Discovery of Giant Magnetoresistance

Giant magnetoresistance (GMR) :
\[ [\text{3 nm Fe} / \text{0.9 nm Cr}] \times 60 * \]

50 % resistance change at 4.2 K

Two-current model is used to explain GMR:

By considering

- a layer with parallel magnetisations to be low resistive,
- a layer with antiparallel magnetisations to be high resistive,

up and down spin currents can be treated independently.

The sum of the two parallel spin-polarised electron currents give

- a large resistance for the antiparallel configuration \( R_{\text{max}} \),
- a small resistance for the parallel configuration \( R_{\text{min}} \).

The magnetoresistance ratio can be obtained as

\[
\frac{\Delta R}{R} = \ldots
\]


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**Current Directions**

Two configurations can be used for GMR measurements:

Current perpendicular to the plane (CPP) GMR:

Current-in-the-plane (CIP) GMR:

* https://www.nims.go.jp/mmu/tutorials/GMR.html
Magnetoresistance changes depending on the angle between the current and field: *

In 1856, Lord Kelvin demonstrated AMR in a ferromagnet. The resistance change is $\leq 5\%$ typically.

$$\rho(\theta) =$$


### Probe Station

HiSOL probe station with non-magnetic setup:

- Measurements: ac & dc
- Sensitivity: < 1 nA
- 4 probes
- Temperature: Room temperature
MR Measurement 1

Place a sample on the stage:

![Image of measurement setup](image1.jpg)

Taken by Dr Kelvin Elphick

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MR Measurement 2

Adjust the probe positions and execute a MR measurement:

![Image of measurement setup](image2.jpg)

Taken by Dr Kelvin Elphick
MR Measurement

Place a sample on the stage and execute the measurement:

![Image](image_url)

Taken by Dr. Marjan Samiepour

MR Analysis

From the MR data measured, a dominant type of a magnetoresistive effect in the sample needs to be discussed.

The corresponding magnetoresistance ratio needs to be estimated using the following equation:

\[
\frac{\Delta R}{R} = \frac{R_{\text{max}} - R_{\text{min}}}{R_{\text{min}}}
\]

The estimated ratio needs to be compared with that the recent magnetic sensors typically use.

The ways how to increase the magnetoresistance ratio further needs to be discussed.