## Summer Fellowships

Each year ECS awards up to five Summer Fellowships to assist students in continuing their graduate work during the summer months in a field of interest to the Society. Congratulations to the five Summer Fellowship recipients for 2014. The Society thanks the Summer Fellowship Committee for their work in reviewing the applications and selecting five excellent recipients. Applications for the 2015 Summer Fellowships are due January 15, 2015 (see http://www.electrochem.org/awards/student/student_awards.htm#n).

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## The 2014 Edward G. Weston Summer Research Fellowship – Summary Report

# Electrodeposition of Hybrid Core-Shell Nanowires

*by Tuncay Ozel*

As an environmentally friendly alternative energy conversion device, solar cells are used to convert solar energy into electric current. Demonstration of electrically and optically favorable, fully absorbing, yet ultrathin semiconductor layers for solar cells is a key scientific challenge.[1-4] For example, designing nanowires with a core-shell type semiconductor segment can improve the carrier collection with radial charge separation, whereas integration of plasmonic nanostructures can enhance the photocurrent generation with intensified electric fields.[1,4-7] However, a full understanding of the mechanisms behind the electrical and optical enhancement processes is still under debate due to a lack of control over the geometry during the synthesis of nanostructured semiconductor segments and lack of precise integration of the plasmonic structures.

Herein, we present the electrochemical deposition of light harvesting hybrid core-shell nanowires with plasmonic nanoantenna segments with excellent control over the size and composition of the nanowire segments resulting from the expertise developed in our lab using the on-wire lithography (OWL) technique.[8,9] We electrochemically deposited gold and polymerized 3-hexylthiophene (P3HT) segments in porous alumina membranes. While gold is mechanically stable after electrodeposition, vacuum treatment induces isotropic shrinking of the P3HT segment, leaving room around the periphery of the P3HT core for the synthesis of shell segments.[10] An n-type cadmium selenide (CdSe) shell was co-electrodeposited using a solution of Cd and Se atoms to create a p-n junction interface. Finally, a top gold segment was deposited under constant potential. Gold segments deposited on both ends of the semiconductor segment serve both as plasmonic antennas and metallic leads for electrical characterization. A scanning transmission electron microscope image (top) and simulated electric field intensity maps (bottom) of a typical nanowire (diameter: ~74 nm) are presented in Fig. 1a. Simulation results highlighted the intensity and position of the localized electric fields around the core-shell semiconductor segment. Experimentally measured extinction spectra of such nanowires dispersed in solution showed two distinct plasmon resonances, demonstrating the tunability of the plasmonic antenna resonance wavelength by tailoring the length of the gold nanorods on opposite sides of the semiconductor segment (Fig. 1b). Emission intensity of the P3HT core considerably dropped as the

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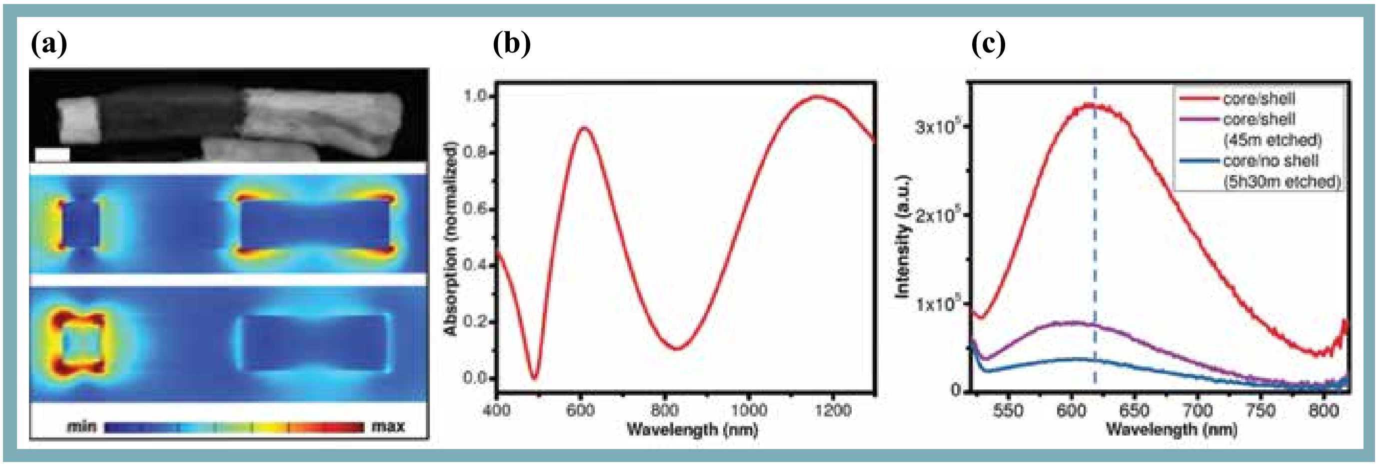


**Fig. 1.** *(a) Scanning transmission electron microscope image (scale bar equals to 50 nm), and electric field intensity maps (recorded at 600 nm 1170 nm) of a hybrid core-shell nanowire. (b) Experimental extinction spectrum, and (c) emission spectra of the nanowires dispersed in solution.*

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CdSe shell segment was removed selectively, signifying the advantageous optical properties of depositing the shell segment (Fig. 1c). Additionally, the current-voltage characteristics of a single nanowire device (diameter: ~280 nm) showed significant photocurrent generation under illumination (Fig. 2), with a notable ~125 fold on/off ratio (under 30 mW/cm$^2$ excitation at 3 V potential bias), demonstrating the functionality of the nanowires prepared using this method.

In summary, our method of template assisted electrodeposition of multisegmented core-shell nanowires via polymer shrinking creates a platform to synthesize the next generation of plasmon enhanced self-standing nanoelectronic devices such as photodetectors, solar cells, and light emitting diodes. We expect this synthetic capability to be very useful for exploring novel plasmonically enhanced nanoelectronic devices.

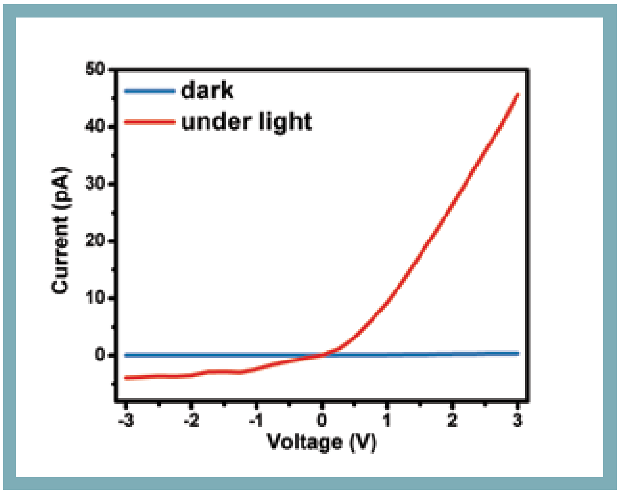


**Fig. 2.** *Electrical characterization of a hybrid core-shell nanowire with and without illumination.*

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## About the Author

**Tuncay Ozel** is currently pursuing a PhD under the supervision of Prof. Chad Mirkin, in the Department of Materials Science and Engineering at Northwestern University, IL. His thesis project focuses on the integration of plasmonic nanostructures into coaxial nanowires to study fundamental light-matter interactions and fabricate optoelectronic devices for nanophotonic applications. He may be reached at ozel@u.northwestern.edu.

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