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Neuromorphic Systems Based on Nanoantennas for Renewable Energy Applications

John Eder Sanchez[1], Miguel José Yacaman[2] and Francisco Javier Gonzalez[1]

[1.] Laboratorio Nacional de Ciencia y Tecnología de Terahertz/Universidad Autonoma de San Luis Potosí, San Luis Potosí, México.
[2.] Department of Physics and Astronomy/University of Texas at San Antonio, San Antonio, USA.

Neuromorphic systems represent the new generation of nano-arrays for opto-electronic applications aimed to harvest energy conversion, data transmission, storage technologies and renewable high energy consumption. For instance, by controlling the geometrical arrangement at nanoscale level, it is possible to have a metal-semiconductor array that resembles a nanoantenna that responds to a particular frequency by varying the geometrical space between elements as well as its morphology. In fact, in the fabrication of neuromorphic arrays, it is useful to consider the coupled properties that exhibit the metal-semiconductor pair in order to generate a system that resembles an antenna. Though, Ag-Au, Cu-Au, Pt-Au, Pt-Ag alloys are being studied because of the plasmonic resonance properties exhibit at nanoscale level useful for neuro and plasmonic applications, it is metal semiconductor systems such as; (silver/zinc oxide) Ag/ZnO that have become greatly recognized as an active element capable to act as receptor/emitter (Ag-metal/ZnO-semiconductor) because of the combined properties of the metal-semiconductor system. Hereafter, we report the fabrication and electrical characterization of Ag/ZnO, resembling a 3D nanoantenna, by coupling ZnO nanorods on silver nanowires as active elements for neuromorphic applications. A combine growth process was employed; wet chemical and microwave irradiation, in order to growth the 3D nanostructures. Figure 1 A), shows a SEM image of ZnO nanorods growing along the metallic faces (110) of silver nanowires, it is believed that the highly polar faces (110) exhibited on the silver nanowires along with polar planes (001-Zn) on ZnO nanorods induced the epitaxial growth. In fact, the nanoassembly could be compared with a schematic of the pixel from the Mahowald retina. It is possible to get an output potential between the local core (silver nanowire) and that of the ZnO semiconductor nanorods when radiated with an external illumination source in order to reach a stimulate impulse across the silver nanowire, (Figure 1 B)). Furthermore, to study the morphology and crystal characterization, crystallographic orientation phase maps have shown a highly ordered assembly of ZnO nanorods distributed epitaxially along silver nanowires for three different orientations x, y, and z (Figure 2). In addition, to understand the electrical properties of the metal-semiconductor nano-system, a Ag/ZnO nanostructure was manipulated by using an Omniprobe coupled to an FIB system with the aim of placed it on an electrical TEM grid (Figure 3(A-D)). Figure 3 (E) shows an *in-situ* TEM electrical measurements, the *V-I* curves shows a diode-type behavior, exciding the threshold current around10 nA, revealing the metal-semiconductor behavior exhibited for the coupled nanostructure.

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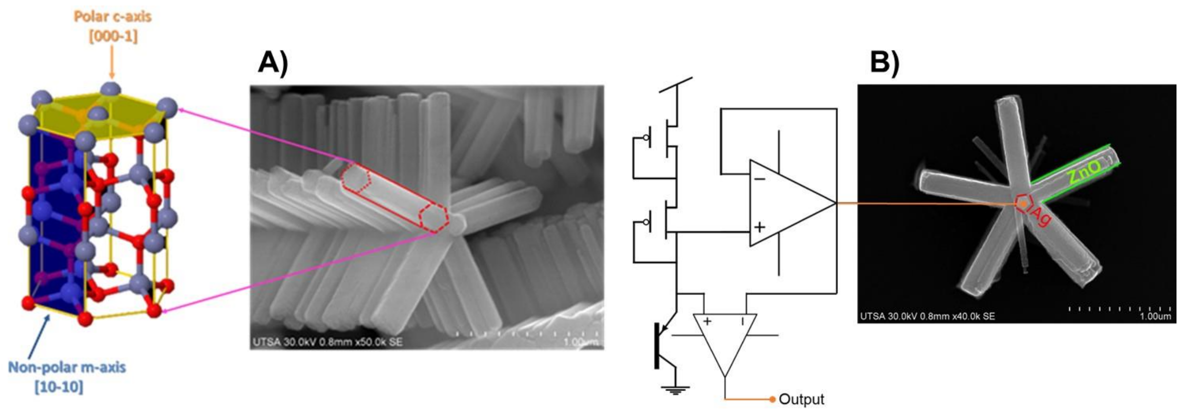

Figure 1. (A) SEM image of Ag/ZnO system resembling a 3D nanoantenna, ZnO nanorods growth epitaxially along the exposed faces of the silver nanowire. (B) Schematic of a pixel from the Mahowald [1] retina compared with a 3D nanoarrays, resembling a neuromorphic system.

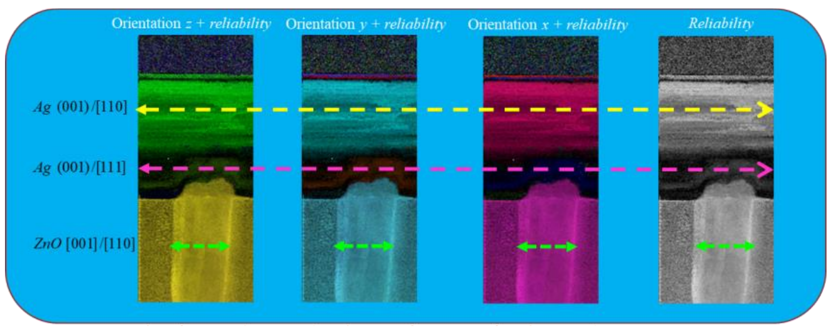

Figure 2. Crystallographic orientation phase maps, ZnO/Ag interface, by using precession electron diffraction (PED) for three different orientations x, y, and z.

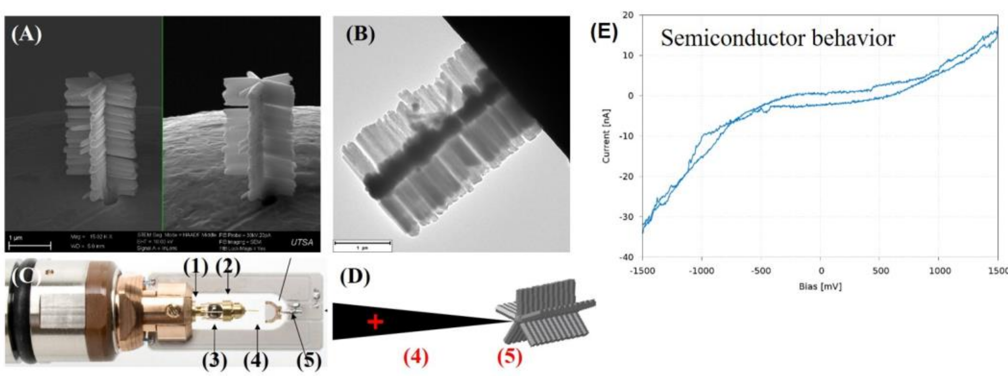

Figure 3. (A-D) FIB/nanomanipulation of nanoantennas is performed by locating an isolated nanostructure on an electrical TEM grid by using an Omniprobe coupled the FIB system. (E) *in-situ* TEM electrical measurements of Ag/ZnO.

[1] C Mead, IEEE, **volume 78** (1990), p. 1632.
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