# Prof. Seung Min Han

Dept. of Materials Science, KAIST

**Ph.D.** in Materials Science and Engineering(2006), Stanford University
Dissertation: Methodologies in determining mechanical properties of thin films using nanoindentation

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| 2014 – Present | **Associate Professor** – *Dept. of Materials Science and Engineering*, KAIST |
| 2010 – 2014 | **Assistant Professor** – *Graduate School of EEWS*, KAIST |
| 2006 – 2010 | **Acting Assistant Professor** – *Department of MSE*, Stanford University |

The main focus of my research is on the understanding of the mechanical behavior of materials at the nanoscale with emphasis on the nanostructures applied to various energy materials. The deformation mechanisms that give rise to the bulk mechanical properties of materials are well-understood, but with current interests in development of new nanostructured materials used for energy materials, it is critical that materials scientists study the deformation mechanisms of these new materials at the appropriate length scales. My research is focused on understanding the mechanisms of deformation of the nanoscale structures at a fundamental level by using ex-situ and in-situ SEM/TEM nanoindentation methods and applying the knowledge to evaluate and enhance the mechanical reliability of nanostructures used for different energy materials applications. Representative contributions include development and analysis of high strength, fatigue tolerant metal-graphene nanolayered composite, highly reliable Ag nanowire based transparent electrode for flexible solar cells and displays, and fracture resistant anode/cathode materials for energy storage applications.

2019
Fall Semester
GIFT
Seminar

**Time:** Dec. 5th, 4:30~5:45 pm
**Location:** GIFT Auditorium #101
**Speaker:** **Prof. Seung Min Han** (KAIST)
**Host:** Prof. Sung-Joon Kim

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## Mechanical Properties of Metal-Graphene Nanolayered Composite

Nanoscale metal-graphene nanolayered composite is known to have ultra high strength due to its ability to effectively block dislocations from penetrating through the metal-graphene interface. The same graphene interface can simultaneously serve as a barrier interface for deflecting the fatigue cracks that are generated under cyclic bendings. Cu-graphene composite with repeat layer spacing of 100 nm was tested for bending fatigue at 1.6% and 3.1% strain up to 1,000,000 cycles that indicated ~5 times enhancement in robustness against fatigue induced damage in comparison to the conventional Cu only thin film. Fatigue induced cracks that are generated within the Cu layer were stopped by the graphene interface, which was confirmed using transmission electron microscopy images acquired ex-situ as well as during in-situ tensile test. Molecular dynamics simulations for uniaxial tension of Cu-graphene showed limited accumulation of dislocations at the film/substrate interface, which makes the fatigue induced crack formation and propagation through thickness of the film difficult in this materials system. Robustness against bending fatigueinduced damage makes this material well-suited for the flexible electrode application, and methods for enhancing the scalability of fabrication will also be discussed.

Another interesting deformation behavior can be observed in metal-graphene nanolayered composite under irradiation conditions. After He+ implantation with a dosage of 13.5 dpa in pure V and V-graphene nanolayers with 110 nm repeat layer spacing, radiation induced hardening of 88% and 25%, respectively, was observed, hence indicating enhanced radiation tolerance in V-graphene nanolayers. Molecular dynamics simulations confirmed that the graphene interface can spontaneously absorb the nearby crystalline defects that are produced from a collision cascade, thereby enhancing the lifetime of the V-graphene nanolayers via this self-healing effect. In addition, the impermeability of He gas through the graphene interface resulted in suppression of He bubble agglomerations that in turn reduced embrittlement. In-situ SEM compression also showed the ability of graphene to hinder crack propagation that suppressed the failure.