveld refinement; analysis. When gamma = 0.00, a nanocrystalline metastable B2 cubic phase is formed, with most of the la site occupied by Ti atoms and the Ib site occupied by either Fe or Ru atoms. When decreasing the Ti content, the B2 structure becomes less stable. A preferential replacement of Ti by Fe on the la occurs and leads to the precipitation of hcp Ru. In situ X-ray diffraction measurements under hydrogen at high pressure were also made. In all cases, a shift of the diffraction peaks of the B2 structure toward the smaller 2 theta values was observed. This shift is totally reversible upon removing hydrogen. It indicates that hydrogen is absorbed into the materials. The volume increase of the B2 structure varies according to the Ti content, reflecting the fact that less hydrogen is absorbed when Ti is reduced. Assuming that the volume occupied by a single hydrogen atom is

similar to 2.5 D-3, the hydrogen content; of the various nanocrystalline Ti:Ru:Fe (2 - gamma:(1 + gamma)/2:(1 + gamma)/2) is calculated from the volume increase of the unit cell of the corresponding materials.

[6] INFLUENCE OF POST PROCESSING ON THE MECHANICAL PROPERTIES OF INVESTMENT CAST AND WROUGHT CO-CR-MO ALLOYS

RM Berlin, LJ Gustavson, KK Wang - COBALT - BASE ALLOYS FOR BIOMEDICAL APPLICATIONS (Series: AMERICAN SOCIETY FOR TESTING AND MATERIALS SPECIAL TECHNICAL PUBLICATION), 1999, Vol 1365, pp 62-70

The mechanical properties of investment cast Co-Cr-h lo ahoy (American Society for Testing and Materials F 75) can be affected to varying degrees by post cast processes such as solution treating (ST), hot isostatic pressing (HIP), sintering used to apply porous coatings, repair welding abrasive blasting and laser marking. The mechanical properties of the wrought version of the alloy (American Society for Testing and Materials F 1537) can be influenced by mill practices. Thermo-mechanical processing such as forging, will change the properties of mill products depending on forging practices. Post forging processes such as abrasive blasting and laser marking can affect the mechanical properties to varying degrees. Testing has shown that abrasive blasting has no significant effect on either alloy. Laser marking can reduce the fatigue strength of both alloys. Sintering the cast alloy will reduce the fatigue strength and that HIP will improve the fatigue strength of the sintered cast alloy. Also, the cast alloy can be repair welded with no loss in tensile properties.

[5] ON THE IMPACT DYNAMICS OF A VIBRATION ROD MILL -

SL Wang, XQ Yang, JG Li - INTEGRATING DYNAMICS, CONDITION MONITORING AND CONTROL FOR THE 21ST CENTURY - DYMAC 99, 1999, pp 465-470 - KeyWords Plus 1ST INTERNATIONAL CONFERENCE ON THE INTEGRATION OF DYNAMIC, MONITORING AND CONTROL (DYMAC 99); MANCHESTER, ENGLAND. SEPTEMBER 1-3, 1999

Impact characterized by variable mass is the most important dynamic performance of the vibration rod mill. A mathematical model of the vibration system is determined by the principal and subharmonic impact of the grinding media, consisted of balls or rods of different materials. The impact mass changes with time and space. In the time domain, it swings both positively and negatively. In other words, the impact acts on the system not only as an excitation, but also as damping. Which effect prevails, depends on the operation parameters of the machine, especially on the vibrating amplitude. The changing rate of the impact mass is proportional to the exciting frequency.

[4] MECHANICAL ALLOYING OF TI-47AL-3CR(AT%) AND TIH2-47AL-3CR (AT%) USING A ZOZ ATTRITOR

S Ozbilen, C Cetinkaya - POWDER MATERIALS: CURRENT RESEARCH AND INDUSTRIAL PRACTICES, 1999, pp 59-69 - INTERNATIONAL SYMPOSIUM ON POWDER MATERIALS - CURRENT RESEARCH AND INDUSTRIAL PRACTICES AT THE 1999 TMS FALL MEETING; CINCINNATI, OHIO. OCTOBER 31-NOVEMBER 4, 1999

Not only morphological evolution of powder mixture particles during horizontal rotary ball milling of elemental ductile-prealloyed ductile (a mixture of acicular Ti + high pressure Ar atomised prealloyed 47Al-3Cr powder mixture) and brittle intermetallic prealloyed ducti le (a mixture of acicular TiH2 + Ar atomised prealloyed 47Al-3Cr spheroidal powder mixture) ternary component materials systems with a Zoz attritor were investigated but also the possibility of obtaining particles of above ternary systems with an average 10 mu m particle size with low contamination rate and short MA times by especially paying attention to the ductility of component powders. For this purpose, crystal structure change during MA was studied by XRD and confirmed by SEM work. It was found that, in 6 hours of MA time with Zoz attritor, 25-30 mu m powder is yielded with no contamination in Ti+Al-Cr ducti le-ductile system while it was 10-15 mu m for brittle-ductile (TiH2+Al-Cr) ternary component materials system due to the existance of the TiH2 brittle component in the as mixed powder. The morphological evolution in this system during Zoz attrition was also observed somewhat different from the ductile-ductile one. In Ti+Al-Cr and TiH2+Al Cr systems during MA of up to 6 hours under Ar with a Zoz attritor alloying took place as confirmed by XRD work resulting in Ti(Al) and TiH2(Al) solid solution formations, respectively, with some free Al and Cr still present in the structure.

[3] COMBINED MECHANICAL ALLOYING AND CONTROLLED COMBUSTION SYNTHESIS IN THE TIH2-B SYSTEM

S Ozbilen, A Gullu - POWDER MATERIALS: CURRENT RESEARCH AND INDUSTRIAL PRACTICES, 1999, pp 159-170 - INTERNATIONAL SYMPOSIUM ON POWDER MATERIALS - CURRENT RESEARCH AND INDUSTRIAL PRACTICES AT THE 1999 TMS FALL MEETING; CINCINNATI, OHIO. OCTOBER 31-NOVEMBER 4, 1999

Combined unreactive mechanical alloying and controlled combustion synthesis (CS) was carried out in the TiH2-B system Samples with different compositions (sample #1: 82wt%TiH2-18wt%B, sample #2:41wt%TiH2-41wt%Ti-18wt%B, sample #3:82wt%Ti-18wt%B) were studied to investigate the influence of the particle size of reactants on the degree of conversion of the self-propagating reactions together with the other effects of mechanical alloying (MA) on CS technique. In the first step mixtures of samples #1 to #3 were converted into fine, crystalline forms without compound formation. For this purpose, unreactive mechanical alloying for up to 8 hours of time under Ar with forced air cooling to keep the temperature at room temperature were utilised. Mechanically alloyed powder samples were then examined by XRD and SEM study. Mixed, unreactively mechanically alloyed and then cold compressed pellets of samples #1-#3 (green compacts) were subsequently combustion synthesized in controlled fashion mode under vacuum to develop Ti-boride compounds formation (TiB and TiB, depending on the composition). Thermal analysis under vacuum by Differential Thermal Analysis (DTA) was carried out on the green compacts. XRD and SEM investigation were used for the examination of unreactively mechanically alloyed, cold-pressed, and as-reacted pellets via CS. It was observed that the degree of conversion of the CS reactions can be increased when the amount of the activated, fresh surfaces of diluent Ti created by TiH2 decomposition during heating of the samples under vacuum is increased by using finer TiH2 particles obtained by mechanical alloying leading to the creation of more activated Ti surface in sample #1 compared to sample #3 thus promoting the better kinetics conditions (i. E., faster CS reactions) for chemical reactions, especially in sample #1 for it has the highest TiH2 content (82wt%) among the samples

studied.

[2] TITANIUM-TITANIUM NITRIDE MMC'S BY REACTIVE MECHANICAL ALLOYING

S Ozbilen, C Cetinkaya - POWDER MATERIALS: CURRENT RESEARCH AND INDUSTRIAL PRACTICES, 1999, pp 187-195 - INTERNATIONAL SYMPOSIUM ON POWDER MATERIALS - CURRENT RESEARCH AND INDUSTRIAL PRACTICES AT THE 1999 TMS FALL MEETING; CINCINNATI, OHIO. OCTOBER 31-NOVEMBER 4, 1999

Reactive mechanical alloying (RMA) of TiH2 (sample #1), 50 wt%Ti-50 wtPb TiH2 (sample #2) powder mix and mechanical alloying (MA) of Ti (sample #3) powder mix for 10 uninterrupted hours with sealed vial was carried out under nitrogen. This was followed by annealing of MA'ed powders under N-2 atmosphere to 950 degrees C for thermal treatment to determine if nitrides are forming. Representative samples of each powder mix subjected to reactive mechanical alloying and thermal treatment were characterised by XRD using Cu K alpha radiation and examined by Cambridge ST40 Stereoscan SEM operating under 25kV to determine morphology and crystal structure change of the powders. It is observed that RMA under N-2 cause to the formation of TiN in all the samples studied. Annealing under N-2 atmosphereto 950 degrees C for I hour leads to the formation of Ti-TiN-Ti2N multi-phase material in samples #1 and #2 (with different rations); to that of Ti-TiN composite material in sample #3. This shows that sintering of the MA'ed powders of TiH2, Ti-TiH2 and Ti is a promising way for producing ultrafine grained titanium-titanium nitride composite materials with RMA processing under N-2 atmosphere.

[1] SEM INVESTIGATION OF THE MORPHOLOGICAL CHANGES DURING MECHANICAL MILLING AND ALLOYING OF SINGLE OR BINARY COMPONENT MATERIALS SYSTEMS USING A ZOZ HORIZONTAL ROTARY MILL

S Ozbilen, M Erdogan - POWDER MATERIALS: CURRENT RESEARCH AND INDUSTRIAL PRACTICES, 1999, pp 197-210 - INTERNATIONAL SYMPOSIUM ON POWDER MATERIALS - CURRENT RESEARCH AND INDUSTRIAL PRACTICES AT THE 1999 TMS FALL MEETING; CINCINNATI, OHIO. OCTOBER 31-NOVEMBER 4, 1999

A characteristic change in particle morphology during horizontal rotary ball milling at the onset of second stage of milling of different materials systems having different combination of elemental powder ductility, i. E., ductile (He atomised Al powder, Cu powder gas atomised under N-2, Ti powder) ductile to brittle (air atomised Al powder, TiAl(delta) powder, Mg powder produced under low and high pressure He) and brittle (TiH2 powder and Ar atomised Al-Li powder) one and ductile-ductile (Ar atomised Ti and Al powder mixture, Ar atomised Ti and air atomised Al powder mixture), ductile-brittle (TiH2 and Ar atomised Al powder mixture, TiH2 and dendritic Al powder mixture, and TiH2 and Ti powder mixture) and brittle-brittle (TiH2 and B powder mixture) two component powder mixtures with Zoz attritor were investigated on the basis of microscopic observations by SEM and particle sizing by Laser sizer for microstructural evolution. The results from SEM investigation and particle sizing show that the process of mechanical mi Iii ng of one component and mechanical alloying of two component powder mixtures are quite different for each system, depending on the ductility of the component powders.

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