Vertically Aligned ZnO Nanowires as Potential Nanoelectronic Building Blocks
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1. Introduction
Several studies have been performed on the fabrication and possible usage of quasi-one-dimensional nanostructures. An example of these nanostructures is ZnO nanowires (ZnO NWs). Horizontal ZnO NWs can be easily fabricated using chemical-vapor deposition. In this project, however, we focus on arrays of vertically-aligned NWs in a highly ordered template of anodic alumina oxide (AAO) membranes. Pulsed electrodeposition (PED) is the method used to literally deposit Zn into the pores of the membrane. Atomic-force microscope (AFM) technique is used to characterize the electron transport characteristics of the Zn NWs. In order to obtain ZnO NWs, annealing is used to oxidize the Zn nanowires. These ZnO NWs are building blocks for nanoscale field-effect transistors for logic gates, high density data storage and other ultra-high density integrated circuits.

2. The fabrication method
Aluminum is first mechanically and electrochemically polished, followed by a two-step anodization process. Gold/Titanium is then evaporated on one side of the membrane to serve as a working electrode. After removing the top aluminum layer, AAO membranes are left on the substrate and ready for the pulsed electrodeposition. Figure 1 shows a picture of the device before the PED:

3. The pulsed-electrodeposition (PED)
PED is the method used to deposit Zn inside the holes of the AAO membranes. In aqueous deposition solutions, the high cathodic potentials cause some hydrogen evolution which can prevent the deposition. Hence, the delay time between pulses in the PED will compensate for the slow diffusion driven transport of Zn$^2+$ into the pores, improving the filling factor of the holes, and consequently, the density of the NWs in the AAO membranes. Figure 2 shows SEM pictures of DC and pulsed electrodeposition methods and the improvement of the filling factor.

4. Characterization of Zn NWs
Atomic force microscopy is used to characterize the morphology of the AAO membrane with Zn NWs inside (Figure 3) and the electron transport characteristic of individual Zn NW (Figure 4). The $I$-$V$ curve in Figure 4B shows indeed that there is a conducting channel between the tip of the probe and the bottom electrode. Furthermore, the curve shows that there is a Schottky contact between the tip and the Zn NWs because the top layer of Zn NW has been naturally oxidized. X-Ray Diffraction (XRD) spectra in Figure 5 also show Zn peaks, which is another proof of the existence of the Zn NWs.

5. Potential Building Blocks
The as grown Zn NWs are to be annealed and thus, oxidized to obtain a semiconductor behavior. Figure 6 from AFM shows the oxidation of Zn on the surface of the membrane after annealing for 2hrs. After obtaining ZnO NWs, top electrodes will be made using e-beam lithography, forming a standard three electrode device. With this structure, transistors are expected to be fabricated and used in integrated circuits and other nanoscale devices.

6. Conclusion
Zn NWs were fabricated in highly ordered AAO membranes. PED is used to deposit Zn in the holes of the membranes. ZnO NWs are expected to form after the annealing process, creating the desired semiconductor behavior. Top electrodes will be evaporated, and transistors will be made out of the vertically aligned ZnO NWs, which will serve as potential building blocks for nanoscale devices.

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