Forum Inżynierii Materiałowej

Materials Engineering Forum

- The Materials Engineering and Metallurgy Committee of the Polish Academy of Sciences
- Polish Materials Science Society

Exploring nanomultilayers for joining technology

Jolanta Janczak-Rusch

Empa, Swiss Federal Laboratories for Materials Science and Technology, Dübendorf, Switzerland

In response to the ever-increasing requirements for joining processes and joint performance, specially designed nanomultilayers (NMLs)have been explored as new materials for the joining technology application. To this end, nanolayers (<20 nm) of brazing filler metals and metal alloys, such as Ag, Cu, Ag-Cu and Al-Si alloys, were confined between chemically inert barrier nanolayers (AlN, W,C)for the use as a bonding material.The comprehensive experimental study of the NML's phase stability and atomic mobility upon heating shows that the nanosized brazing filler metals may exhibit a significant melting point depression in combination with a high atomic mobility along NMLs internal interfaces (i.e. phase and grain boundaries).The observedfast directional "outflow" of the confined metal to the NML surface at temperatures can be controlled by the NML design (material composition, layer thicknesses, interface structure, internal stresses),deposition parameters and environmental parameters, as well as NMLs surface pre-treatment. Finally, this effect can be utilized for bond formation or surface patterning.

When using nanomultilayers of immiscible metallic systems - such as Cu-W -as bonding materials, high-strength nanocomposites can be formed in-situ during the joining process, which offers a new route to create joints with excellent mechanical properties.

Another example of nanomultilayers with significant potential for the joining technology are NMLs based on reactive materials such as Ni/Al, serving as a local heating source and allowing nearly "room-temperature"soldering and offering many opportunities for joining of heat-sensitive materials as for example nanostructured metals and alloys.

The obtained fundamental knowledge on the phase stability and atomic mobility of confined solids in nanomultilayersis not only relevant for joining technology but also for many other application areas, such as hard coatings, optical filters, X-ray mirrors, energy storage, micro-electronics and plasmonics.

Helium in metal nanocomposites

Forum Inżynierii Materiałowej

Materials Engineering Forum

- **The Materials Engineering and Metallurgy Committee of the Polish Academy of Sciences**
- **Polish Materials Science Society**

Michael J. Demkowicz

Department of Materials Science and Engineering, Texas A&M University, College Station, TX, 77840, USA

The introduction of helium (He) into metal components is a major concern in nuclear energy applications. In fission reactors, it causes embrittlement of load-bearing components, especially ones made of nickel-base alloys. In future fusion reactors, He is expected to severely degrade the surfaces of plasma-facing materials. In both cases, the deleterious effect of He may be traced back to its insolubility in metals, leading to its precipitation into nano-scale bubbles. Metal nanocomposites provide opportunities for mitigating He-induced damage by providing greater control over where He bubbles form and how they interact with other defects.This talk will summarizeexperimental and modeling work on the behavior of He in multilayer metal nanocomposites.

While He bubbles are approximately uniformly distributed within grain interiors of polycrystalline alloys, in nanocomposite metals they show a distinct preference for growth in one of the constituent phases. Moreover, while both grain boundaries in polycrystalline alloys and heterophase interfaces in metal nanocomposites are preferential trapping sites for He bubbles, the latter exhibit a distinct asymmetry in bubble formation, with bubbles preferentially growing into one of the adjacent phases. We explain these differences in terms of the properties of the composite constituent phases as well as the internal structure of the interfaces between them.

Next, we compare a series of layered composites with different interface structures and layer thicknesses. We show that, with decreasing layer thickness, the critical He concentration needed to form bubbles is reduced in all of these materials. The rate of reduction is shown to depend on the structure of the heterophase interfaces found in these materials, in particular the areal density of interfacial He trapping sites.The distribution of such trapping sites within any given interface is directly related to the distribution of interface misfit dislocations, in particular the density of intersections between these dislocations within the interface plane. Such sites have high local interface energy, giving rise to preferential wetting by He bubbles and, therefore, preferential He bubble nucleation.

Finally, we examine the effect of confinement on bubble morphology in layered composites where the layer thickness is reduced to ~5nm. In such cases, there is dramatic shift in bubble shape, from relatively equi-axed to high aspect ratio, linear channels. The formation and stability of these channels is again explained based on the structure of the interfaces between constituent phases in the composite. Upon aging, these channels are shown to transform into wide, faceted plate-shaped voids, which nevertheless remain confined within individual layers in the composite. I conclude with a discussion of how insights gained from this fundamental research may translate into strategies for developing novel, He damage-resistant materials for future nuclear energy applications.