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### Stackable electronics enabled by freestanding 2D & 3D materials

**August 12** Bldg. 101  
**Monday, 4 PM** Seminar Room on the 1<sup>st</sup> floor

Special Guest Seminar

2D material-based devices have received great deal of attention as they can be easily stacked to obtain multifunctionality. With their ultrathin thicknesses, such multifunctioning devices become so flexible and conformal that they can be placed onto any 3D featured surfaces. However, 2D heterostructures are typically demonstrated as stacked flakes where single or few devices can be fabricated due to lack of strategies for layer-by-layer stacking of 2D materials at the wafer scale. In this talk, I will discuss about our unique strategy to isolate wafer-scale 2D materials into monolayers and stack them into a heterostructures by using a layer-resolved splitting (LRS) technique [1,2]. This technique enables my group at MIT to explore unprecedented wafer-scale 2D heterodevices including integrated photonics, 3D neuromorphic computing, and microLEDs, which will be introduced in my talk.

While 2D heterostructures promise interesting futuristic devices, the performance of 2D material-based devices is substantially inferior to that of conventional 3D semiconductor materials. However, 3D materials exist as their bulk form, thus it is challenging to stack them together for heterostructures. Obviously, conformal coating of such single-crystalline bulks on 3D features is impossible. My group at MIT has recently invented a 2D materials-based layer transfer (2DLT) technique that can produce single-crystalline freestanding membranes from any compound materials with their excellent semiconducting performance [3,4]. This technique is based on remote epitaxy of single-crystalline films on graphene followed by peeling from graphene. Stacking of freestanding 3D material membranes will enable unprecedented 3D heterostructures whose performance is expected to be superior to that of 2D heterostructures. I will talk about our group's effort to apply single-crystalline freestanding membranes for flexible, conformal electronics as well as for 3D heterostructures.

Finally, I will conclude my talk by discussing perspectives of coupling 2D-3D freestanding membranes for 2D-3D mixed heterostructured devices that can be enabled by our LRS and 2DLT techniques [5].

- [1] J. Kim et al., "Layer-resolved graphene transfer via engineered strain layers", *Science*, 342, 833 (2013)
- [2] J. Shim, S. Bae, et al, and J. Kim, "Controlled crack propagation for atomic precision handling of wafer-scale two-dimensional materials" *Science*, 362, 665 (2018)
- [3] Y. Kim, et al, and J. Kim, "Remote epitaxy through graphene enables two-dimensional material based layer transfer" *Nature*, Vol. 544, 340 (2017)
- [4] W. Kong, et al, and J. Kim, "Polarity govern atomic interaction through two-dimensional materials", *Nature Materials*, Vol. 17, 999 (2018)
- [5] S. Bae, et al, and J. Kim, "Integration of bulk materials with two-dimensional materials for physical coupling and applications", *Nature Materials* (2019)

**You are cordially invited to attend!**