Plenary Session

Monday AM | August 19, 2019

Room: Lily Hall of Golden Hall (1st Floor)

Chairs:
Zhiling Tian, Central Iron & Steel Research Institute, China
Yafang Han, Chinese Materials Research Society, China

8:30-8:50

Opening Remarks

Huibin Xu (Conference Chairman), Beihang University, China

8:50-9:30

Recent Progress in Space Materials Science and Technology

Bingbo Wei, Northwestern Polytechnical University, China

The extraordinary physical and chemical states of outer space provide a special environment to design, investigate and apply advanced materials. Owing to the continuous achievements of manned space flight programs, world-wide researchers have got rid of the narrow-minded and dubious privilege of microgravity. Instead, space materials science and technology is evolving into a vigorous cross-disciplinary research field. Almost all categories of typical materials, from aluminum through superalloys to semiconductors and even artificial bones, were taken into account for space experiments. This presentation tries to make a brief survey about the essential progress in the recent decade. Since China is greeting our era of space station in the years to come, both ground simulation study and space experiment design are conducted extensively. Although the keynote of such a field is still mainly for fundamental research, some promising application approaches from novel materials to creative techniques are proposed for discussion. With respect to the speaker's own work, both the space experiments of ternary eutectic growth on board China's Spacelab TG-II and the most up-to-date investigations on containerless rapid solidification of W-based refractory alloys are presented in detail.

9:30-10:10

High Entropy Alloy and Microstructure Design, Mechanical Properties, and Processing

Hyoung Seop Kim, Department of Materials Science and Engineering, POSTECH, Korea

Multi-principal element alloys also referred to as high-entropy alloys (HEAs), have attracted considerable attention due to their great potential with an endless playground for alloy design. Most of the HEA researchers have focused on the alloying effect, phase evolution, mechanical properties, and deformation behavior of HEAs developed based on intuition and incomplete thermodynamic database with microstructural and deformation theories. Also, few studies on processing, up-scaling, and applications have been tried so far. The successful development of HEAs and their industrial applications critically depend on processing and formability for industrial products as well as fundamental understanding. In this presentation, systematic approaches for new HEA design and microstructural optimization using sequential alloy selection and computer simulation approaches, such as molecular dynamics, finite element method, machine learning, and their integrations are introduced. For an excellent combination of tensile strength and ductility, multiple-stage deformation-induced phase transformation, as well as strong solid solution strengthening, was employed. The in-situ neutron diffraction studies make it clear that the martensite formation and the concurrent load partitioning between the fcc and the bcc phases play an important role in the increase in strength. This multiple mechanism strengthening results in heterogeneous microstructures, which can be optimized using machine learning. This result and optimization scheme underlines insights to provide expanded opportunities for the future development of HEAs for cryogenic applications. Lastly, the processability of the HEAs and its sheet formability are investigated using Erichsen testing, deep drawing testing, and hole expansion testing. Mechanical properties and microstructure characterization are investigated to obtain a basic understanding of the sheet formability and deformation behavior.

10:10-10:30 Tea Break

10:30-11:10

Understanding and Developing Nanostructured Materials with Requisite Properties and Stability

Kevin Hemker, Johns Hopkins University, United States

The focus on nanoscience has greatly advanced our ability to synthesize, characterize, and model nanomaterials with unprecedented physical and chemical properties that are derived from dimensional constraints. In applications where engineered components must withstand load, structural nanomaterials show clear promise owing to "smaller is stronger" trends. Dislocation activity in nanocrystalline metals is mitigated by the greatly reduced volume in which they can exist. Comparisons of experiments and molecular dynamics simulations have elucidated unique plasticity mechanism and highlighted the inherent mechanical and thermal instability of nanocrystalline metals. Challenges in bridging nano-to-mesoscale fabrication and microstructural insta-bilities present serious obstacles to the wide spread commercialization of structural nano materials.

Nanotwinned metals have received considerable attention in recent years to do their unique balance of properties. Nanotwinning has historically been observed in low stacking fault metals and alloys, and to date most studies have focused on nanotwinned Cu. Our recent observation of nanotwins in sputter deposited NiMoWfilms was unexpected, but subsequent characterization of this material indicates that the nanotwins underpin ultrahigh mechanical strength, extreme anisotropic plasticity, low electrical resistivity, low thermal expansion, and superior thermal and mechanical microstructural stability.

We have produced a compositional spread of solid solution NiMoW films, revealing ultrahigh strengths exceeding 3.5GPa and an exceptional balance of thermal, mechanical and physical properties due to the presence of nanotwins. We have further demonstrated the ability to shape and micromachine NiMoW metal MEMS cantilevers with the requisite dimensional precision and stability. To date, the vast majority of MEMS devices have been made of silicon, but NiMoW has the potential to supplant silicon in extreme MEMS applications. Thus, use of high temperature MEMS materials like nanotwinned NiMoW, that possess a balance of properties (e.g. high strength, electrical conductivity, dimensional stability and microscale manufacturability) well beyond what is possible with silicon, may pave the way for widespread digital monitoring and control and enable what is widely referred to as the Internet of Things (IoT).

11:10-11:50

Research and Development of Metallic Biomaterials for Inhibiting Stress-Shielding Between Implant and Bone

Mitsuo Niinomi, Tohoku University, Osaka University; Meijo University, Nagoya University, Japan

In the very early stage of titanium usage for biomedical applications, only pure titanium and (alpha + beta)-type Ti-6Al-4V ELI were used. These materials are still widely used. However, V-free titanium alloys were developed in the 1980s when it was discovered that V is a harmful element for human beings. Then, when Al was also determined to be a harmful element, V- and Al- free titanium alloys were developed in the 1990s. V-free, and V- and Al-free titanium alloys for biomedical applications are all (alpha + beta)-type alloys. In the middle of the 1990s, researchers were focusing on the stress shielding problem between metallic implants and bone, which is the inhomogeneous stress transfer between implant and bone; bone resorption occurs because the stress is preferentially transferred through implants because they have higher Young's moduli than that of the bone. The research and development of beta-type titanium alloys compose of non-toxic and allergy-free elements with low Young's modulus were started in the 1980s, and are currently being continued; they are mostly Ti-Nb, Ti-Ta, Ti-Mo, Ti-Zr-beta stabilizing element based alloys. It was found in the case of the surgical operation of scoliosis diseases using spinal fixation devices that high Young's modulus of the rod, which is one of the parts of spinal fixation devices, is advantageous for surgeons because they need to bend it to fix spin with keeping bent shape, but the low Young's modulus of the rod is advantageous for patients. To satisfy these conflicting demands simultaneously, it should be possible to increase the Young's modulus of the bent parts of the rod via deformation at room temperature to introduce a deformation-induced secondary phase with high Young's modulus, while allowing the Young's modulus of the remainder of the rod to remain unchanged at a low Young's modulus. Then, the Young's modus changeable beta-type titanium alloys for biomedical applications, especially for spinal fixation rods were developed.

During research and development of the aforem-entioned beta-type titanium alloys, peculiar deformation behaviors were found in some low Young's modulus beta-type titanium alloys used for biomedical applications. In this case, mainly the effects of the non-toxic and allergy-free light weight interstitial element, oxygen (O) on the biological mechanical properties is highly interesting.

The research and development of beta-type titanium alloys composed of non-toxic and allergy-free elements with low Young's moduli for biomedical applications will be discussed. Then, the peculiar deformation behaviors found in some beta-type titanium alloys with low Young's moduli used for biomedical applications will be also discussed.

11:50-12:30

Finding the Atoms that Matter in Functional Materials

Joanne Etheridge, Monash Centre for Electron Microscopy and Dept of Materials Science and Engineering, Monash University, Australia

In many materials, it can be a small subset of atoms that control the important properties of the whole. These are the atoms that matter! Finding them and identifying their role can be challenging. In modern transmission electron microscopes, electron wavefields can be focussed to a point less than an Ångström in diameter, providing a powerful tool with which to probe small volumes of matter. By tuning the incident probe and harvesting selected parts of the scattered signal, specific structural, chemical and/or electronic information can be obtained. This talk will give an overview of these methods. It will illustrate them with a range of applications to functional materials, such as crystal growth and shape control in metal nanoparticles; structure-property relationships in photoactive perovskites and III-V semiconducting quantum wells; Li-driven superlattices in Li-ion conductors; surface plasmon polaritons in metallic nanostructures; and 'imaging' the distribution of electrons as they scatter within an atomic lattice.