Low defect density in electrodeposited epitaxial Ni(111) films on GaAs(110)

S. Vutukuri, R. Schad, P. LeClair, and G. Zangari

Department of Physics and Astronomy and MINT Center, University of Alabama

*Dept. of Materials Science and Engineering, Center for Electrochemical Science and Engineering, University of Virginia

**Motivation**

- Integration of ferromagnetic thin films with semiconductors, and implementation of novel devices based on spin-dependent transport (spin FET)
- ECD is a particularly suitable process: low energy → avoid interdiffusion, clean interface. High quality, epitaxial films can be produced

**Objective:** To grow epitaxial Ni films on GaAs(110) substrate and perform electrical and Hall measurements.

**Thickness dependence of Resistivity**

Fuch’s model:

\[
\rho(t) = \rho_\infty + \frac{3}{8} (1 - p) t + \frac{3}{8} (1 - p) \rho_\infty \frac{l_n}{t}\\
\]

- \(\rho(t)\) - film thickness, \(\rho_\infty\) - bulk resistivity, \(l_n\) - bulk electron mean free path and \(p\) - specularity parameter which is the fraction of electrons specularly reflected at the film interfaces.

Tesanovic model:

\[
\rho(t) = n_e \rho_\infty \left( 1 + \frac{n_e l_{max}}{l_{\text{Fermi}}^2} \right)^{-1}
\]

- \(n_e = k_F t/\hbar^2\), the number of sub bands in the k space located at the Fermi level,
- \(l_{max} = \hbar n_e/2(k_F t)\), \(k_F\) - Fermi momentum and \(\hbar\) - microscopic roughness amplitude.

**Hall Measurements**

- In ferromagnetic materials the Hall resistivity is described by

\[
R_{H} = R_B + 4nR_{M}
\]

- Ordinary Hall coefficient is related to the resistivity in the following way:

\[
R_x \propto \rho^n
\]

**Ordinary (R_x) and spontaneous (R_s) Hall coefficients of Ni films measured at 4K as a function of film thickness.**

**Experimental**

- Galvanostat

  ![Galvanostat Image]

- MeSO₄, 0.1 M, pH 2.5

**Growth**

- Substrate: n-GaAs (110)
- Back contact: Ga/In eutectic
- EG&G 273A Galvanostat
- Room Temperature
- Graphite counter electrode

**Characterization**

Resistance and Hall Effect measurements were done by the van der Pauw method using a Quantum Design Physical Property Measurement System.

**Thickness dependence of resistivity of Ni measured at 15K and 290K along with the fits using Fuch’s model.**

**Conclusions**

- Bulk resistivity is essentially zero at low temperatures
- Hall effect for a magnetic material typically consists of Ordinary Hall effect - carrier concentration
- Spontaneous Hall effect - skew and side-jump scattering

**References**

- K. Fuchs, Proc. Camb. Phil. Soc. 34, 100 (1938)