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Editorial

Preface to the special issue: Processing bulk nanostructured materials

Megumi Kawasaki[1,*] and Praveen Kumar[2]

[1] School of Mechanical, Industrial and Manufacturing Engineering, Oregon State University, Corvallis, OR 97331, USA
[2] Department of Materials Engineering, Indian Institute of Science, Bangalore 560012, India

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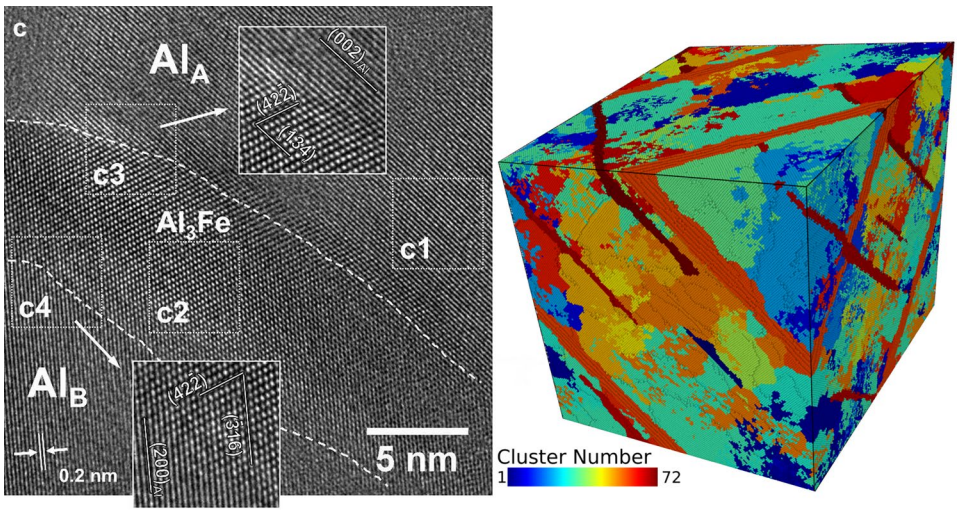
GRAPHICAL ABSTRACT



Over the past decades, a variety of techniques, collectively known as Severe Plastic Deformation (SPD), have been recognized as a promising method for processing bulk nanostructured metals (BNM) and materials. These materials exhibit unique grain and subgrain configurations, typically within the scale of approximately 50–500 nm, surrounded by non-equilibrium grain boundaries. Employing SPD techniques enables the efficient production of such materials in large volumes, which is important for developing SPD-processed materials for a variety of applications.

Substantial research efforts have been in progress across numerous countries, resulting in significant breakthroughs in the SPD and BNM fields. This has led to the realization that the commercialization of materials processed through SPD techniques is now attainable [1]. The NanoSPD community has been expanding continuously, evidenced by a remarkable upswing in the volume of academic publications from researchers all over the world [2]. Moreover, the SPD research community has been building a strong network aiming to facilitate research collaboration, knowledge sharing, and collective contributions to educate young researchers and scientists. It can be represented by the holding of the NanoSPD conference series every three years, where the latest one, NanoSPD 8, took place on

Address correspondence to E-mail: megumi.kawasaki@oregonstate.edu

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February 26–March 3, 2023, at the Indian Institute of Science (IISc) in Bangalore, India. Praveen Kumar, a Professor in the Department of Materials Engineering at the Indian Institute of Science, Bangalore, and the Co-Chair of the NanoSPD 8 conference, along with myself, Megumi Kawasaki, an Associate Professor at Oregon State University and a member of the NanoSPD international steering committee, as well as an editor of the Journal of Materials Science, have been eager to encapsulate the remarkable research advancements in the field of SPD research following the challenging times of COVID-19. Consequently, we find ourselves at an opportune time to publish a special issue on Processing Bulk Nanostructured Materials to summarize the current developments and achievements in the SPD community. Short bios of us, the special issue editors, are listed at the end of the preface.

This special issue comprises numerous aspects of SPD and BNM, such as the fundamental behaviors and enhanced mechanical properties of materials following nanostructuring through SPD and pre- and post-SPD heat treatments, functionalities of SPD-processed materials, and development as well as refinement of SPD techniques and the application of the processed materials. We are proud to announce a total of 28 invited reports, comprising two review papers and 26 original research reports, are compiled in this special issue. To illustrate the comprehensive coverage of important topics in Materials Science within this special issue, Table 1 provides a detailed list of seven key subjects along with specific information (keywords, SPD process, and materials) for the 28 invited articles and their respective lead authors.

Presented below is a summary of the special issue outlined in Table 1. Topic 1 focuses on the advanced applications of the SPD-processed materials given by two review articles. In particular, Zohrevand et al. describe the application of several SPD techniques for the improvement of the properties of Zn-, Li-, Mg- and Al-based batteries, and Valiev et al. summarize the recent advancement in achieving a higher level of properties in the metallic biomaterials and the challenges and uncertainties to produce a new generation of medical implants. Topic 2 describes the fundamental but essential subject of the microstructure-mechanical property-SPD processing relationships by six articles. Special focuses are given to microstructure and texture evolution by processing, improvement in mechanical properties, and the changes in microstructure after heat treatments of various metallic materials, such as Al alloys, pure Ag, Ti alloy, and medium entropy alloys. Such changes in the SPD-processed materials have been attributed to the non-equilibrium grain boundaries with an excess number of defects, leading to unique features of SPD-processed materials. Subsequently, the three articles in Topic 3 examine the diffusion and kinetics of SPD-processed nanocrystalline materials, including Cu-Ag, Mg, and high-entropy alloys, during processing and post-processing heat treatments. Topic 4 relates the deformation mechanism of BNM, reported by Figueiredo in this issue, demonstrating theoretical relationships between strain rate sensitivity and ductility of nanostructured metals. Nine articles in Topic 5 demonstrate the utilization of SPD processing for fabricating functional materials having improved corrosion properties in Mg and high-entropy alloys, enhanced hydrogen absorption in a Mg alloy, electrical conductivity in Al–Mg-Zr and Cu-Cr-Hf alloys, magnetic properties in Ni-NiO composites and Fe–Ni-Mo alloy, high-temperature superconductivity in an Al-TiO system, and photocatalytic properties in Ti oxides. This topic, along with the review articles in Topic 1, opens the opportunities for SPD-processed materials for a variety of applications and industries. Topic 6, consisting of two articles, describes the further opportunity of SPD processing for the post-additive manufacturing treatment, by examining the microstructural changes and the density and porosity of additively manufactured metals of 316L stainless steel and Al–Fe alloys. Finally, five articles in Topic 7 describe the heart of the SPD research of understanding and invention of new SPD techniques and unique nanocrystalline structures in both experimental (Topic 6.1) and computational approaches (Topic 6.2). It is apparent from Table 1 that the well-developed SPD and BNM research is progressing to explore new opportunities in the application of processing techniques and fabricated materials across various industries. To illustrate the essence of this special issue, we present two distinct visualizations of bulk nanostructured materials in the Graphical Abstract. The images are sourced from the articles contributed by Cubero-Sesin et al. (depicted on the left) and Prakash (depicted on the right) within this special issue.

We hope that this special issue will attract numerous researchers, fostering the development and continued growth in this research field. We extend our sincere appreciation to all the authors who contributed

Table 1 Seven research topics with the information of the 28 contributed articles for the special issue

Keywords	SPD process	Material	Lead contributors
Topic 1. Applications of SPD-processed materials [Review articles]			
Battery materials, metallic electrodes	ARB, ECAP, HPT, FSP, DDM	Zn, Li, Mg, Al and their alloys	N. Hassanzadeh, T.G. Langdon
Advanced medical devices, fatigue resistance, osseointegration, devise design	ECAP, ECAP-Conform, HPT	Ti-, Mg-, Zn- alloys, HEAs	R.Z. Valiev, K. Edalati
Topic 2. Microstructure-mechanical property-SPD processing relationship			
Texture, microstructure	ECAP	Pure Ag	W. Skrotzki, S. Suwas
Texture, microstructure, strength	HPT	Al-Li-Sc alloy	S. Suwas
Microstructure, strength & ductility	HPT	CoCrNi-Zn alloy	N. Tsuji
Strength, high-pressure sliding (HPS)	HPS	A5052 Al alloy	Z. Horita
Annealing, omega phase	HPT	Ti-V alloy	B.B. Straumal
Precipitation, strength, HR-S/TEM	HPT	Al–Fe alloy	J.M. Cubero-Sesin, Z. Horita
Topic 3. Diffusion and kinetics of nanocrystalline materials			
Grain boundary diffusion	ECAP	CoCrFeNiMn alloy	G. Wilde, S. Divinski
Precipitate, dynamic equilibrium	HPT	Cu-Ag alloy	B.B. Straumal
Recrystallization, neutron diffraction, synchrotron high-energy X-rays	HPT	AZ31 alloy	K.-D. Liss, M. Kawasaki
Topic 4. Deformation mechanisms of nanocrystalline metals			
Strain rate sensitivity, ductility, grain boundary sliding	-	Al, Cu, Fe, Mg, Ti and Zn alloys	R.B. Figueiredo
Topic 5. Functionality of SPD materials			
Corrosion	HPT	Mg-Zn-Ce alloy	P. Kumar
Corrosion	HPT	CoCrFeNi, CoCrFeMnNi alloys	H. Miyamoto, K. Edalati
Hydrogen storage	HPT, FSP	ZK60 alloy	M.J. Zehetbauer
Electrical conductivity	ECAP-Conform	Al–Mg-Zr alloy	N.A. Enikeev
Electrical conductivity	Rotary swaging	Cu-Cr-Hf alloy	S. Dobatkin, B.B. Straumal
Magnetic property	HPT	Ni-NiO composites	A. Bachmaier
Magnetic property	HPT	Fe–Ni-Mo alloy	D. Bradai, T.G. Langdon
High-Tc superconductivity	HPT	Al-TiO_x system	M. Mito, Z. Horita
Photocatalytic properties	HPT	TiO_2	K. Edalati
Topic 6. Application of SPD techniques on additively manufactured materials			
XRD, microstructure	HPT	AM 316L steel	J. Gubicza, M. Kawasaki
Density, porosity	HPT	AM Al-Si alloy	Y. Zhu, J.M. Cabrera
Topic 7.1. Development in SPD techniques and nanocrystalline structure			
Uniform strain high-pressure torsion (US-HPT), strain gradient	HPT, US-HPT	Pure Ni	A. Hohenwarter
Friction assisted lateral extrusion process (FALEP), friction	ECAP, NECAP, FALEP	AA1050 alloy	L.S. Tóth, T.C. Lowe
Topic 7.2. Modeling of SPD techniques and advanced nanostructure			
Atomistic simulation, Molecular dynamics	ECAP	Al, Cu, Ni	A. Prakash
Crystal plasticity simulation	HPT	$(CrFeNi)_{99}Si_1$ alloy	N.P. Grao
Harmonic structure, finite element modeling	–	Pure Ni	D. Orlov

to this special issue. Their dedication and enthusiasm for SPD and BNM research were instrumental in the successful completion of this special issue. Finally, we extend our special thanks to the Editor-in-Chief of the Journal of Materials Science, Professor Barry Carter, and the Deputy Editor-in-Chief, Prof. Grant Norton, for their kind assistance in ensuring the success of this special issue.

References

[1] Lowe TC, Valiev RZ, Li X, Ewing BR (2021) Commercialization of bulk nanostructured metals and alloys. MRS Bull 46(3):265–272

[2] Horita Z, Edalati K (2020) Severe Plastic Deformation for Nanostructure Controls. Mater Trans 61(11):2241–2247

Megumi Kawasaki is currently a Jack R. Meredith Faculty Scholar and Associate Professor in the School of Mechanical, Industrial, and Manufacturing Engineering at Oregon State University. She also holds a Visiting Research Associate Professor position in Materials Science at Osaka Metropolitan University, Japan, since 2013. Megumi received her M.S. degree in 2002 and Ph.D. degree in 2007 in Materials Science from the University of Southern California. Her recent pioneering work includes the investigation of the microstructural evolution and phase transformation of bulk nanostructured metals under extreme conditions, utilizing lab-scale X-ray and neutron diffraction, as well as synchrotron high-energy X-rays. She serves as the first female member of the international NanoSPD Steering Committee. She assumed the role of General Chair for the Superplasticity Research Society, overseeing the International Conference on Superplasticity of Advanced Materials (ICSAM). She has been an editor of Journal of Materials Science since 2020.

Praveen Kumar received his Bachelor of Technology degree in Mechanical Engineering from the Indian Institute of Technology, Kanpur, in 2003. Subsequently, he received M.S. and Ph.D. degrees in Mechanical Engineering from the University of Southern California, Los Angeles in 2005 and 2007, respectively. He is currently a Professor in the Department of Materials Engineering, Indian Institute of Science, Bangalore. His main research interests are the mechanical behavior of materials, with particular emphasis on studying the effects of severe plastic deformation, electric current, temperature and sample length scale, and constructive usage of electromigration, both in solid and liquid metals. He served as an editor of Advanced Powder Technology from 2017 to 2022 and has been an associate editor of MRS Advances since 2019 and an editor of Transactions of Indian Institute of Metals since 2023.