

Frontiers in Mechanochemistry and Mechanical Alloying



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Editors

Rakesh Kumar, Srinivasan Srikanth and Surya Pratap Mehrotra



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Rakesh Kumar  
Srinivasan Srikanth  
Surya Pratap Mehrotra

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A stylized, bold, italicized letter 'M' logo.

*Frontiers in Mechanochemistry and Mechanical Alloying*

is a compilation of papers received for publications in the proceedings of

VI International Conference on

Mechanochemistry and Mechanical Alloying (INCOME2008)

organised by CSIR-National Metallurgical Laboratory (CSIR-NML), Jamshedpur (India) during 1-4 December, 2008 under the aegis of International Mechanochemistry Association (IMA).

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## Foreword



**Prof. V.V. Boldyrev**

*Founder President  
International  
Mechanochemistry  
Association*

I am very happy, that the tradition of INCOME continues, and the sixth conference in the series, which like all previous meetings attracted large number of people from all over the world, was successfully held at National Metallurgical Laboratory, Jamshedpur, India during December 2008. To me, hosting of INCOME2008 in India was special – India represents a country of great thinkers and scientists which is developing presently very dynamically its industry and technology; a country which I respect and admire, and in which I always felt at home when I was younger and could travel. I find it as a very important sign that mechanochemistry has become popular in the most rapidly developing countries. I find it as an equally important sign that INCOME2008 was hosted in India, the country, where people always tried to understand the Nature and its phenomena very deeply. Mechanochemistry is not only a promising tool to solve practical problems, Mechanochemistry is a serious scientific discipline, which requires fundamental approaches and new ideas.

Since the first International Meeting on Mechanochemistry in the USSR in 1968, since the first INCOME organized by Klara Tkacova in Slovakia in 1993, Mechanochemistry has conquered the scientific world. It is no longer a Cinderella at the Party for other Sciences, it is no longer an Ugly Duckling Science – it has become a beautiful Swan. In my opening message to the INCOME2003 in Braunschweig I focused on three main problems, which I find the most important for the progress of mechanochemistry – paying proper attention to the fundamental aspects of research, developing various types of apparatuses specially adapted to different types of mechanical treatment required for different processes, educating and training people in the field of mechanochemistry. I am very happy that INCOME2008 touched upon some of these issues in a comprehensive and much focused way through the organization of a number of thematic sessions. It gives me great pleasure that the Indian colleagues have made an extra effort to publish the submitted papers in the form of a book, 'Frontiers in Mechanochemistry and Mechanical Alloying'. The thematic structure of the conference is retained in the book which I believe would certainly be helpful in identifying current trends and focus. The book, a useful compilation of papers, would serve as an important reference for the researchers and engineers in the field.

Novosibirsk,  
November 18, 2011

Vladimir Boldyrev



## Preface

Since the classical papers on mechanical activation of solids by Carey Lea over hundred years back (1893-94), mechanochemistry and mechanical activation has come a long way and evolved as a frontier area of research and applications in the last two to three decades. The cornerstones of the growth of this field have been enhanced fundamental understanding, widening of the spectrum of applications encompassing newer materials and processes and, design and development of new equipment and devices. The areas of applications of mechanochemistry have expanded exponentially and today it encompasses all facets of metallurgy, including metal extraction, alloying, composites, mechanical metallurgy, traditional and advanced ceramics processing, pharmaceuticals, utilization of wastes, energy and environment, and many more. The INCOME series of conferences initiated by the International Mechanochemistry Association [an associate member of International Union of Pure and Applied Chemists (IUPAC)] has served as a common platform to bring together all stakeholders from academia, Research and Development organizations, and industry to foster the growth of the discipline. The first international conference on 'Mechanochemistry and Mechanical Alloying (INCOME1993)' was held in Koásice (Slovakia) in 1993. This was followed by INCOME1997 in Novosibirsk (Russia), INCOME2000 in Prague (Czech Republic); INCOME2003, in Braunschweig (Germany), and INCOME2006 again in Novosibirsk.

The sixth conference in the series, INCOME2008, was held at Jamshedpur (India) during December 1-4, 2008. It is interesting to note that the perception about Mechanochemistry as a scientific discipline has changed over these years as reflected by the words of Prof. V.V. Boldyrev, the founding president of IMA ...

*"... It (mechanochemistry) is no longer a Cinderella at the Party for other Sciences, it is no longer an Ugly Duckling Science – it became (has become) a beautiful Swan...."*

and those of the current President, Prof. Mamoru Senna,

*"Are you confident to write a winning proposal with "mechanochemistry" as a central keyword?"...I personally feel to reconsider, how and why mechanical stressing on a particular set of materials is indispensable and valuable? Reply to this question can be and must be manifold"*

While there are genuine concerns in some cases, the fact also remains that stressing of solids is perhaps the only answer to novel processes and materials development in many cases. INCOME2008 stimulated interesting debate on several of these issues.

The hosting of the Conference in India was not a mere coincidence. In line with the international developments, in India, the activities in the area of mechanical alloying were initiated at Indian Institute of Science, Bangalore, nearly two to three decades ago, and later spread over to several other institutions covering important facets of the discipline. The National Metallurgical Laboratory at Jamshedpur has been the torch bearer for mechanochemistry at least since 2000, when a major programme on metal extraction processes and waste utilization/minimization strategies, requiring application of mechanical activation on a large scale, was taken up.



A marked deviation between INCOME2008 and the previous INCOMEs has been the introduction of thematic sessions. The sessions included: Mechanochemistry of Macromolecules and Applications in Pharmaceuticals, Nano-particle and Nano-composites, Advance Ceramics Science and Technology, Severe Plastic Deformation and Friction Stir Welding; Mechanical Alloying and Advanced Materials, Mineral Processing and Extractive Metallurgy and, Building Materials and Environment Management. About hundred and fifty papers were presented in the conference under various themes. Abstracts of these papers were made available to the participants during the conference. This book, 'Frontiers in Mechanochemistry and Mechanical Alloying' is a compilation of select papers for which full manuscripts were received. The papers were peer reviewed and edited to the extent possible. The original thematic structure of the conference is retained in the book. While a clear cut demarcation in terms of themes is not possible, the structuring has certainly helped to bring in focus.

We, the editors, would like to thank several of our colleagues whose cooperation and support made it possible to bring out this edited volume. The patronage of Academician V.V. Boldyrev (Founding President IMA), Prof. Mamoru Senna (President, IMA) and Prof. Samir K. Brahmachari (Director General Council of Scientific and Industrial Research (CSIR)) is gratefully acknowledged. Profs. Nikolai Z. Lyakhov, Elena V. Boldyreva, Peter Baláž, K. Anantha Padmanabhan, Gabriele Mulas and Thierry Grosdidier supported us in all possible ways to complete this book. We are grateful to all our colleagues who rendered support for review, editorial assistance and composing. The assistance received from NML colleagues, especially, Dr. Soumitro Tarafdar (Materials Division), Dr. Sanjay Kumar, Mr. T.C. Alex (Mechanochemistry and Reactivity Group), Dr. N.G. Goswami (Information Management and Dissemination Division) and Mr. Nimai Halder (Engineering Division) is gratefully acknowledged.

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Applications in Pharmaceuticals*

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*Severe Plastic Deformation and Friction  
Stir Welding*

K. Anantha Padmanabhan

*Nano-particle and Nano-composites, Advance Ceramics Science and Technology  
Mechanical Alloying and Advanced Materials*

Mamoru Senna, Nikolai Lyakhov  
Indranil Manna, B.S. Murthy

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