Material challenges and opportunities in next generation electronics: from non-silicon electronics to artificial neural networks

Jeehwan Kim
Department of Mechanical Engineering
Department of Materials Science and Engineering
Massachusetts Insitute of Technology
jeehwan@mit.edu

The current electronics industry has been completely dominated by Si-based devices due to its exceptionally low materials cost. However, demand for non-Si electronics is becoming substantially high because current/next generation electronics requires novel functionalities that can never be achieved by Si-based materials. Unfortunately, the extremely high cost of non-Si semiconductor materials prohibits the progress in this field. I will discuss about my group's efforts to address these issues. Our team has recently conceived a new crystalline growth concept, termed as "remote epitaxy", which can copy/paste crystalline information from the wafer remotely through graphene, thus generating single-crystalline films on graphene [1-2]. These single-crystalline films can be easily released from the slippery graphene surface, and the graphene-coated substrates can be reused infinitely to generate single-crystalline films. Therefore, the remote epitaxy technique can produce expensive non-Si semiconductor films with unprecedented cost efficiency while allowing additional flexible device functionality required for current ubiquitous electronics.

Lastly, I will discuss about an ultimate alternative computing solution that does not follow the conventional von Neuman method. As Moore's law approaches its physical limits, brain-inspired neuromorphic computing has recently emerged as a promising alternative because of its compatibility with AI. In the neuromorphic computing system, resistive random access memory (RRAM) can be used as an artificial synapse for weight elements in neural network algorithms. RRAM typically utilizes a defective amorphous solid as a switching medium. However, due to the random nature of amorphous phase, it has been challenging to precisely control weights in artificial synapses, thus resulting in poor learning accuracy. Our team recently demonstrated single-crystalline-based artificial synapses that show precise control of synaptic weights, promising superior online learning accuracy of 95.1% – a key step paving the way towards post von Neumann computing [3]. I will discuss about how we design the materials and devices for this new neuromorphic hardware.

[1] Y. Kim et al., and J. Kim, "Remote epitaxy through graphene: Role of underlying substrates on van der Waals epitaxy" ***Nature***, Vol. 544, 340–343 (2017)

[2] Wei Kong et al., and J. Kim, "Polarity governs atomic interaction through two-dimensional materials" ***Nature Materials*** (2018) *In Print*

[3] S. Choi et al, and J. Kim, "SiGe epitaxial memory for neuromorphic computing with reproducible high performance based on engineered dislocations," ***Nature Materials*** Vol. 17, 335–340 (2018)

Professor Jeehwan Kim is an Associate Professor of Massachusetts Institute of Technology in the Mechanical engineering and Materials Science and Engineering. He is a Principal Investigator in Research Laboratory of Electronics at MIT. Prof. Kim's group focuses on innovation in nanotechnology for next generation computing and electronics. Before joining MIT in 2015, he was a Research Staff Member at IBM T.J. Watson Research Center in Yorktown Heights, NY since 2008. Many of his patents have been licensed for commercialization. Prof. Kim is a recipient of 20 IBM high value invention achievement awards. In 2012, he was appointed a "Master Inventor" of IBM in recognition of his active intellectual property generation and commercialization of his research. He is an inventor of 200 issued/pending US patents and an author of 40 articles in journals. He received his B.S. from Hongik University, his M.S. from Seoul National University, and his Ph.D. from UCLA in 2008, all of them in Materials Science.

Email: jeehwan@mit.edu ● Website: http://jeehwanlab.mit.edu/