

International Review of Physics (IREPHY)

Contents:

A Simple General Solution of the Radial Schrödinger Equation for Spherically Symmetric Potentials and Some Applications <i>by H. H. Erbil</i>	1
Overview of the ATLAS TileCal High Voltage DCS <i>by A. Elkarrim</i>	11
Effects of Atom-light Interaction Parameters on the Photonic Mean Numbers and Atomic Level Populations in the Interaction of Three Level Atoms with Classical and Coherent Fields <i>by B. Vaseghi, M. M. Golshan, A. Fallah Zadeh</i>	15
Vortex Flow and Frequency Mode Inside Different Cavities Interacting with Boundary Layer <i>by H. Khouloud, M. Bouterra, A. El Cafsi, A. Belgibib, F. Lusseyran, P. Gongat</i>	25
Materials Developed by Mechanical Alloying and Melt Spinning <i>by J. J. Suiñol, J. J. Fort</i>	31
Finite Element Method Analysis of the Behaviour of a Multilayered Screen Polarizer <i>by M. Lasca</i>	36
Crystalline Silicon Solar Cell on Ceramic Substrates Under Solar Concentration <i>by A. Cheknane, A. Chaker, B. Benyoucef, H. S. Hilal</i>	42
Transitions in S XI, Cl XII, and Ar XIII <i>by W. O. Younis</i>	46
ESR Dating of Laterite from Muang Sing Historical Park, Kanchanaburi, Thailand <i>by S. Limsuwan, T. Vichaidid, W. Onreabroy</i>	64
Finite Element Method for the Prediction of Magnetic Fields and Losses in Three Phase Underground SF6 Insulated Cables <i>by S. Sadeghi, M. Jalalifar, A. H. Isfahani</i>	69



Praise Worthy Prize

International Review of Physics (IREPHY)

Managing Editor:

Santolo Meo
Department of Electrical Engineering
FEDERICO II University
21 Claudio - I80125 Naples, Italy
santolo@unina.it

Editorial Board:

Vladimir M. Agranovich	(U.S.A)	University Of Texas At Dallas – Nano Tech. Institute
Anastasios Anastasiadis	(Greece)	National Observatory of Athens
Jean-Pierre Badiali	(France)	Université Pierre et Marie Curie
Marcia C. Barbosa	(Brasil)	Universidade Federal do Rio Grande do Sul
Israel Felner	(Israel)	The Hebrew University - Racah Institute of Physics
Peter Hanggi	(Germany)	University of Augsburg - Institute of Physics
Hans Herrmann	(Brasil)	Universidade Federal do Ceará - Departamento de Física
Joshua Jortner	(Israel)	Tel Aviv University – School of Chemistry
Vladimir G. Kadyshevsky	(Russia)	Joint Institute for Nuclear Research
Yuri Kozitsky	(Poland)	Maria Curie-Sklodowska University, Lublin
Jukka Maalampi	(Finland)	Department of Physics - University of Jyväskylä
Dorin Poenaru	(Romania)	H. H. National Institute of Physics & Nuclear Engineering
Kestutis Pyragas	(Lithuania)	Semiconductor Physics Institute
Antoni Rogalski	(Poland)	Military University of Technology - Institute of App. Physics
Padma K. Shukla	(Germany)	Universitaet Bochum - Fakultae fuer Physik und Astronomie
Gowind Swarup	(India)	National Centre for Radio Astrophysics
Hugo Thienpont	(Belgium)	Vrije Universiteit Brussel
Sergey Vladimirov	(Australia)	University of Sydney - School of Physics
Christian Von Ferber	(U.K.)	Coventry University - Applied Mathematics Research Centre
Miki Wadati	(Japan)	University of Tokyo - Department of Physics
Xin-Nian Wang	(U.S.A)	Lawrence Berkeley National Laboratory

The *International Review of Physics (IREPHY)* is a publication of the **Praise Worthy Prize S.r.l.**
The Review is published bimonthly, appearing on the last day of February, April, June, August, October, December.

Published and Printed in Italy by **Praise Worthy Prize S.r.l.**, Naples, February 29, 2008.

Copyright © 2008 Praise Worthy Prize S.r.l. - All rights reserved.

This journal and the individual contributions contained in it are protected under copyright by **Praise Worthy Prize S.r.l.** and the following terms and conditions apply to their use:

Single photocopies of single articles may be made for personal use as allowed by national copyright laws.
Permission of the Publisher and payment of a fee is required for all other photocopying, including multiple or systematic copying, copying for advertising or promotional purposes, resale and all forms of document delivery.
Permission may be sought directly from **Praise Worthy Prize S.r.l.** at the e-mail address:

administration@praiseworthyprize.com

Permission of the Publisher is required to store or use electronically any material contained in this journal, including any article or part of an article. Except as outlined above, no part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without prior written permission of the Publisher. E-mail address permission request:

administration@praiseworthyprize.com

Responsibility for the contents rests upon the authors and not upon the **Praise Worthy Prize S.r.l.**

Statement and opinions expressed in the articles and communications are those of the individual contributors and not the statements and opinions of **Praise Worthy Prize S.r.l.** **Praise Worthy Prize S.r.l.** assumes no responsibility or liability for any damage or injury to persons or property arising out of the use of any materials, instructions, methods or ideas contained herein.

Praise Worthy Prize S.r.l. expressly disclaims any implied warranties of merchantability or fitness for a particular purpose. If expert assistance is required, the service of a competent professional person should be sought.

Materials Developed by Mechanical Alloying and Melt Spinning

J. J. Suñol, J. J. Fort

Abstract – *Materials science is a multidisciplinary research topic related to the development of physics and technology. Mechanical alloying of ribbon flakes is a two steps route to develop advanced materials. In this work, a Fe based alloy was obtained using three pathways: mechanical alloying, melt-spinning and mechanical alloying of previously melt-spun samples. Processing conditions allow us to obtain amorphous or nanocrystalline structures. Furthermore, a bibliographic revision of mechanical alloying is here presented. Copyright © 2008 Praise Worthy Prize S.r.l. - All rights reserved.*

Keywords: *Mechanical alloying, Fe based alloys, XRD, DSC*

I. Introduction

One of the main fields concerning physics research is materials science. Materials science is a multidisciplinary research discipline involving physics, engineers and chemists. The history of the humanity is closely associated to the development of new materials. In fact, materials with a metastable structure (amorphous, nanocrystalline, extended solid solution) present interesting technological applications. Mechanical alloying (MA) and rapid solidification (RS) are two important routes to obtain amorphous or nanocrystalline alloys. The field of rapid solidification ($\sim 10^6$ K/s) of alloys from the liquid state started with Pol Duwez and coworkers successful rapid quenching experiments in 1960 [1]. In these experiments, an extended crystalline solid solution and an amorphous phase, the metallic glass $\text{Au}_{80}\text{Si}_{20}$, were obtained. One of the typical methods to develop alloys by rapid solidification is the melt-spinning (MS) technique. It is known that Fe-based alloys prepared by rapid solidification techniques in ribbon form can exhibit superior soft magnetic properties [2]. Nevertheless, ribbons not attain a more important level of applicability due to various shortcomings: the ribbon form, the limited alloy compositions (near deep eutectics) and the usually brittle behavior [3]. Recently, mechanical alloying of ribbons is applied as an alternative route to obtain powdered materials [4]-[5]. The MA of bulk amorphous or nanocrystalline metallic glasses may be a two-step procedure in the powder metallurgy industry. In principle, the MA alloys may be consolidated to any desired shape and form.

In this work, we present: a) an historical perspective and analysis of the MA technique and b) a comparison of three routes (MA, MS and MS+MA) to develop a Fe based alloy.

II. Mechanical Alloying

II.1. Historical Perspective

Mechanical alloying is a processing technique that allows alloys production starting from mixtures of elemental and/or compounds powders (flakes). During MA, a lamellar structure arises in the powders due to the cold welding and fracture of the particles. The MA process produces a refinement of the microstructure and an intimate mixing of the constituents that favors the formation of a metastable structure. MA was developed around 1966 by John Benjamin and coworkers at the Paul D. Merica Research Laboratory of the International Nickel Company (INCO) to produce a material combining oxide dispersion strengthening with gamma prime precipitation hardening in a nickel-based superalloy for gas turbine applications [6]-[7]. Initially, the process was referred to as milling or mixing. The first scientific article was "Dispersion strengthened superalloys by mechanical alloying" [8]. Nevertheless, this process was known 40 years earlier from the work of Hoyt, who reported coating of tungsten carbide, WC, with Co by ball milling. The term "mechanical alloying" was introduced by INCO in a patent [9].

MA has been utilized in several areas of materials processing and applied to obtain different materials, sometimes combined with consolidation techniques to develop bulk materials: oxide dispersion strengthened materials [10], intermetallics [11], nanomaterials [12], composites [13], ceramics [14], polymers [15], amorphous [16], hydrogen storage [17] and extended solid solutions [18]. As an example, Fig. 1 shows the solubility limits of several elements into Fe bcc structure at the equilibrium state and after MA process.

The recent status of MA has been reviewed in several works [9]-[19]-[20]. The MA and related topics literature available up to 2007 has been collected.

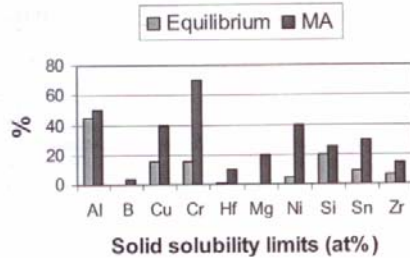


Fig. 1. Solid solubility limits of several elements in Fe [22-30]

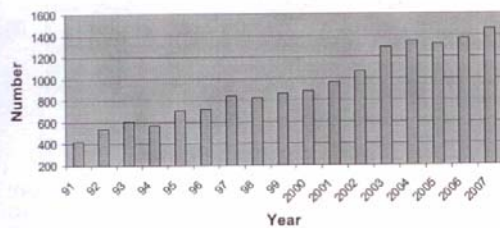


Fig. 2. Amount of publications concerning materials developed by mechanical alloying

Fig. 2 presents the growth of publications in the field of MA and related topics during the period 1990-2007 [21]. The article amount increases a factor three.

II.2. Milling Parameters

MA is a complex process which depends on many physical, chemical and geometrical factors. Those parameters affect the milling efficiency and the energy transfer. A detailed list must include the geometric and dynamic parameters of mill design, the character of motion of milling media, the physical and mechanical characteristics of milling media, the characteristics of processed substances, the mass ratio of milling balls to powder, the milling time, the temperature of the vial, the milling atmosphere, the selection of process control agents or the filling factor of the vial. The milling time (BPR) and the ball-to powder mass ratio (BPR) are the parameters usually given to characterize an experimental MA setup. It should be pointed that the use of different milling conditions and/or ball mills results in different reaction pathways. The milling intensity is a measure of the milling energy, which is directly proportional to the powder generated in the milling process. The modification of the milling conditions will strongly affect the way by which energy is transferred to the milled powder and, hence, the nature of final alloys. As an example, using other milling device, and milling alloys of similar composition can be obtained a nanocrystalline or an amorphous phase as main phase [31]. Fig. 3 shows the evolution of the crystalline size of a Fe based alloy using different milling intensity. A higher value of the

rotation speed (here given in r.p.m.) correspond to a higher milling intensity.

It is necessary to consolidate the nanocrystalline or amorphous materials developed by melt spinning to obtain bulk alloys for practical applications in the powder metallurgy or magnetic sectors. For it, an option is to mill ribbon flakes to produce a material with a like-powdered form. In this moment, consolidation of amorphous or nanocrystalline powders into bulk, full density compacts while retaining final nanoscale grain size is obviously a major challenge [32]. If the original material is amorphous, it can be easier to obtain a nanocrystalline material after consolidation. As an example, bulk amorphous and nanocrystalline FeZrNbB alloys were prepared by consolidating amorphous powders crushed from as-quenched ribbons [33].

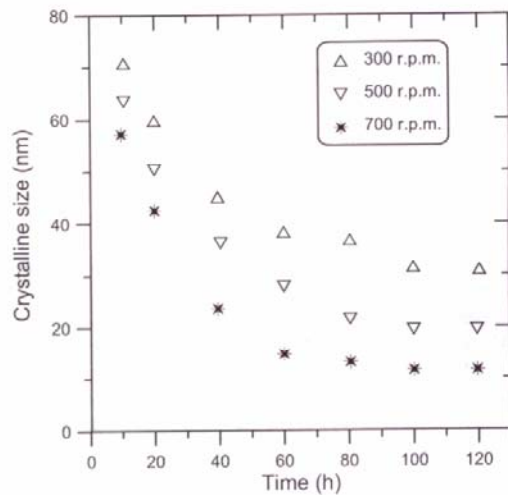


Fig. 3. Crystalline size versus milling time for different milling intensities

As increasing the milling time, the ribbon pieces were fractured, and the final form corresponds to a powdered-like material. Fig. 4 shows the percentage of alloy in ribbon form using a sieving method as a function of milling time. Results show a general diminution of the necessary milling time, considered as the lowest limit time at which powdered particles represents ≥ 95 wt.%, with the increase of the rotation speed. As expected, when increasing the total energy involved in the ribbon fracture, the limit time decreases. A lower milling time favors the technological reliability of this combined route. For ribbon flakes milled at 200, 300 and 400 r.p.m. the times were 24 h, 24 h and 8h, respectively. In previous works [34], only slight differences due to the ball-to-powder weight ratio were found.

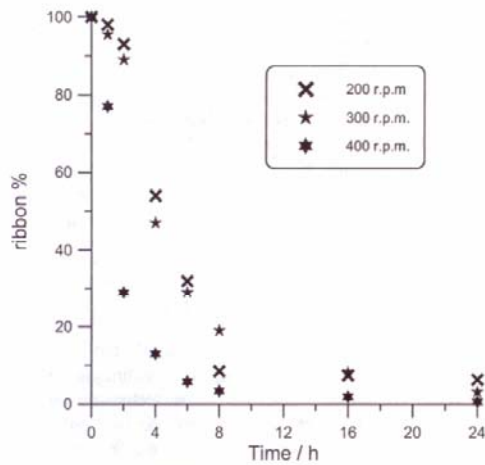


Fig. 4. Percentage of alloy in ribbon form as a function of milling time

III. Materials and Methods

The composition analyzed in this article is $\text{Fe}_{70}\text{Ni}_{10}\text{B}_{20}$. The alloy was produced directly by milling (MA alloy), by melt spinning (MS alloy) or by the combined route (MS + MA alloy). Milling (MA alloy) was performed in a planetary ball-mill (Fritsch Pulversitte P7) starting from pure element and compound powders (99.7%-purity Fe, with a particle size under $10\ \mu\text{m}$; 99.8%-purity Ni, with a particle size under $50\ \mu\text{m}$; and 99.6%-purity B, with a particle size of $50\ \mu\text{m}$). Powder was loaded into a cylindrical Cr-Ni stainless-steel vial together with balls of the same material in an argon atmosphere. The ball-to-powder ratio was 5:1. The milling process was performed at a speed of 700 r.p.m. at different milling times until 100 hours.

The Fe-Ni based alloy was also produced by melt-spinning (MS alloy). The precursors used were pressed powders of elemental Fe, Ni and B. The ribbon has a size of about 0.1 cm wide and $20\ \mu\text{m}$ thick. The molten alloy was quenched on the surface of a rapidly spinning (about 30 m/s) Cu wheel. The working atmosphere was inert, Ar. The ribbons ulterior milling was performed at 400 rpm during 10 hours (MS + MA alloy). Ribbons were cut into pieces about 0.5 cm large. The size reduction of the ribbons was followed by a sieving method after different milling times, using a $50\ \mu\text{m}$ sieve to control the percentage of original ribbon considered as well fractured or powdered-like.

The sample thermal characterization was carried out by differential scanning calorimetry (DSC) under an argon atmosphere in a Mettler-Toledo DSC30 device. The morphology and composition study was performed by scanning electron microscopy (SEM) in a Zeiss DSM960 A equipment coupled with energy dispersive X-ray microanalysis (EDX).

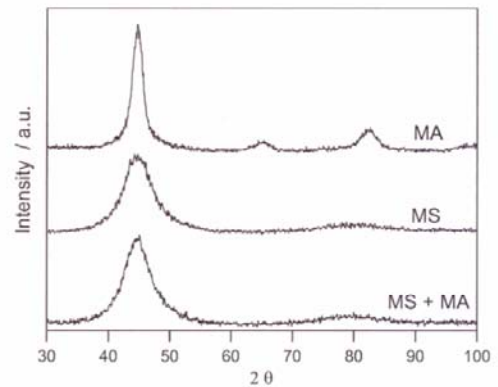


Fig. 5. XRD spectra corresponding to: as milled powders (MA), as quenched (MS) and as milled flakes (MS + MA)

The X-ray diffraction (XRD) patterns were carried out in Siemens D-500 equipment and the analysis of the patterns was performed by Rietveld refinement using MAUD software.

IV. Results and Discussion

Low contamination from the milling tools (< 1.35 at.%) was found by ICP and EDX in the milled alloys (MA and MS + MA). Furthermore, oxygen was detected probably due to the large surface area and the high reactivity of the fine particles. Likewise, MS alloy shows the same nominal composition after and before melt-spinning production. Similar results are reported in other Fe based alloys [35]. Fig. 5 shows the X-ray diffraction patterns of the alloy as quenched, the alloy as milled and the as milled ribbon. MS alloy show the typical halos of an amorphous structure. The same structure remains after flakes milling. The microstructure of MA alloy after 100 h milling is nanocrystalline, a bcc Fe solid solution, with a lattice parameter of $0.2865(3)$ nm and a crystallite size of 12.4 nm.

DSC measurements performed support the existence of a metastable structure as determined by XRD. Fig. 6 shows DSC scans performed at a heating rate of 10 K/min, for quenched and milled samples. One or two main exothermic processes were detected that are related to the structural relaxation (MA and MS + MA) and crystallization (all samples). The first process is shallow and broad. It is typical for a relaxation process and starts at about 425 K. A crystallization peak starts at high temperature. The crystallization process in the rapidly solidified samples produces a very sharp exothermic peak. Both, the onset temperature of the main peak and the crystallization enthalpy are comparatively higher for rapidly solidified sample than for samples MA, as expected since the last ones are powders with some remains of crystallinity.

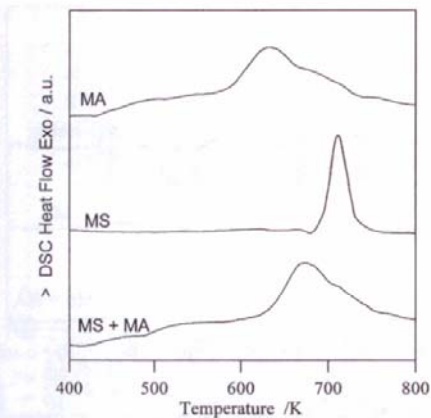


Fig. 6. DSC scans at 10 K/min of: as milled powders (MA), as quenched (MS) and as milled flakes (MS + MA)

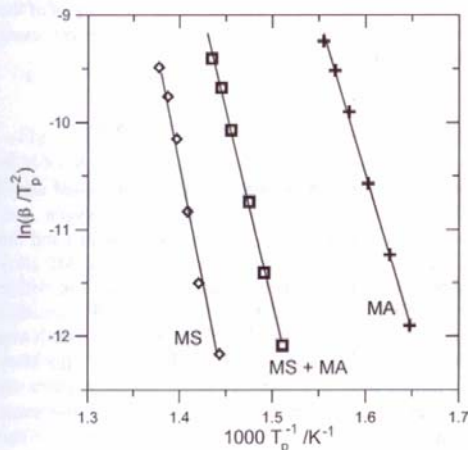


Fig. 7. Kissinger plots to determine the apparent activation energy of the crystallization process

The apparent activation energies of the crystallization process were calculated by the Kissinger's shift peak method [36]. For it, the samples were heated at different rates: $\beta = 2.5-5-10-20-40$ K min^{-1} . The value of the apparent activation energy, E , of the crystallization process are 241 ± 21 , 361 ± 32 and 298 ± 23 kJ/mol for alloys MA, MS and MS + MA respectively. The values obtained in other alloys were between 230 and 380 K/mol in MA samples, and between 320 and 690 K/mol in MS samples [37]-[38]. The apparent activation energy of the MA alloyed powders seems reasonable to be associated with a grain growth process in the nanocrystalline MA alloy and to nucleation plus crystalline growth in the amorphous alloy obtained by MS or by MS + MA.

The combination of higher activation energy and crystallization temperature is associated to a higher

thermal stability. In this work, the alloy produced by MA is nanocrystalline and the alloys produced by MS are amorphous. It is reasonable to expect that structure and properties could be different when using MA, MS or MA + MS methods [39]. Nevertheless, it is also possible to develop amorphous MA alloys by modifying milling conditions [40]. In this moment, it is possible to design advanced materials for specific applications by the combination method of melt-spinning and mechanical alloying [41].

V. Conclusion

In this work, we perform a brief bibliographic revision of mechanical alloying as a technique able to develop metastable materials. This technique can be combined with melt-spinning to obtain powdered materials. In our case, the same Fe-rich alloy was produced by three routes: mechanical alloying (MA), melt spinning (MS) and mechanical alloying of melt-spun sample (MS + MA). Different processing pathways produce alloys with different microstructure (amorphous or nanocrystalline) and thermal stability front crystallization.

Acknowledgements

Financial support from MICYT MAT2006-13925-C02-02 (FEDER) and DURSI 2005SGR-00201 projects is acknowledged.

References

- [1] W. Klement Jr et al, Non-crystalline structure in solidified gold-silicon alloys, *Nature* 186 (2005), 869-870.
- [2] J.S. Garitaonandia et al. Low-temperature magnetic properties of Fe nanograins in an amorphous Fe-Zr-B matrix, *Physical Review B*, 26-9 (2000), 6150-6155.
- [3] T.D. Shen et al, Soft magnetism in mechanically alloyed nanocrystalline materials, *Physical Review B* 72 (2005), 014431.
- [4] M. Pekala et al., Magnetic and structural studies of ball milled $\text{Fe}_{70}\text{B}_{10}\text{Si}_{20}$, *J. Non-Cryst. Solids*, 287 (2001), 380-384.
- [5] J.J. Suñol et al, Thermal and structural studies changes induced by mechanical alloying in melt-spun Fe-Ni based amorphous alloys, *Mater. Sci. Eng. A*, 375 (2004), 881-887.
- [6] J.S. Benjamin, Dispersion-strengthened electrical heating alloys by powder metallurgy. *US Patent US3 660 049*. May 2 (1972).
- [7] J.S. Benjamin. Powder metallurgical products. *British patent 1 298 944*. December 6 (1972).
- [8] J.S. Benjamin, Dispersion strengthened superalloys by mechanical alloying, *Metallurgical Transactions* 1(10) (1970), 2943.
- [9] C. Suryanarayana, Mechanical alloying and milling, *Progress in Materials Science* 46(1-2) (2001), 1-184.
- [10] C.F. Tang et al, Spark plasma sintering of ODS cobalt base alloy powder by mechanical alloying, *Rare Metal Materials and Engineering* 36 (2007), 1461-1464.
- [11] J.C. Crivello et al, Limits of the Mg-Al gamma-phase range by ball milling, *Intermetallics* 15 (2007), 1432-1437.
- [12] V. Chawla et al, State of the art: Applications of mechanically alloyed materials - A review, *Materials and Manufacturing processes* 22 (2007), 469-473.

- [13] V.V. Cherdynstev et al, Structure and properties of mechanically alloyed composite materials Al/Al-Cu-Fe quasicrystal, *Physics of Metals and Metallography* 104 (2007), 497-504.
- [14] M. Krasnowski et al, Nanocrystalline FeAl-TiN composites obtained by hot-pressing consolidation of reactively milled powders, *Scripta Materialia* 57 (2007), 553-556.
- [15] M. Karttunen et al, Electrically conductive composite powders and compounds produced with solid state synthesis, *Materials and Manufacturing processes* 20 (2005), 887-892.
- [16] S. Sharma et al, Mechanical crystallization of Fe-based amorphous alloys, *Journal of Applied Physics* 102 (2007), 083544.
- [17] E.Y. Lee et al, Synthesis of composite Mg-Ni-Ca metal hydride by mechanical alloying, *Journal of Alloys and Compounds* 446 (2007) 129-133.
- [18] Y. Ueda et al, Magnetoresistance and Magnetism in Fe-Cu alloys produced by electrodeposition and mechanical alloying methods, *Mater. Sci. Eng. A*, 217 (1996), 371-375.
- [19] C. Suryanarayana et al, The science and technology of mechanical alloying, *Mater. Sci. Eng. A* 304 (2001), 151-158.
- [20] Murthy B.S. et al. Novel materials synthesis by mechanical alloying/milling. *International Materials Reviews* 1998, 43(3) 101-141.
- [21] www.isinet.com, 15/02/2008.
- [22] H. Schropf et al, Ordering versus disordering tendencies in mechanically alloyed (Ni,Fe_{1-x}) Al alloys, *Scripta Metallurgica and Materialia*, 30 (1994), 1569-1574.
- [23] R.J. Pérez et al, Thermal stability of nanocrystalline Fe-10 wt.% Al produced by cryogenic mechanical alloying, *Nanostructured Materials*, 7 (1996), 565-572.
- [24] C. Stiller et al, The influence of alloy composition and thermal treatment on structural and magnetic properties of mechanically alloyed Fe-Transition metal-based alloys, *Metastable, Mechanically Alloyed and Nanocrystalline Materials*, 225 (1996), 695-700.
- [25] T. Koyano et al, Mechanical alloying process of Fe-Cr powders studied by magnetic measurements, *Journal of Applied Physics*, 73 (1993), 429-433.
- [26] N. Kataoka et al, Magnetic properties of iron-base bcc alloys produced by mechanical alloying, *Journal of Materials Science*, 26 (1991), 4621-4625.
- [27] A. Hightower et al, Mechanical alloying of Fe and Mg, *Journal of Alloys and Compounds*, 252 (2007), 238-244.
- [28] S.K. Xia et al, Phase segregation in mechanically alloyed Invar Fe-Ni alloys, *Metastable, Mechanically Alloyed and Nanocrystalline Materials*, 225 (1996), 453-457.
- [29] M. Abdellaoui et al, Far from equilibrium crystalline to amorphous phase-transition induced by mechanical alloying in the Fe-Si system, *Journal de Physique IV*, 2 (1992), 73-78.
- [30] A.F. Cabrera et al, Mechanical alloying of iron and tin powders: A Mössbauer study, *Metastable, Mechanically Alloyed and Nanocrystalline Materials*, 179 (1995), 231-235.
- [31] S. Suriñach et al, Preparation of Fe-Ni based metal-metalloid amorphous powders by mechanical alloying, *Mater. Sci. Eng. A* 182 (1994), 1285-1290.
- [32] N.E.Fenineche et al, Structure and magnetic properties of nanocrystalline Co-Ni and Co-Fe mechanically alloyed, *Materials Letters* 27 (2003), 4165-4169.
- [33] J. Eckert et al, Nanostructure formation and properties of ball-milled NiAl intermetallic compound, *Mater. Sci. Eng. A* 240 (1997), 619-624.
- [34] J.J. Suñol et al, Development of Fe based nanocrystalline materials by mechanical alloying, *Revista de Metalurgia* (2008). *In press*.
- [35] J.J. Suñol et al, Thermal and structural changes induced by mechanical alloying in melt-spun Fe-Ni based amorphous alloys, *Mater. Sci. Eng. A* 375 (2004), 881-887.
- [36] H.E. Kissinger, Reaction kinetics in differential thermal analysis. *Analytical chemistry*, 29 (1957), 1702-1706.
- [37] J.J. Suñol et al, Mechanically induced thermal changes in amorphous metallic melt-spun alloys, *Materials Letters*, 57 (2003), 4222-4226.
- [38] J.J. Suñol et al, Comparison of Fe-Ni-P-Si alloys prepared by ball milling, *J. Non-Cryst. Solids*, 287 (2001), 114-119.
- [39] A. Grabias et al, Structure of the nanocrystalline Fe₄₁Ni₂₈Co₂₀Zr₇B₁₂ alloy formed by ball milling, *Journal of Alloys and Compounds*, 434 (2007), 493-496.
- [40] R. Bråting et al, A comparison between the thermal properties of Ni-Zr amorphous alloys obtained by mechanical alloying and melt-spinning, *Mater. Sci. Eng. A*, 97 (1988), 317-320.
- [41] L.J. Chang et al, Synthesis of the magnesium-based nano/amorphous composite alloy powder by the combination method of melt-spinning and mechanical alloying, *Key Engineering Materials*, 313 (2006), 97-103.

Authors' information

Dept. Physics,
Girona University,
17071 Girona,
Spain.
E-mails: joanjosep.sunyol@udg.edu (GRMT)
joaquim.fort@udg.edu (GSC)



Joan Josep Suñol (Barcelona, 1965) got his B. Sc. in Physics at the University of Barcelona (Spain); a M. Sc. in Physics at the Autonomous University of Barcelona (Spain) in 1993; and his Ph. D. in Physics at the Autonomous University of Barcelona in 1996.

He has published in leading Physics and Materials Science journals, including Applied Physics Letters, Journal of Applied Physics and Acta Materialia. His worked has dealt with materials science, thermal analysis and recently with complex systems.

Dr. Suñol is member of: the Royal Spanish Physics Society and the Spanish Committee of the European Powder Metallurgy Association.



Joaquim Fort (Madrid, 1966) got his B. Sc. in Physics at the University of Barcelona (Spain) in 1989; a M. Sc. in Physics at Tufts University, Boston, in 1991 and at the Autonomous University of Barcelona (Spain) in 1993; and his Ph. D. in Physics at the Autonomous University of Barcelona in 1997.

He has published in leading Physics journals, including Physical Review Letters and a review published in Reports on Progress in Physics in 2002. His worked has dealt with materials science as well as complex systems, including front propagation problems and their applications.