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High Resolution Scanning Electron Microscopy of Surface Functionalized Nanocoax Biosensors

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This study reports on an extension of previous work which utilized an adaptation of a nanocoax array architecture for high sensitivity chemical sensing, where parts per billion detection sensitivity to volatile organic compounds (VOC's) in dry air was demonstrated with nanoporous coax annuli [1].

This unique architecture is now being extended to biological sensing by modifying and functionalizing the coax metal surfaces to enable specific binding of target molecules (eg. proteins, toxins and pathogenic organisms), and by using capacitance/impedance spectroscopy, determine their presence with a similar sensitivity to the VOC's (down to a few tens of molecules per coax).

In order to confirm the selective functionalization of the desired surfaces in the nanocoax structure, a proxy for target molecules was used. Streptavidin-functionalized core-shell CdSe/ZnS quantum dots were introduced to the nanocoax sensing array. These samples were then examined using a JEOL JSM-7600F field emission scanning electron microscope. An effective accelerating voltage of 1 kV was used by applying a 3 kV accelerating voltage at the electron source, and a 2 kV bias to the sample, enabling high spatial resolution imaging of the quantum dots by maximizing the spatial resolution at low voltage, yet minimizing the beam/sample interaction volume to allow for highly surface sensitive imaging. This was essential in order to discern the quantum dots from the granular surface structure of the metal films of the samples. An in-lens secondary electron detector was used for all imaging.

For the first step, Au coated nanopillars were functionalized and the quantum dots introduced to the structure. Representative images of a control sample and the functionalized sample are shown in Fig. 1. The quantum dots are clearly evident in the functionalized sample, giving a "measles-like" appearance to the nanopillar (for example, in the circled area). However, the non-functionalized control sample is clearly devoid of the quantum dots, indicating that the functionalization was effective.

The next step in the study was to proceed further with the complex fabrication process to transform the nanopillars into the nanocoax architecture, involving several deposition and etching procedures. An example of a functionalized nanocoax is shown in Fig.2. The inner annulus was indeed found to have captured to quantum dots, as indicated by the "measles-like" appearance indicated in the elliptical region shown. These initial results, combined with improvements made in the fabrication process, demonstrate that the nanocoax based biological sensor shows excellent promise. The next steps will include substituting antibodies for the quantum dots and measuring the capacitance and impedance response after the introduction of proteins in serum, with the goal of achieving a sensitivity matching or exceeding that already shown by this sensor for VOC's.

References:

[1] Zhao Z.F., Rizal B., McMahon G., Wang H., Dhakal P, Kirkpatrick T., Ren Z.F., Chiles T.C., Cai D. and Naughton M.J. (submitted 2012)

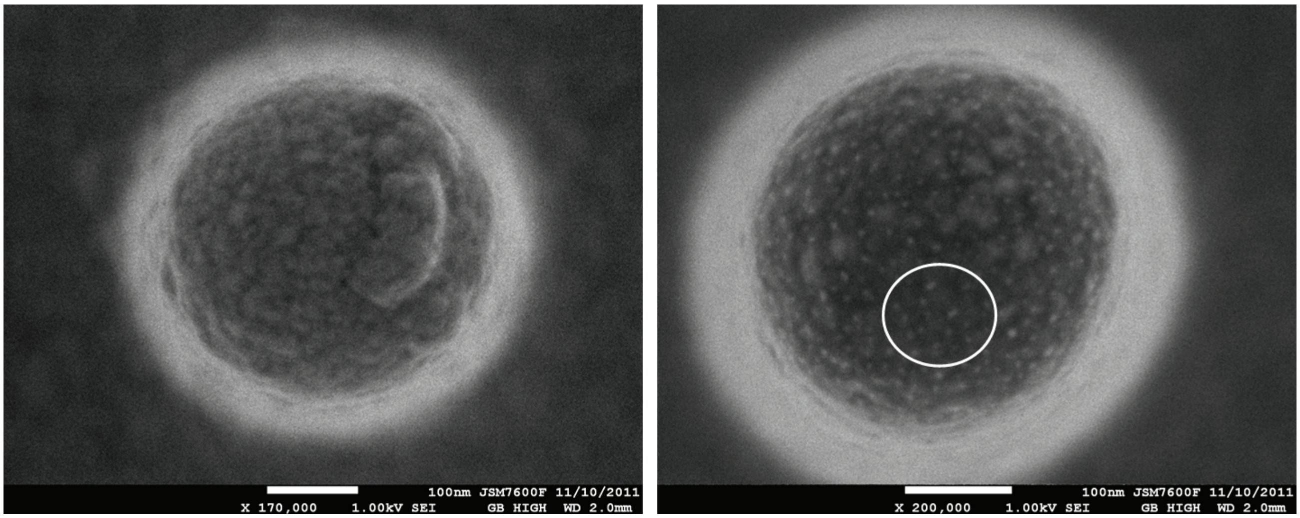

Fig. 1. Non-functionalized (control) nanopillar sample (left) and functionalized nanopillar sample (right). The quantum dots on the functionalized sample are clearly evident, giving a "measles-like" appearance to the structure (eg. within circle) that is clearly not observed in the control sample.

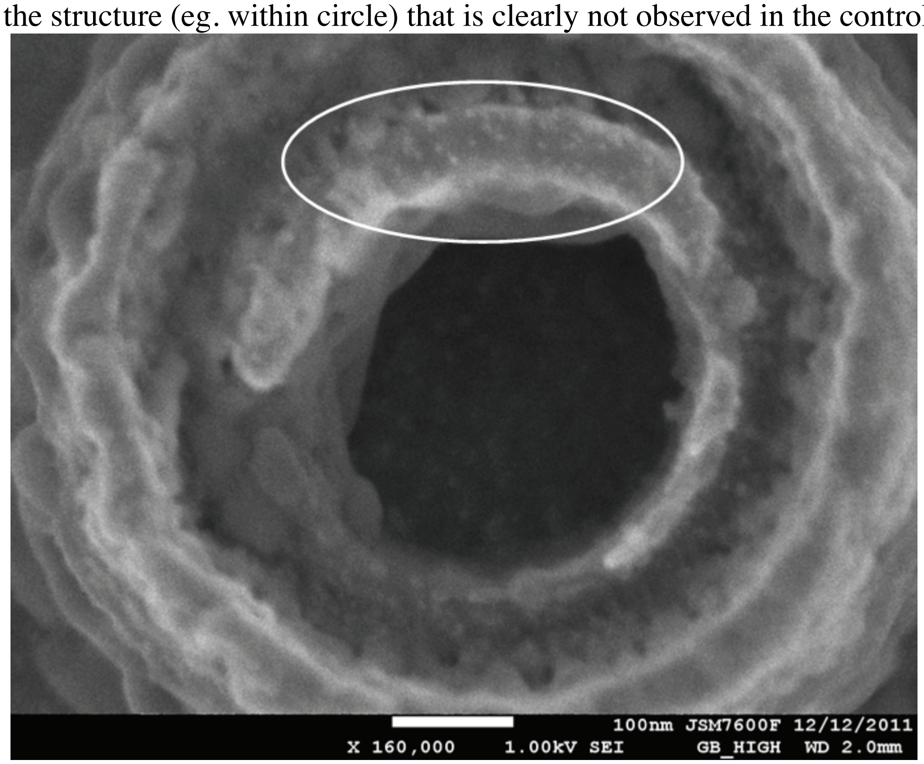

Fig. 2. Functionalized nanocoax sensor showing captured quantum dots at the inner annulus (indicated within the ellipse).