Noise Characteristics of Superparamagnetic Tunnel Junctions

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Superparamagnetic tunnel junctions

Tunnel-magnetoresistance specifications

sensitivity

absolute resistance

hysteresis $H_c$

signal noise
Superparamagnetic tunnel junctions

Tunnel-magneto-resistance specifications

- Sensitivity
- Absolute resistance
- Hysteresis $H_c$
- Signal noise
Superparamagnetic tunnel junctions
Thermally unstable magnetization

Arrhenius equation:

\[ \frac{1}{\tau} = f_0 e^{-\Delta E / kT} \]

\[ \Delta E = K_{\text{anisotropy}} \times \text{Volume} \]
**Superparamagnetic tunnel junctions**

Magnetization of superparamagnetic particles

\[
L(a) = \coth(a) - \frac{1}{a}
\]

\[
a = M_s \cdot \text{Vol} \cdot H / kT
\]

- volume
- magnetic field
- temperature

![Graph of NiFeCo 1 $\mu_B$ / 300K](image)
1.6 nm NiFeCo

- glue
- Cu
- Cu
- Si₃N₄
- NiFeCo
Cu / 0.8 nm NiFeCo / Cu

(400)_{FM}
(400)_{Cu}

(222)
(220)
(200)
(111)
Superparamagnetic tunnel junctions

Cu / 0.8 nm NiFeCo / Cu

\[ \mu \text{ (memu)} \]

magnetic field (Oe)

170 K
Superparamagnetic tunnel junctions

Cu / 0.8 nm NiFeCo / Cu

![Graph showing magnetic field vs. magnetic moment for 170 K and 270 K temperatures.](image-url)
Superparamagnetic tunnel junctions

Cu / 0.8 nm NiFeCo / Cu
Superparamagnetic tunnel junctions
Cu / NiFeCo / Cu

0.8 nm

0.6 nm

Center for Materials for Information Technology
A NSF Materials Research Science and Engineering Center
Superparamagnetic tunnel junctions

hysteresis-free magnetic field sensor

![Graph showing voltage vs. field for different materials]

- CrMnPt
- FeCo
- Al₂O₃
- NiFeCo
- Ru

\[ R = 20 \text{ k}\Omega \]
Superparamagnetic tunnel junctions

Tunnel-magnetoresistance specifications

- sensitivity
- absolute resistance
- hysteresis $H_c$
- signal noise
Thermal Fluctuations and Noise in Superparamagnetic Nanoparticles
Asymmetric RTS (Random Telegraph Signal) Noise

\[ S(\omega) \sim \left\{ (\tau_1 + \tau_2) \left[ \left( \frac{1}{\tau_1} + \frac{1}{\tau_2} \right)^2 + \omega^2 \right] \right\}^{-1} \]

\[ \tau_1 = \tau_0 \exp(-\Delta E_1 / kT), \quad \tau_2 = \tau_0 \exp(-\Delta E_2 / kT) \]

\[ \Delta E_{1,2} = \frac{KuV}{kT} (1 \mu m)^2, \quad h = \frac{H}{H_k} \]


Temperature and Frequency Dependence of Noise at H = 0

![Graph showing the temperature and frequency dependence of noise at H = 0. The graph plots KV/kT on the y-axis and omega on the x-axis for different values of omega (1 and 10).]
Field Dependence of Noise

$$\frac{KV}{kT} = 18$$

$$\omega = 1$$

$$h = \frac{H}{H_k}$$

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Superparamagnetic tunnel junctions
The SDT sensor
Noise measurements in superparamagnetic tunnel junctions

Setup

Shields

Cooler

Sample

Thermocouple

Batteries

Low noise preamplifier

DAC Card

Control System Analyzer

+- 50 Oe
250K - 320K
60 µHz - 100 kHz
(planned: -20 GHz)
Noise measurements in SPM tunnel junctions

preliminary results

![Graph showing noise voltage (mV) vs. time (s) and magnetic field (Oe).]
Noise measurements in SPM tunnel junctions
preliminary results

@ switching point
[zero field]
under applied field
Noise measurements in superparamagnetic tunnel junctions

Planned Work

• Noise measurement as a function of: frequency, field, temperature and voltage

• Transport and Magnetization measurements of superparamagnetic layers