Biomimetic Si nanotips and their hetero-junctions: from moth-eye to LEDs and supercapacitors

Li-Chyong Chen[a*] and Kuei-Hsien Chen[b]

[a]Center for Condensed Matter Sciences, National Taiwan University, Taipei 106, Taiwan

[b]Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei 106, Taiwan

The periodic sub-wavelength structures as antireflection (AR) surfaces were first discovered in nature while inspecting the eyes of night-flying moths by Bernhard in 1967. Several other interesting biological species with similar micro-features have also been known that manipulates light [*Mater. Sci. Eng. Rev.*, **2010**, *69*, 1-35]. We have shown that, by using the self-masked dry etching technique, arrayed silicon nanotips (SiNTs) with high aspect ratios can be fabricated, on planar Si wafers monolithically, which can render the wafer to be black and shine-less. Remarkably, such a man-made moth eye suppresses reflection of light from ultraviolet to the terahertz frequency region, a world-record broad band coverage, and its AR property also holds good for a wide angle of incidence and both *s* and *p* forms of polarizations of light [*Nature Nanotechnology*, **2007**, *2*, 770-774].

In this talk, several examples of nano-scale hetero-junctions based on SiNTs array will be presented. Owing to the localized field effect at the nanoscale-sharp apex of the tip under applied bias, enhancement in electrically driven device performance and novel field-induced properties are anticipated. An ultralow turn-on field and a higher attainable emission current density have been demonstrated for the SiNTs. The electroluminescence properties of the light emitting diode (LED) consisted of ZnO/SiNTs hetero-junctions are found to be enhanced by the tip structure. These tip-structured LEDs are energy-efficient, namely, they offer more light emission at a much lower turn-on voltage than their thin-film counterparts [*Nano Lett.*, **2009**, *9*, 1839-1843]. Meanwhile, when ZnO and aluminum oxide (Al_2O_3) bi-layer dielectric is deposited on the SiNTs using atomic layer deposition to form a 3D trenched-structured metal-insulator-metal nano-capacitor array, ultra-high value of equivalent planar capacitance (~300 μF cm^{-2}) is achieved, which is about 30 times higher than those previously reported [*Nano Lett.*, **2013**, *13*, 1422-1428]. More examples for highly functioning devices using SiNTs-based hetero-junctions will also be illustrated. Our approach opens up new possibilities to Si-based nano-structured sensors, optoelectronic, supercapacitor, spintronic and photovoltaic devices with standard ultra-large-scale integrated technology.

Keywords:
Si, nanotips, hetero-junctions, antireflection, light emitting diode, supercapacitor