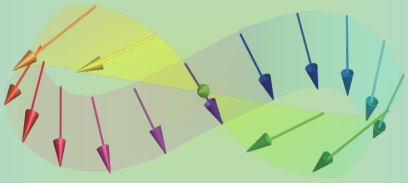
Information Storage and Spintronics
Practical Session 4

~ Magnetoresistance ~



Atsufumi Hirohata

Department of Electronic Engineering

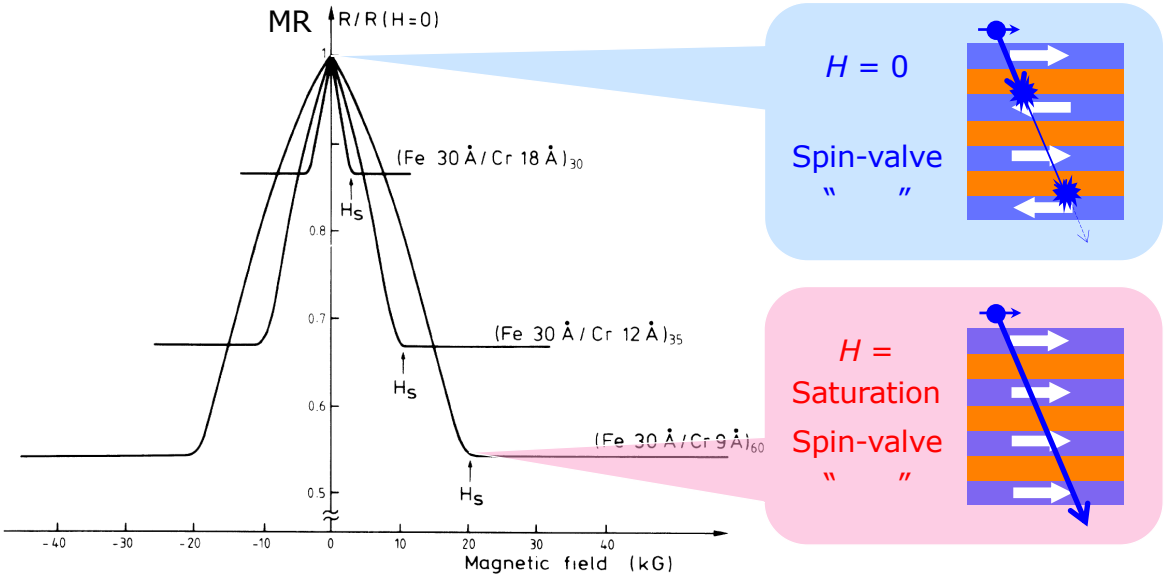
THE UNIVERSITY of York

13:00 Wednesday, 2, 9 & 16/November/2022

Discovery of Giant Magnetoresistance

Giant magnetoresistance (GMR) :

[3 nm Fe / 0.9 nm Cr] × 60 *



50 % resistance change at 4.2 K

* M. N. Baibich *et al.*, *Phys. Rev. Lett.* **61**, 2472 (1988); P. Grünberg *et al.*, *Phys. Rev. Lett.* **57**, 2442 (1986).

Two-Current Model

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,

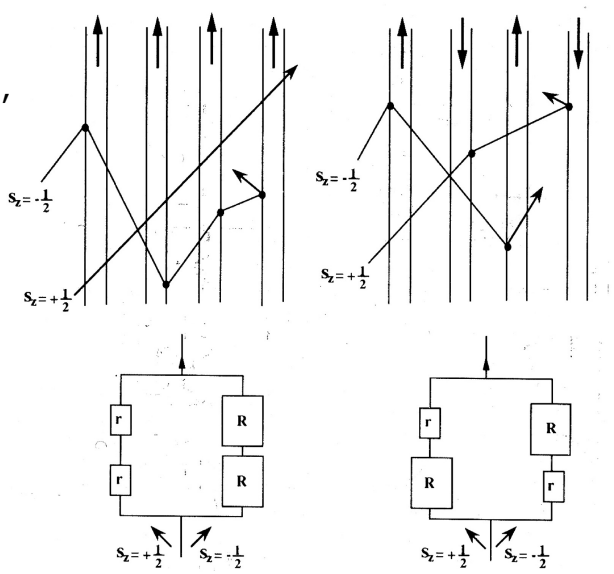
up and down spin currents can be treated independently.

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

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

The magnetoresistance ratio can be obtained as

$$\frac{\Delta R}{R} =$$

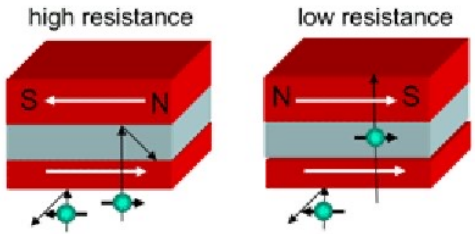


* M. N. Baibich *et al.*, *Phys. Rev. Lett.* **61**, 2472 (1988).

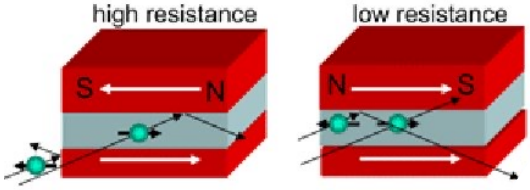
Current Directions

Two configurations can be used for GMR measurements : *

Current perpendicular to the plane (CPP) GMR :



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



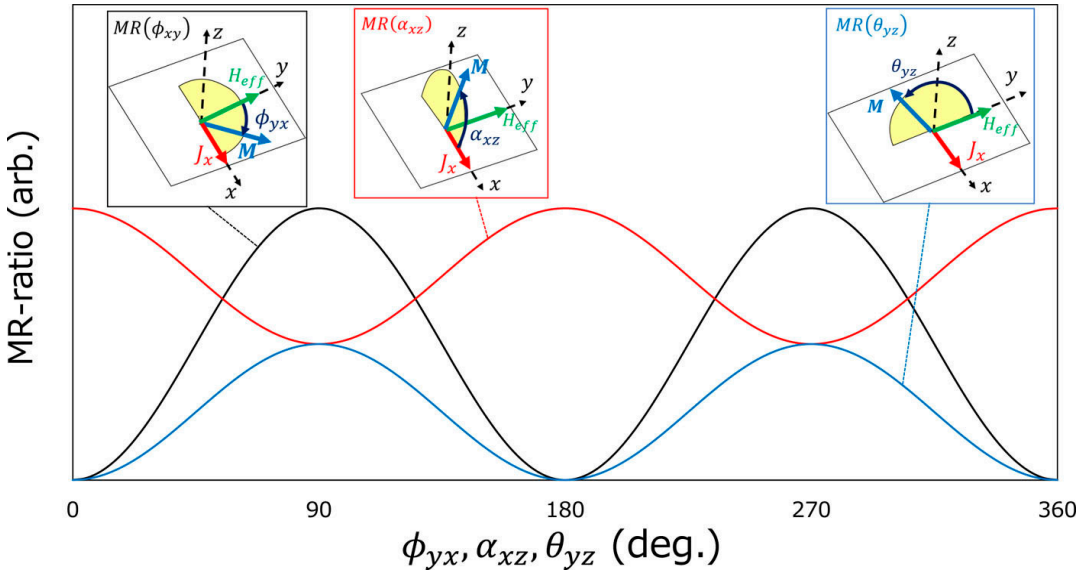
* https://www.nims.go.jp/mmu/tutorials/GMR.html

Anisotropic Magnetoresistance (AMR)

Magnetoresistance changes depending on the angle between the current and field : *

In 1856, Lord Kelvin demonstrated AMR in a ferromagnet.

The resistance change is ≤ 5% typically.



For the in-plane current and field, the resistivity can be determined as

$$\rho(\theta) =$$

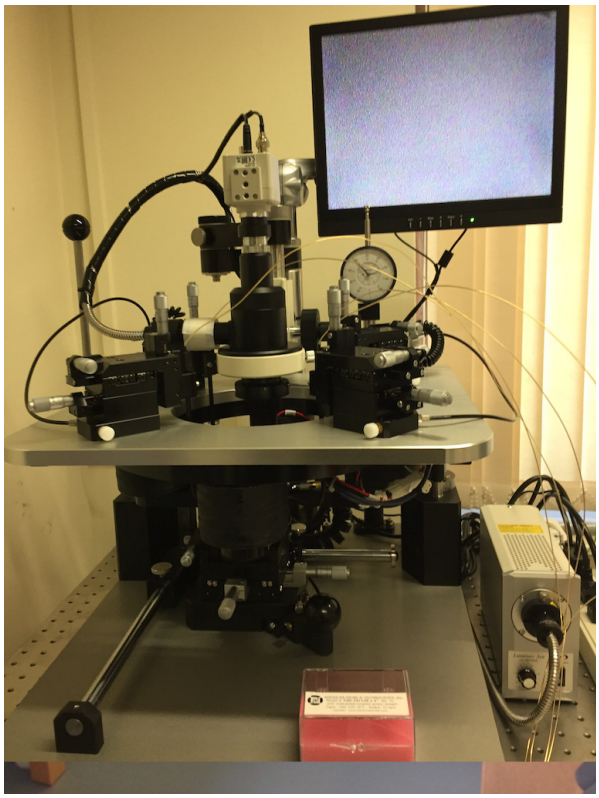
* W. Thomson, *Proc. Roy. Soc.* **8**, 546 (1857);

** Y. Yahagi *et al.*, *AIP Adv.* **8**, 055822 (2018).

Probe Station

HiSOL probe station with non-magnetic setup :

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



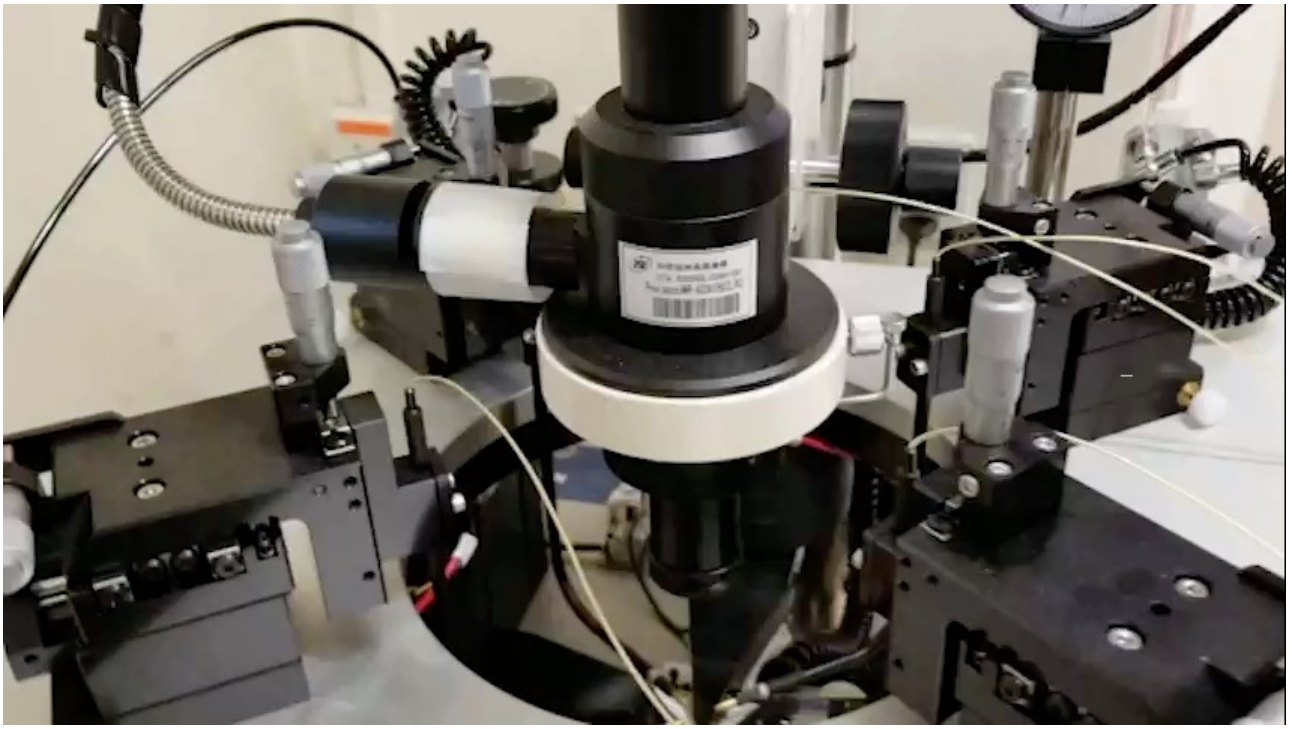
MR Measurement 1

Place a sample on the stage :

Taken by Dr Kelvin Elphick

MR Measurement 2

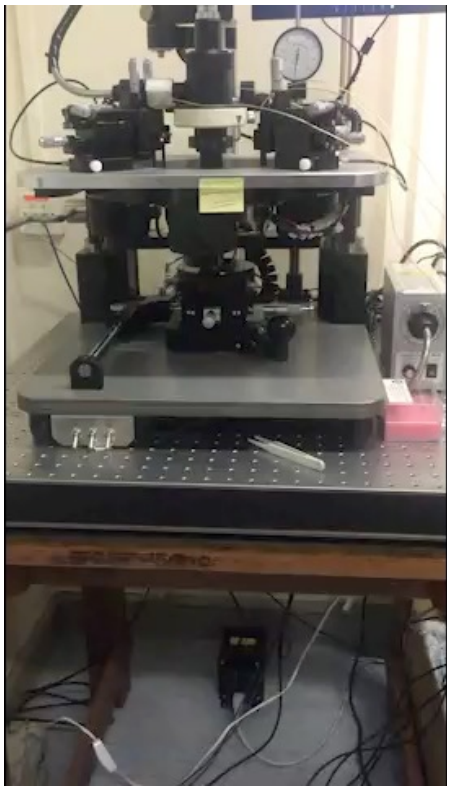
Adjust the probe positions and execute a MR measurement :



Taken by Dr Kelvin Elphick

MR Measurement

Place a sample on the stage and execute the measurement :



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.

$$\frac{\Delta R}{R} = \frac{R_{\max} - R_{\min}}{R_{\min}}$$

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.