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INTRINSIC AND EXTRINSIC SIZE EFFECTS IN MATERIALS

FOCUS ISSUE

Introduction

Shuozhi Xu[1], Marat I. Latypov[1], Jaafar A. El-Awady[2], Irene J. Beyerlein[1]

[1]*University of California, Santa Barbara, USA*
[2]*Johns Hopkins University, USA*

Materials are hierarchical in nature. The science of materials concerns objects and phenomena ranging from celestial bodies to electrons. At small scales, the behavior of materials cannot be predicted by classical models that involve no characteristic size or length scale. The substantial variation in properties and performance of materials with different characteristic length scales is known as the size effect. There are two types of size effect: intrinsic and extrinsic. Intrinsic size effects, which have long been the subject of materials studies, arise from microstructural heterogeneities. For example, the strength of pure metals and alloys can be altered over more than two orders of magnitude by introducing soluble alloying elements, second phase precipitates, and grains of varying sizes. In contrast, extrinsic size effects came to materials researchers' attention more recently. This type of size effect is associated with dimensional constraints, which are of increasing relevance in the age of micro and nanotechnology. For instance, the electrical and thermal conductivities of thin films decrease significantly once the film thickness is reduced below the mean free path of electrons or phonons. Collectively, the two types of size effects, along with the chemical composition, fundamentally govern behavior of materials. Therefore, knowledge of the combined intrinsic and extrinsic size effects can open up new avenues for designing materials with superior properties.

This Focus Issue consists of review papers and research articles written by leading scientists around the world. A wide range of material systems is explored, including, but not limited to, crystalline metals (e.g., Zr/Nb multilayers, Ni/Al nanolaminates, ferrite/cementite multilayer stainless steels, nanocrystalline CuTa, nanocrystalline CuZr), metallic glasses (e.g., amorphous CuNb, amorphous CuZr, amorphous CuTi), metal matrix composites (e.g., Al/SiC), ceramics (e.g., CeO_2, UO_2), semiconductors (e.g., PbTe, PbSe), polymers (e.g., silicone rubber), and carbon-based materials (e.g., carbon nanotubes, graphene). In these materials, intrinsic and extrinsic size effects on mechanical, thermal, and chemical properties are analyzed by theories, experiments, simulations, and modeling. We hope the readers will find that this Focus Issue provides a timely summary of recent advancements in size dependence of multiphysics phenomena in a variety of materials.

This Focus Issue would not have been possible without the endeavors, dedication, and time commitment of a large number of authors and reviewers worldwide. We thank the authors for their high-quality, well-crafted manuscripts and the reviewers for their prompt, unbiased, and careful evaluations. We are optimistic that the articles presented can inspire and spark new ideas and development in the exciting and constantly evolving field.

On the cover

An abstract illustration of a regular lattice of semi-transparent spheres visualized in perspective together with a "spiral of length scales" symbolize the hierarchical nature of materials and the presence of size effects.