DIELECTRIC RESPONSE IN NiFe NANOWIRE - NANOPOROUS SILICON STRUCTURES

R. Vasic, J.S. Brooks, E. Jobiliong (NHMFL, FSU, Physics); S. Bhansali, S. Aravamudhan, K. Luongo (University of South Florida)

We are exploring the magnetic, dielectric and transport properties of NiFe nanowires electrodeposited in nanoporous silicon templates[1] (Figure 1). Fabrication of magnetic nanowire arrays by electrodeposition is important for diverse applications in fields such as magnetic recording and bio-magnetics.

The focus of this report is on the dielectric response of these nanostructured materials vs. temperature and high magnetic fields. Samples were prepared as small square pieces of order several mm square with capacitor leads on either face, perpendicular to the axis of the nano-wires. An ac capacitance bridge was used to monitor the real ε' and imaginary ε'' parts of the response vs. temperature, frequency, and magnetic field. For a dielectric with a characteristic dipolar relaxation rate, there will be a characteristic frequency and temperature were the response will show a peak in the dissipation ε' and a phase shift in the imaginary response ε''. In general, the relationship between f and T where the response has a "resonance" and will follow the Arrhenius relationship $1/\tau(T) \sim f(T) = f_0 \exp(E_a/T)$, which for the NiFe-n-Si system yields $E_a = 4.5$ meV and $f_0 = 7 \times 10^{14}$ Hz. Typical results are shown in Fig. 2 for the NiFe-n-Si system where ε' and ε'' are monitored vs. temperature for fixed frequency and magnetic field. What was not expected was that the dipolar relaxation rate would be magnetic field dependent, and that multiple dipolar relaxation rates would appear at higher magnetic fields. In Fig. 3 a plot of the field dependence of the "resonant" temperature of the structures vs. magnetic field is shown for both the silicon template and the NiFe-n-Si system. This suggests that the field dependence of the dipolar relaxation rate is a general feature of n-type Silicon ($n \sim 10^{14}/cm^3$), and that in the NiFe-n-Si system there are additional components that lead to additional, field dependent, dipolar rates. The general form of the field dependence follows approximately a Brillouin function (at least at lower fields), characteristic of the polarization of paramagnetic spins. Further work is underway[1] to characterize the magnetic, dielectric, and electrical transport characteristics of this nano-structured material.

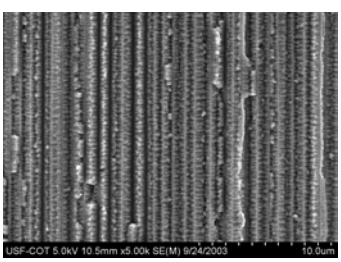

FIG. 1. SEM image of 290 nm diameter and 145 μm deep nanopores electrochemically etched in n-type Si substrate (resistivity: 0.4-0.6 ohm-cm).

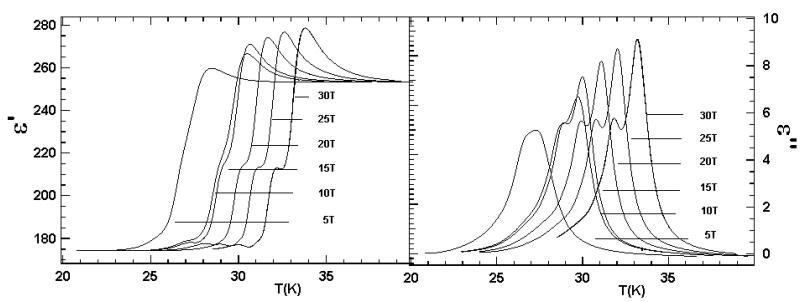

FIG. 2. Magnetic field dependence of dielectric response for the NiFe-n-Si system vs. temperature at 100 kHz. The resonant structure shifts to higher temperatures, and multiple relaxation rates appear, with increasing field.

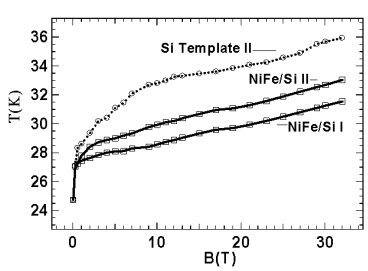

FIG. 3. Magnetic field dependence of resonant structures in both the NiFe-n-Si system and silicon template.

Acknowledgements
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References
[1] R. Vasic *et al.*, Ph.D. thesis, in progress.