A zero-nanometer technology for electromagnetic wave control

Dai-Sik Kim[1,2,3,4]

[1]Department of Physics, Ulsan National University of Science and Technology, Korea

[2]Quantum Photonics Institute, Ulsan National University of Science and Technology, Korea

[3]Center for Angstrom Scale Electromagnetism, Ulsan National University of Science and Technology, Korea

[4]Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea

E-mail: daisikkim@unist.ac.kr

Modern nanotechnologies such as scanning tunneling microscopy (STM) and atomic force microscopy (AFM) heavily rely on our ability to control and maintain the gap width between two objects, often with sub-nanometer precisions. However matured these quantum technologies are, their applications are limited to imaging or to single molecular manipulations because of the small device footprints of the point-like, 1 nm^2 variable gap architectures. We refer to the AFM and STM technologies and the scanning probe microscopies (SPM) in general '0-dimensional gaptronics'. For photonic applications encompassing the microwave and terahertz regime, we need to vastly increase the effective area of gap control, to truly a macroscopic scale. We addressed this issue by extending picometer distance controllability to the wafer-length and -scale. Based on atomic layer lithography, high aspect ratio-nanotrenches of 10 nm width, up to 2 cm-long are fabricated by etching-out the alumina spacer, on a flexible substrate[1]. While our as-fabricated structure can be transparent to electromagnetic waves owing to the slot antenna action of the nanotrenches, inherently embedded point-contacts become activated when gentle bending closes the gap. Quantum plasmonic actions over the uniform length of nanotrenches traversing tunneling, quantized conductance and semi-classical regimes produce an extinction better than 10,000 repeatable over 10,000 times in real time that can alter resonance and symmetry as well. We also present a zero-gap technology[2], whereby sequential depositions with pre-patterned objectives result in tunable gaps that start from full contact-zero nanometer to hundreds of nanometers with excellent fidelity. Our results have far-reaching implications in bridging the gap between the quantum world to the macroscopic one and we anticipate wide ranging applications in radiation and molecular sensing, quantum conductances measurements, electrochemistry and photocatalysis. A brief introduction of our graduate school will also be given.

REFERENCES

[1] Dasom Kim, Hyeong Seok Yun, Bamadev Das, Jiyeah Rhie, Parinda Vasa, Young-Il Kim, Sung-Hoon Choa, Namkyoo Park, Dukhyung Lee, Young-Mi Bahk, and Dai-Sik Kim., "Topology-Changing Broadband Metamaterials Enabled by Closable Nanotrenches," *Nano Letters*, vol. 21, no. 10, p. 4202, 2021.

[2] B. Das, H. S. Yun, N. Park, J. Jeong, and D. S. Kim, “A transformative metasurface based on zerogap embedded template,” *Advanced Optical material*, vol. 9, p. 2002164, 2021.