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Layered Structures in Deformed Metals and Alloys

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Meeting	2014 TMS Annual Meeting & Exhibition
Symposium	Ultrafine Grained Materials VIII
Presentation Title	Layered Structures in Deformed Metals and Alloys
Author(s)	Niels Hansen, Xiaodan Zhang, Xiaoxu Huang
On-Site Speaker (Planned)	Niels Hansen
Abstract Scope	Layered structures characterize metals and alloys deformed to high strain. The morphology is typical lamellar or fibrous and the interlamellar spacing can span several length scales down to the nanometer dimension. The layered structures can be observed in bulk or in surface regions, which is shown by the way of examples of different processing routes: friction, wire drawing, shot peening, high pressure torsion and rolling. The interlamellar spacing reaches from 5-10 nanometers to about one micrometer and the analysis will cover structural evolution, strengthening parameters and strength-structure relationships. Finally, the results will be discussed based on universal principles for the evolution of microstructure and properties during plastic deformation of metals and alloys from low to high strain.
Proceedings Inclusion?	Planned: Publication Outside of TMS

<http://www.programmaster.org/PM/PM.nsf/ApprovedAbstracts/A94470C9D04137EB85257BAD00357C4A?OpenDocument>

References:

- [1] Hughes DA, Hansen N. Graded nanostructures produced by sliding and exhibiting universal behavior. Physical Review Letters 2001; 87:135503.
- [2] Xiaodan Zhang, Niels Hansen, Yukui Gao, Xiaoxu Huang. Hall–Petch and dislocation strengthening in graded nanostructured steel. Acta Materialia 2012; 60: 5933-5943.

Ultrafine Grained Materials VIII: Special Session: Gradient and Layered Nanostructures

Sponsored by: TMS Structural Materials Division, TMS/ASM: Mechanical Behavior of Materials Committee

Program Organizers: Suveen Mathaudhu; Yuri Estrin, Monash University; Zenji Horita, Kyushu University; Enrique Lavernia, University of California, Davis; Xiaozhou Liao, The University of Sydney; Lei Lu, Institute for Materials Research; Qiuming Wei, University of North Carolina, Charlotte; Gerhard Wilde, University of Muenster; Yuntian Zhu, North Carolina State University

Monday 2:00 PM

February 17, 2014

Room: 6E

Location: San Diego Convention Center

Session Chair: Xiaozhou Liao, The University of Sydney; Lei Lu, Institute for Materials Research

2:00 PM Keynote

Gradient Nanostructures in Materials: *K. Lu*¹; *Yi Li*²; ¹Chinese Academy of Sciences; ²Department of Materials Science, National University of Singapore

Materials with spatial gradients of various constituents including different types of defect and chemical compositions have drawn increasing attentions. Particular interests are stimulated by engineering microstructure graduations in the nano-scale in metals where the corresponding spatial gradients in properties become so pronounced that lead to superior properties and performance. In this talk, classification and processing of various gradient nanostructured materials will be introduced. Several examples will be demonstrated to highlight property enhancements of gradient nanostructured materials relative to their homogeneous-structured counterparts with emphasis on different microstructure gradients and their effects on mechanical properties. Perspectives on gradient nanostructured materials will be addressed as well.

2:20 PM Invited

Grain Size Gradient-induced Work Hardening and Extraordinary Ductilization:

*Xiaolei Wu*¹; *Yuntian Zhu*²; ¹Institute of Mechanics, Chinese Academy of Sciences; ²North Carolina State University

Strain hardening is critical for structural materials to secure desired ductility, especially for high-strength metals that often suffer from poor ductility. Here we report that the gradient nano-grained (GNG) surface layers sandwiching a coarse-grained core render an extra strain hardening. The grain size gradient in the

nano-micro-scale induced a notable strain gradient under tension that converts the applied uniaxial stress to multi-axial stresses. Thereby the accumulation and interaction of dislocations are promoted in the GNG layers, resulting in an extra hardening and an obvious strain hardening rate up-turn. Such a unique extra strain hardening inherent to the GNG structures, which does not exist in homogeneously-structured materials, provides a novel strategy to develop strong-and-ductile materials by architecturing heterogeneous nanostructures. The work uncovers the intrinsic large uniform tensile elongation of the nanostructures and paves the way toward a combination of high strength and good ductility for their structural application.

2:40 PM

Gradient Structure: Perspective, Prospect and Problems: *Yuntian Zhu*¹; Xiaolei Wu²; Ke Lu³; ¹North Carolina State University; ²Chinese Academy of Sciences; ³Institute of Metal Research

In this talk we will present and discuss the perspective, prospects, and problems of gradient structures, especially in the nano-scale. Gradient structures are formed and evolved naturally in many biological systems such as bones and plant stems for superior mechanical and functional properties. They have been engineered into mechanical parts via thermochemical routes such as nitriding and surface heat treatments. Recently gradient structures with grain size gradient from nano-scale to micro-scale were introduced into metals, producing excellent strength and ductility. Materials with gradient nanostructures and mechanical parts with gradient structured surface layers represent an emerging academic field with many fundamental and engineering problems to be solved by researchers from the communities of materials science and materials mechanics. Some of the issues can only be solved by team effort from both experimentalists and theorists.

3:00 PM Invited

Interfaces by Design: *Irene Beyerlein*¹; ¹Los Alamos National Laboratory

In this presentation, we will present our recent studies on the severe plastic deformation processing of nanolayered composites and on the properties of the bimetal interface structures that develop. Two different processing pathways are shown to produce two different interfaces, both possessing a regular, ordered atomic structure. As a testament to the quality of the interfaces produced, both interface structures are shown to lead to exceptional stability at high temperatures, radiation conditions, and shock loading. At present, there is a critical need for novel synthesis methods that lead to transformational changes in material properties. To this end, this work reveals that severe plastic deformation can enable innovative routes for tuning interface structures at the atomic level.

3:20 PM Invited

Layered Structures in Deformed Metals and Alloys: *Niels Hansen*¹; Xiaodan

Zhang¹; Xiaoxu Huang¹; ¹Technical University of Denmark

Layered structures characterize metals and alloys deformed to high strain. The morphology is typical lamellar or fibrous and the interlamellar spacing can span several length scales down to the nanometer dimension. The layered structures can be observed in bulk or in surface regions, which is shown by the way of examples of different processing routes: friction, wire drawing, shot peening, high pressure torsion and rolling. The interlamellar spacing reaches from 5-10 nanometers to about one micrometer and the analysis will cover structural evolution, strengthening parameters and strength-structure relationships. Finally, the results will be discussed based on universal principles for the evolution of microstructure and properties during plastic deformation of metals and alloys from low to high strain.

3:40 PM Break

3:55 PM Invited

Ni Based Gradient Materials: Y Lin¹; Yi Li¹; K Lu¹; ¹Institute of Metal Research

Materials with spatial gradients of various constituents can achieve superior mechanical properties and performance. However the key to optimize the properties is to properly control gradient structure. In our present work through electro-deposition, we demonstrate the production of gradient structure in Ni based materials. The constituent gradient can be grain size gradient and phase gradient including amorphous phase. Their effect on the mechanical properties will be reported.

4:15 PM Cancelled

Grain Size Effect on Twinning Propensity in Ultrafine-grained Ti Processed by Dynamic Plastic Deformation: Jingli Sun¹; Patrick Trimby²; Fengkai Yan³; Xiaozhou Liao²; Nairong Tao³; Jingtao Wang¹; ¹Nanjing University of Science and Technology; ²The University of Sydney; ³Institute of Metal Research, Chinese Academy of Sciences

The scanning electron microscopy transmission Kikuchi diffraction and high-resolution transmission electron microscopy techniques were used to characterize the deformation behavior of ultrafine-grained Ti processed by dynamic plastic deformation at room temperature. Results show that the deformation twinning propensity in ultrafine-grained Ti decreases monotonously while the number of dislocations having the $\langle c \rangle$ component increases with decreasing grain size, indicating that the transformation of the deformation mechanism from twinning to slip occurs and that the twinning mechanism does not change within the observed grain size range.

4:35 PM Invited

Deformation and Fracture Mechanisms in Gradient Nano-grained Metals: Zhi

Zeng¹; Ting Zhu¹; ¹Georgia Institute of Technology

Recent experiments revealed the extraordinary intrinsic tensile plasticity in nano-grained copper with gradient grain size. In this work we perform the molecular dynamics and crystal plasticity simulations to study the deformation and fracture mechanisms in nanocrystalline copper with both uniform and gradient grain sizes. Molecular dynamics simulations show the mechanically-driven grain growth that evolves progressively from the surface to substrate, giving rising to the drastically increased tensile ductility. The combined atomistic and crystal plasticity modeling further demonstrate that the decrease of grain size can delay the onset of necking, thereby promoting the tensile ductility. The detailed atomistic analyses of deformation processes uncover the controlling deformation and fracture mechanisms that well correlate with experimental observations.

4:55 PM Cancelled

Investigation of Deformation Behavior of Surface Nano-crystalline Materials:

Andrey Molotnikov¹; Yuntian Zhu²; Xiaolei Wu³; Yuri Estrin¹; ¹Monash University; ²North Carolina State University; ³Chinese Academy of Sciences

Materials processed by severe plastic deformation of near-surface regions attract considerable interest due to their good combination of strength and ductility. They possess gradient structures with extremely fine grain size in a near-surface layer, while retaining coarse grained interior. Computational models are required to accelerate design of such materials with architected microstructure. This study aims at investigating the deformation behavior of surface nano-crystalline IF steel processed by SMAT using computational modelling. The analytical model that provides a microstructural basis for this study utilizes an approach in which the material is partitioned in two 'phases': the dislocation cell walls and the cell interior, the respective dislocation densities entering the model as scalar internal variables. The model is combined with strain gradient theory and accounts for geometrical dimensions of the specimen and microstructural features. The model is validated by comparing the experimental and simulation results of uniaxial tensile tests and bending tests.

5:15 PM Invited

Influence of Length Scale on Mechanical Behavior of a Multilayered

Nanocrystalline Ni-Fe: Lilia Kurmanaeva¹; Hamed Bahmanpour¹; Haiyan Wang²; Jon McCrea³; Enrique Lavernia¹; Amiya Mukherjee¹; ¹University of California, Davis; ²Texas A & M University; ³Integran Technologies Inc.

Multilayered structures offer unique opportunities for improving the strength of structural materials due to the capability of high volume of grain boundaries and layer interfaces for hindering dislocation activity. Despite encouraging preliminary results, however, limited ductility has hindered their extensive industrial application. An

introduction of coarse grains into nano-grained matrix is a well-known method to improve poor ductility. In the present work bimodality in Ni-Fe samples with total thickness of about 600 μ m is obtained by electrodepositing alternative layers. To investigate the mechanical response and understand the underlying deformation mechanisms tensile tests were performed at various temperatures and strain rates. Structural studies before and after tensile deformation were conducted using electron microscopy. Reported properties are discussed in context of bimodal micro structure of multilayered samples and contribution of each grain size regime to strength and ductility. This investigation is supported by separate ONR grants to UCD, Texas University and Integran Technologies.
