Properties of Magnetic Nanostructured Materials

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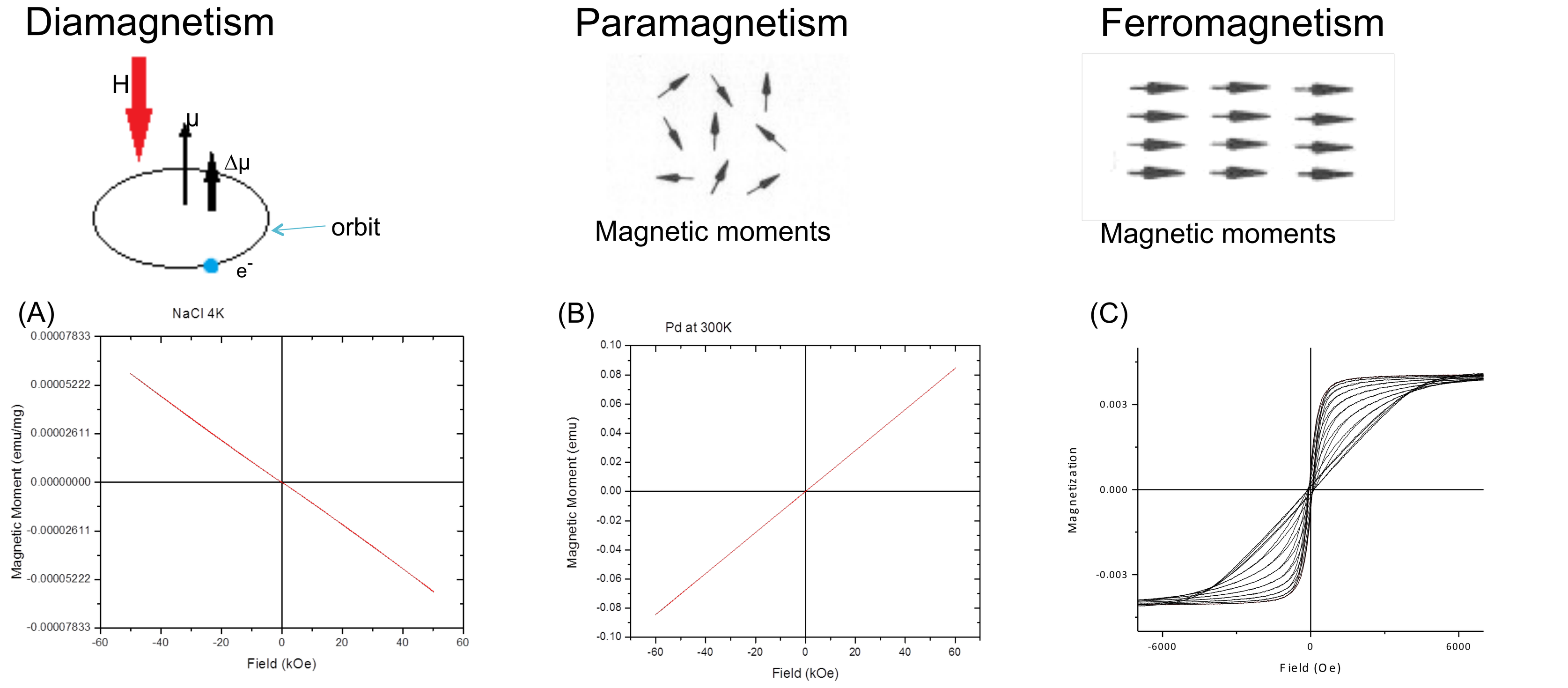
Abstract

This study focused on analyzing magnetic properties of nickel nanowires grown by electrodeposition in anodized aluminum oxide templates with pore size of 200 nm. Wires of lengths of 3, 12, and 15 µm were grown to investigate how magnetic behavior differs with varying aspect ratios. The static magnetization properties were studied using a vibrating sample magnetometer (VSM) and the dynamic magnetization properties were studied using X-band ferromagnetic resonance measurements.

Introduction

Types of Magnetism



NaCl (salt) was chosen as a diamagnetic material. The slope is negative which indicates the material is diamagnetic.

Palladium was chosen as a paramagnetic material. The slope is positive which indicates the material is paramagnetic.

Nickel was chosen as a ferromagnetic material. The graph shows that the material retains its magnetic properties even when the applied field is zero.

FIGURE 1 (A) SQUID measurements of NaCl at 4K. (B) SQUID measurements of Pd at 300 K. (C) Magnetic Hysteresis Loops from VSM measurements of Ni nanowires with a length of 12 µm. This graph shows angular variation of wire axis with respect to the applied field from 0º to 90º. 0º is defined as the having wire axis along the direction of the applied field.

Nanostructured Materials

Magnetic nanomaterials have important information technology applications. They can be used in devices such as digital recording media, microwave filters, and sensors.

Nanowires were fabricated through electrodeposition using an anodized aluminum oxide (AAO) commercial template at a current of 2 mA. Length was controlled by deposition time and predicted by Faraday's Law.

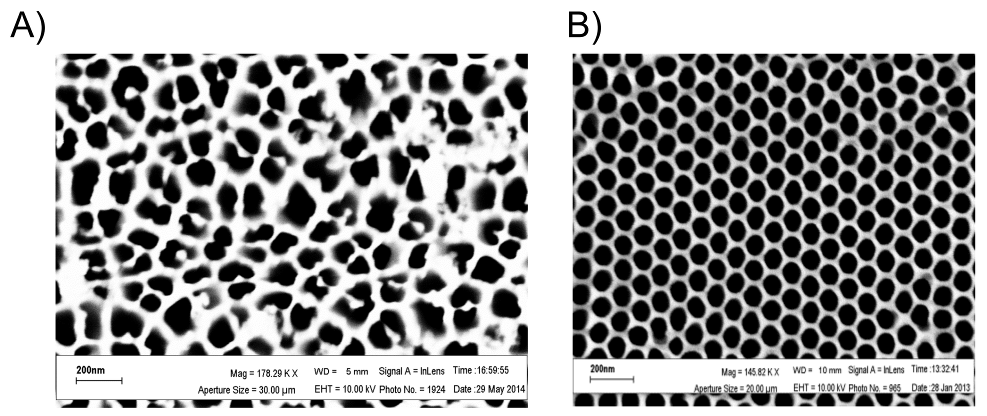


Figure 2 (A) Commercial AAO template. (B) AAO template made in the lab. This lab-made template has a higher porosity than the commercially-made template.

Experimental Results

Scanning Electron Microscopy (SEM)

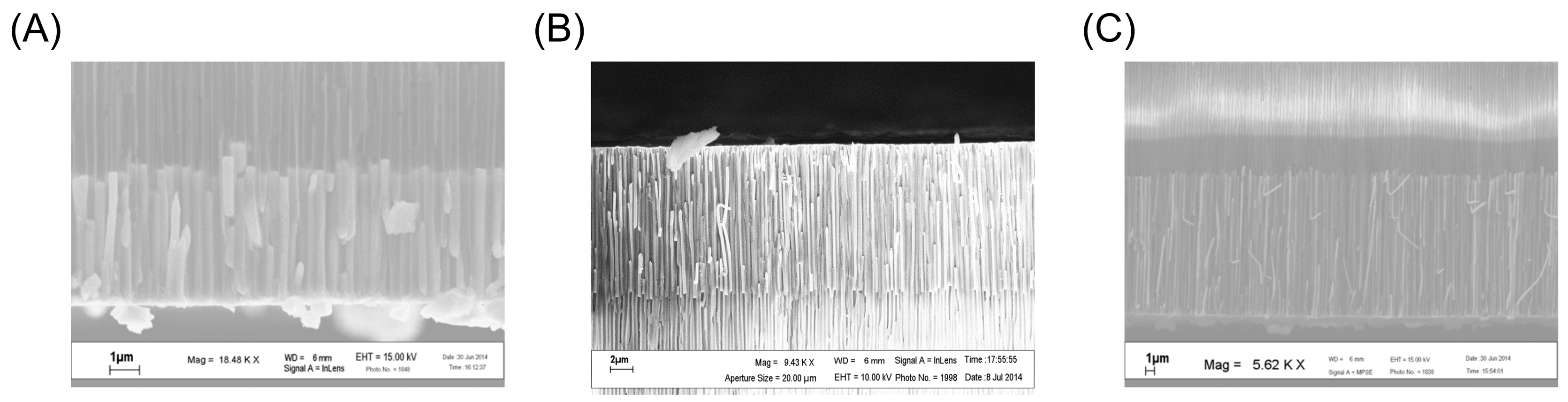


FIGURE 3: (A) SEM image for 3.04 µm Ni nanowires. (B) SEM image of 12.74 µm Ni nanowires. (C) SEM image of 15.45 µm Ni nanowires.

Magnetic Hysteresis Loops

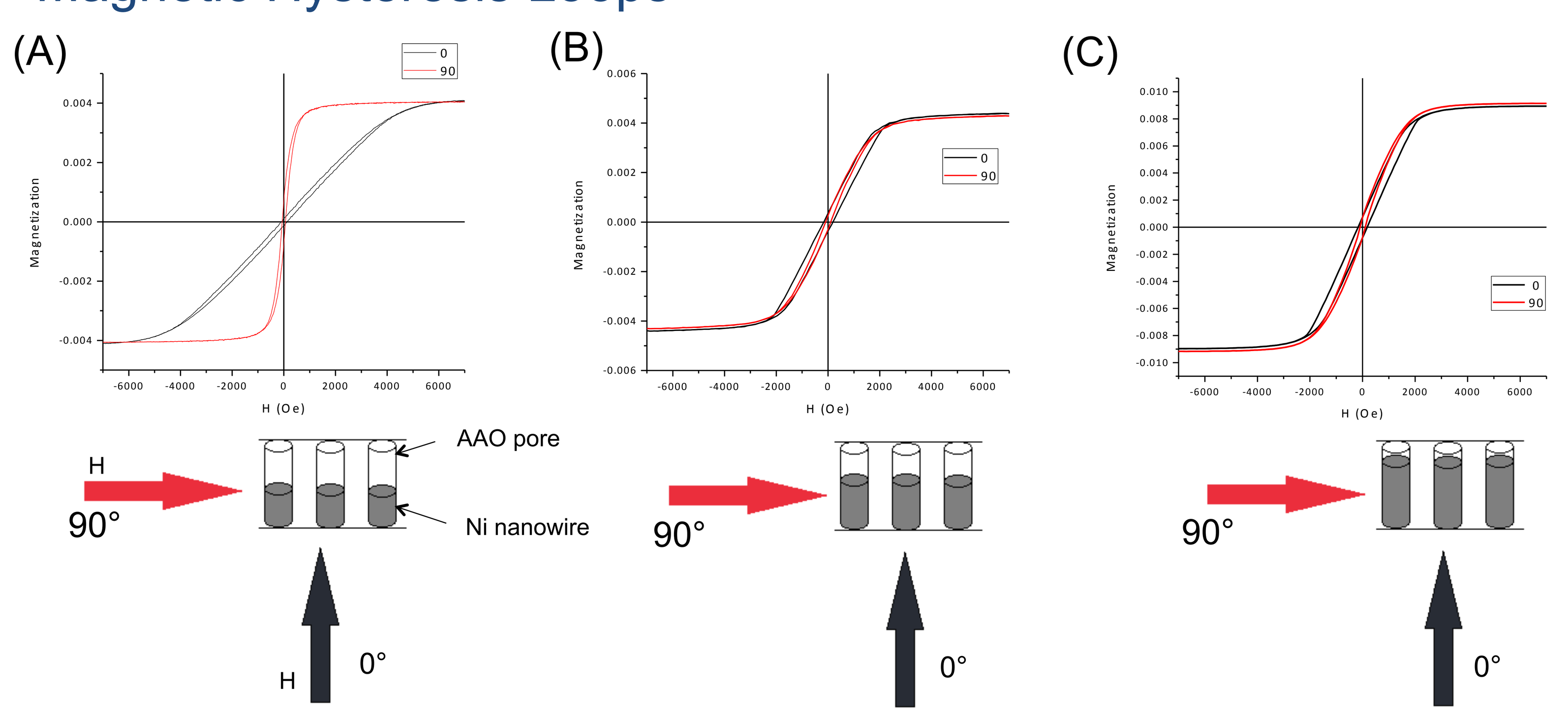
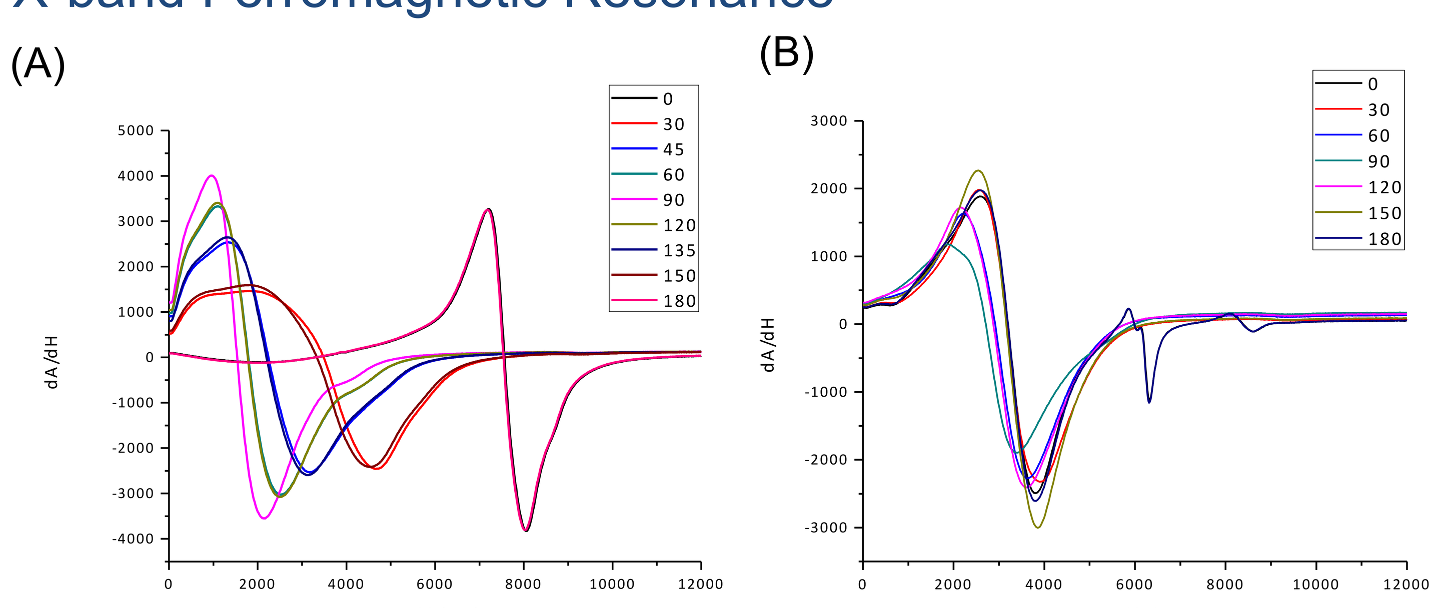


FIGURE 4 (A) 3.04 µm Ni nanowires. (B) 12.74 µm Ni nanowires. (C) 15.45 µm Ni nanowires. (A, B, and C) Magnetic Hysteresis Loops when field is parallel to the nanowire axis (0º) as well as when field is perpendicular to the wire axis (90º).

X-band Ferromagnetic Resonance



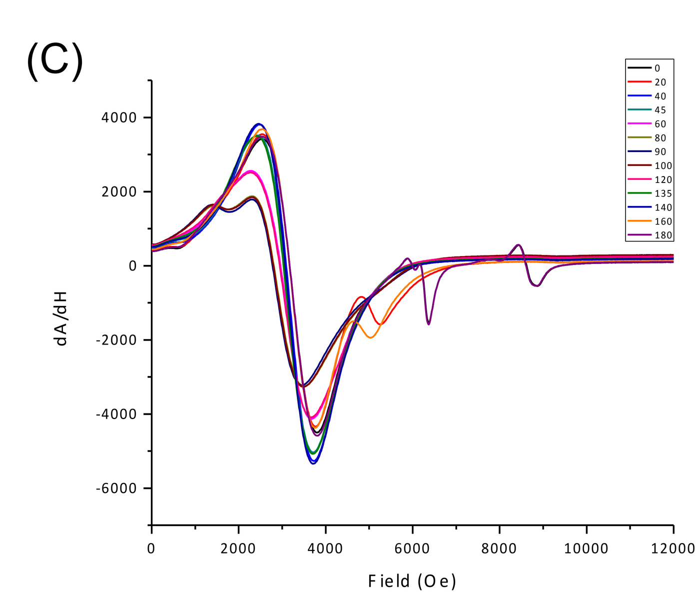
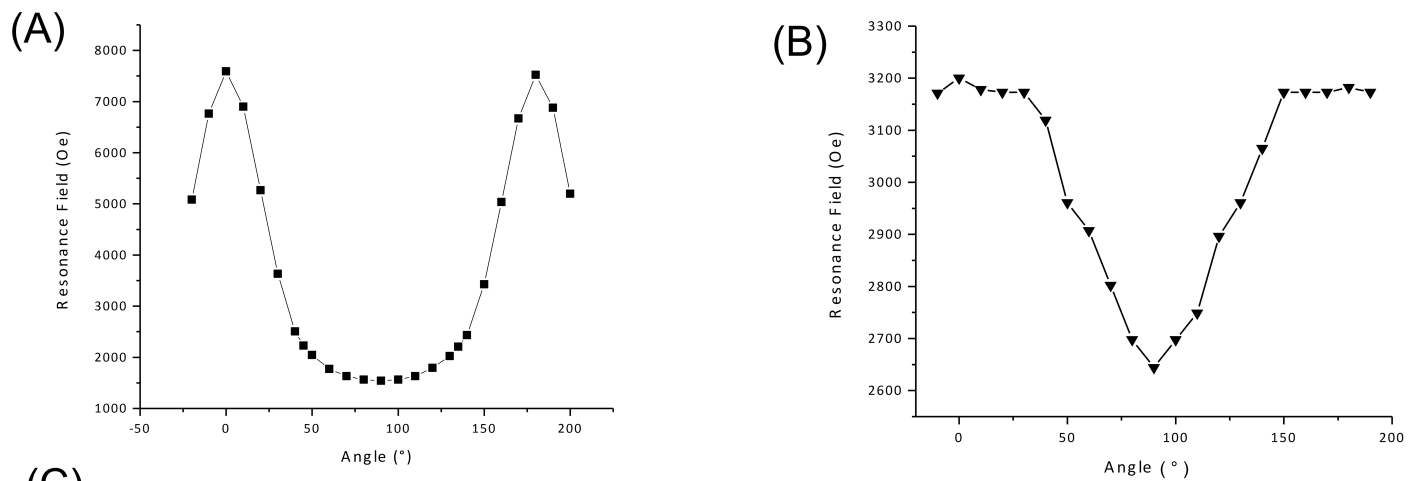


FIGURE 5 (A) 3.04 µm Ni nanowires. (B) 12.74 µm Ni nanowires. (C) 15.45 µm Ni nanowires. (A, B, and C) X-band ferromagnetic resonance measurements (FMR). FMR occurs when the applied field causes the magnetic moment to precess at a frequency which equals the microwave frequency (9.8 GHz) present during the experiment.

Angular Variation of Resonance Field



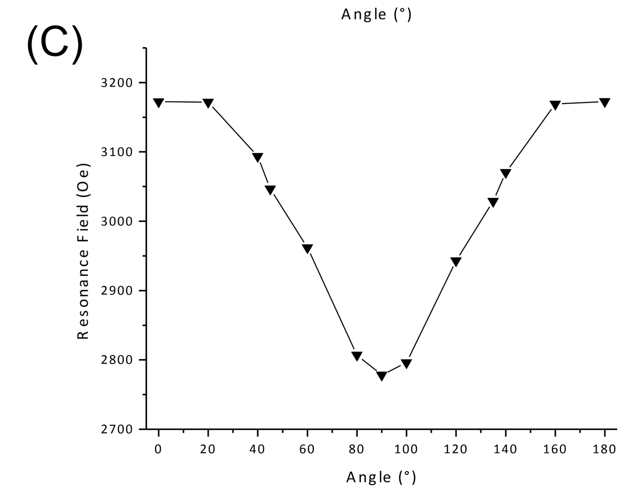


FIGURE 6 (A) 3.04 µm Ni nanowires. (B) 12.74 µm Ni nanowires. (C) 15.45 µm Ni nanowires (A, B, and C) Angular variation of resonance field based on X-band FMR results.

Conclusion

For the nanowires with a smaller aspect ratio, the saturating field when applied along the direction of the wire axis is very different from the saturating field when applied perpendicularly to the wire axis. As length increases, therefore increasing aspect ratio, the saturating fields are much closer for different applied field orientations.

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Acknowledgments

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