Analysis of nanowire growth on AAO templates with various electrodes

Jessica Talbert[1,2], Manvitha Marni[2,3], Daniel Adams[1,2], Nicolas Vargas[1,4], Kevin Stokes[1,2], Leonard Spinu[1,2]

[1]AMRI, University of New Orleans [2]Department of Physics, University of New Orleans [3]Washington University in St. Louis [4]Universidad de Santiago de Chile

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Abstract

This project compared the growth of Ni nanowires, grown on AAO templates through electrodeposition. Three different metals were used as electrodes, and the resulting nanowires were analyzed using the VSM and SEM to determine if the choice of electrode affected the properties of the wires. The wires grown on silver- and copper-platinum-titanium-sputtered templates appeared similar, but the same procedure yielded no nanowires when aluminum was used as the electrode.

Introduction

Due to their small size, conductance, data storage capabilities, and ferromagnetic properties nanowires are an important component of modern electronics. To better understand the application of Faraday's Law of Electrolysis in the electrodeposition of these nanowires, one variable, time, was isolated in this project to determine its affect on the nanowire length. Although Faraday's Law does not include values related to the electrode, a series of nanowires was replicated using each electrode to determine if the properties of these nanowires were affected.

Methods

For each set of nanowires, a commercial-grade anodic aluminum oxide (AAO) template was coated in approximately 165 nm of the chosen electrode. The three electrodes tested were silver, aluminum and copper, which was covered with platinum and titanium to prevent oxidation. The sputtered templates were placed in a chamber filled with nickel sulfamate solution and run through electrodeposition for the times shown in Table 1. The theoretical lengths of the wires were calculated using Faraday's Law of Electrolysis (Eqn. 1). The porosity of the template was determined using an SEM image like that in Figure 3.

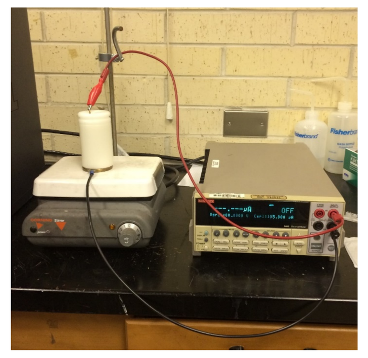

Figure 1: Electrodeposition setup

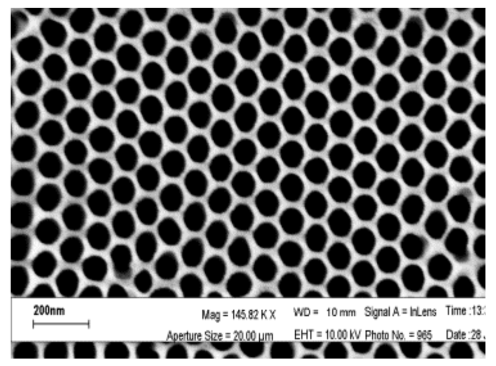

Figure 2: SEM image of lab-grade AAO template

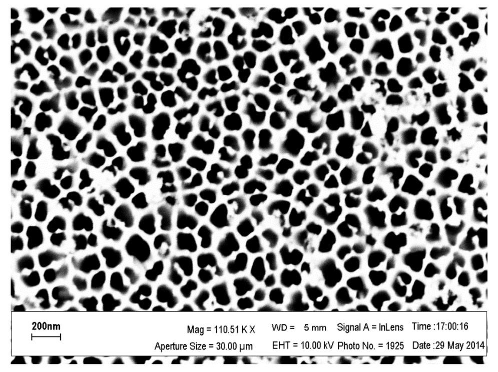

Figure 3: SEM image of commercial-grade AAO template

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Characterization

The grown nanowires were analyzed using a vibrating sample magnetometer (VSM) and a scanning electron microscope (SEM).

VSM: The VSM was used to determine if nanowires had grown and, if so, what their saturation magnetization was.

SEM: Pictures of the nanowires were taken with the SEM. These images were analyzed in ImageJ to find the true length (graphical length) of the nanowires. The graphical length was compared to the length predicted by Faraday's law of Electrolysis (Eqn. 1), which, given the duration of the electrodeposition, can be used to calculate the anticipated length (theoretical length) of the nanowires.

$$l = 10MIt/\rho FzpA$$

Eqn. 1: Faraday's Law of Electrolysis, where p and A are porosity and area of the template, respectively, and t is growth time

EPR: Electron paramagnetic resonance (EPR) was used to analyze the nanowires grown on the Cu-Pt-Ti-sputtered templates (see Figure 12), but data was not obtained for the other electrodes.

Results

Electrode	Growth Time	Theoretical Length	Graphical Length
Cu/Pt/Ti	42 m 44 s	4.34 microns	3.036 microns
Cu/Pt/Ti	1 h 45 m	12.6 microns	12.74 microns
Cu/Pt/Ti	2 h 8 m 12 s	13.02 microns	15.45 microns
Ag	35 m 30 s	4.34 microns	3.52 microns
Ag	1 h 28 m 49 s	10.66 microns	9.53 microns
Ag	1 h 47 m 38 s	13.02 microns	5.33 microns
Al	35 m 30 s	4.34 microns	0 microns
Al	1 h 28 m 49 s	10.66 microns	0 microns
Al	1 h 47 m 38 s	13.02 microns	0 microns

Table 1: Table of growth times and lengths of nanowires

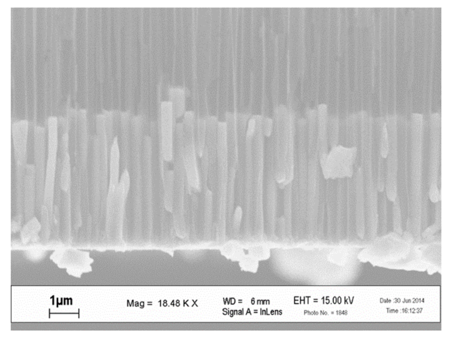

Figure 4: SEM image of nanowires grown on Cu

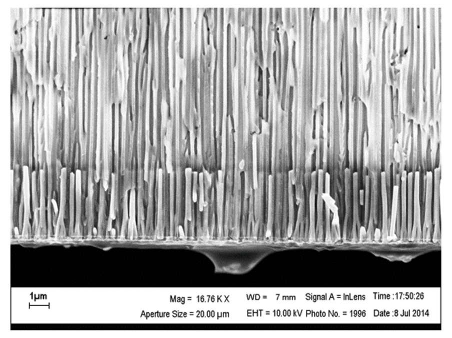

Figure 5: SEM image of nanowires grown on Ag

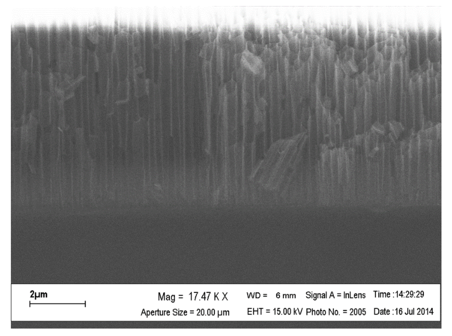

Figure 6: SEM image of nanowires grown on Al

Results (cont.)

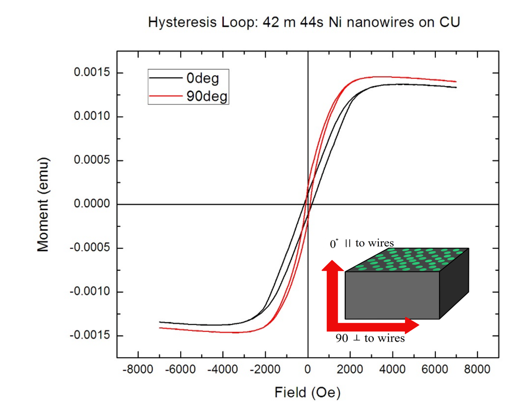

Figure 7

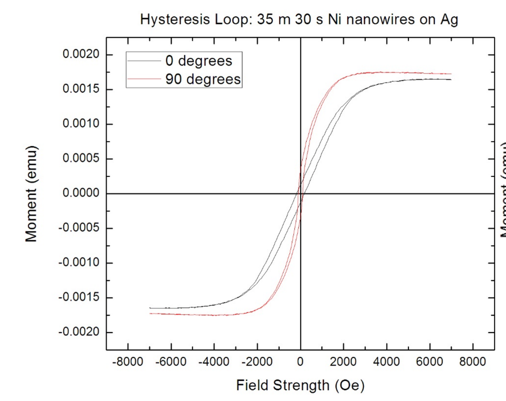

Figure 8

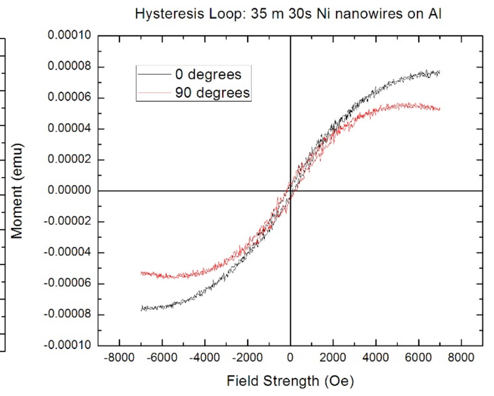

Figure 9

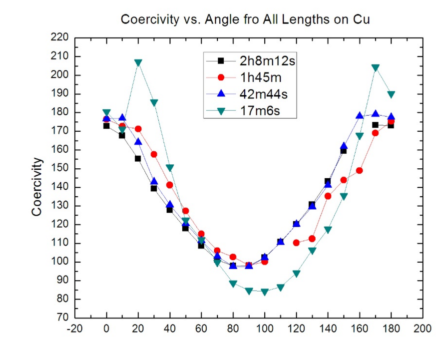

Figure 10

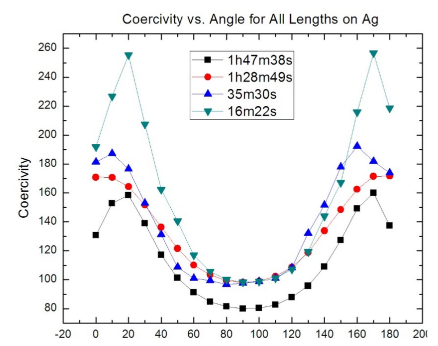

Figure 11

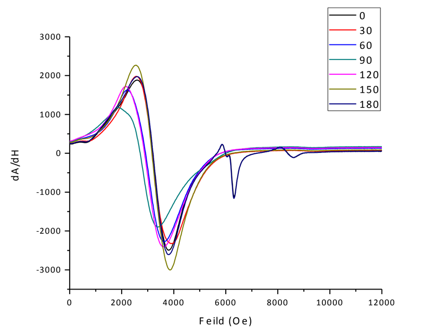

Figure 12: EPR data for 1h 45m wires on Cu

Discussion

As shown in Table 1 and Figure 6, no nanowires grew on the Al-sputtered templates. This result is supported by the VSM data for the wires grown on Al (see Figure 9). The lack of wire growth may be due to the standard reduction potential of Al, which is less than the standard reduction potential of Ni.

In contrast, Cu and Ag (and Au, used successfully in prior experiments) all have reduction potentials greater than that of Ni. Future experiments might be able to successfully grow Ni nanowires on an Al-sputtered template if the circuit is reversed so that the template serves as the anode rather than the cathode.

References

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