Setup for Magnetic Tunnel Junction measurements

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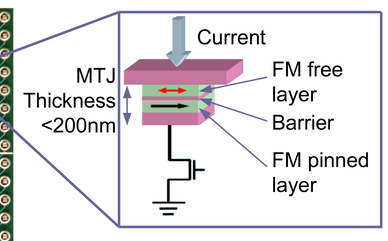
Introduction Magnetic Tunnel Junctions (**MTJs**) are devices that consists of two ferromagnetic electrodes separated by insoulating barrier. It has been reported that a properly designed junction can change its resistance (by changing magnetization vectors of electrodes from parallel to antiparallel state) up to 500% in room temperature by applying magnetic field [1]. Therefore MTJs are considered as a key component for ultrahigh-density read heads of HDD and very sensitive magnetic field sensors. Recent papers [2] shows that change of tunnel magnetoresistance (**TMR**) can also be obtained by current induced magnetization switching (**CIMS**) using spin torque effect which can be very suitable for next generation of magnetic random access memory (**MRAM**).

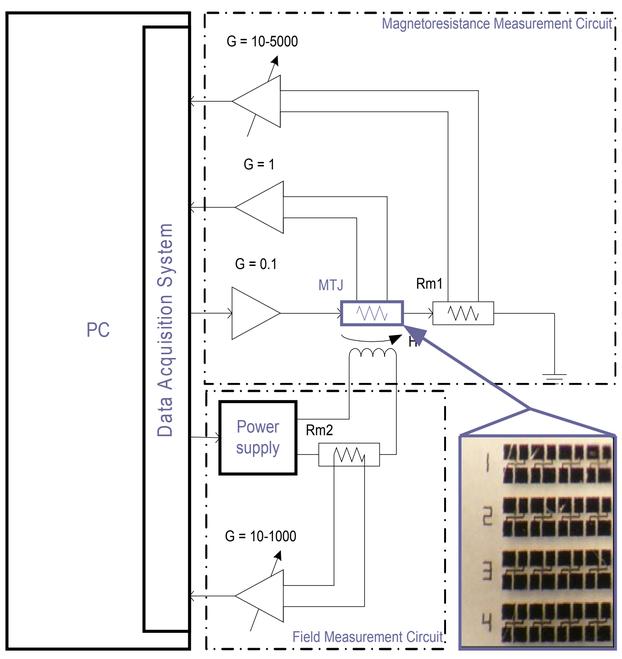


MRAM based on MTJ elements. Sources: Spintec, Motorola

Aim To build a setup that allowes complex characterisation of MTJs. Electronics and software must allow measurement of various properties of junctions, such as TMR vs. magnetic field characteristics, current vs. voltage (**I-V**) curve, CIMS curve. Mechanical parts should enable measurement of nano size devices with electrodes without necessity of bonding.

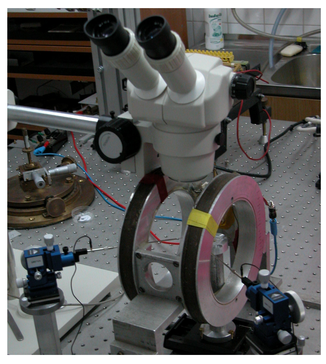
Hardware

A1. Block diagram of setup

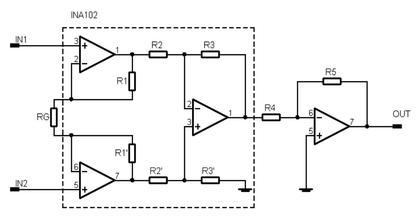


Data Acquisition Card (PCI-6035E by National Instruments) controlls whole measurement procedure:

- measures voltage drop on MTJ
- measures current of MTJ sample by measuring voltage drop across precision resistor Rm1
- measures current flowing through coils, which is converted to magnetic field
- sets bias voltage to a sample
- controlls power supply, that generates magnetic field

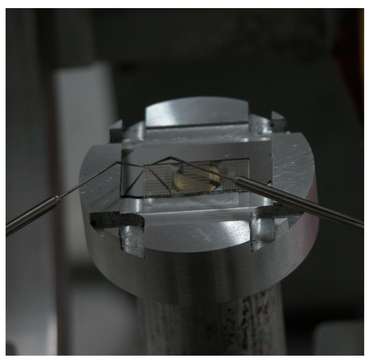


A2. Amplifiers

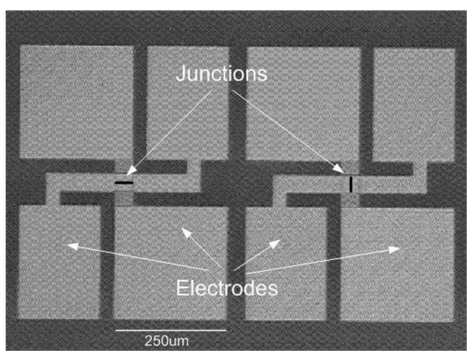


To reduce influence of noise on voltage measured across precision resistor, dedicated differential amplifiers were constructed. Input stage based on instrumentation amplifier INA101, is characterised by very high input impedance, high CMRR, low offset voltage. Output stage provides regulated gain within range of 10 – 5000.

A3. Measurement system

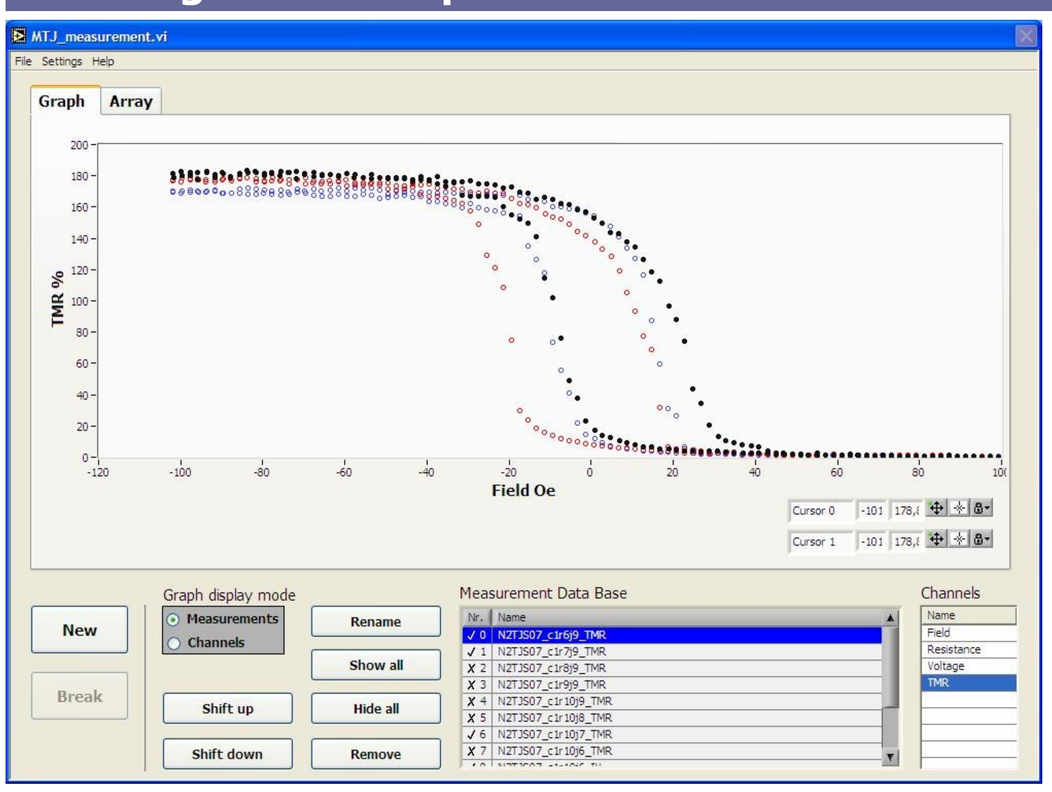


For measurement of devices patterned to nano sizes set of 2 micropositioners **DCM-100** were applied. Probe tips with diameter of 12 um are made of tungsten.



Software

B1. Program descripton



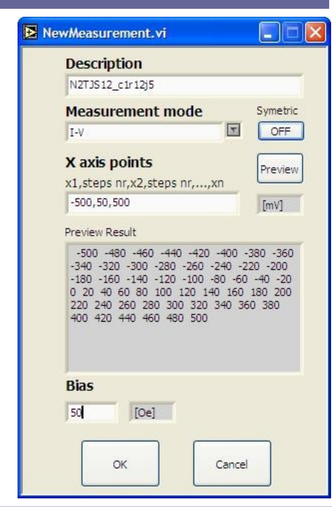
For experimental setup dedicated program in **LabVIEW** environment was written. From control panel following operations can be proceed:

- new measurement start
- management of measurement database
- results presentation on graph and in array
- save and load option in *.dat format
- data export to standard ASCII file

B2. New measurement

There are three measurement modes possible

- TMR vs. magnetic field
- current voltage characterization (with single bias or with symmetric bias starting from 0 V)
- current induced magnetization switching characteristics



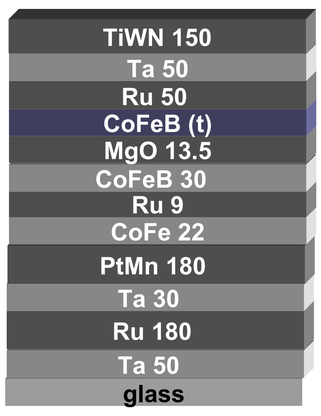
B3. Principals of operation

Program's architecture was based on **MVC** pattern: Model-View-Controller. Main assumption of MVC is isolation between these three application components:

- Model - represents measurement data and set of rules used to manipulate them
- View - corresponds to certain elements of user interface such as graph, tables, buttons etc.
- Controller - manages measurement procedure, external devices etc.

Test measurement

C1. Sample description

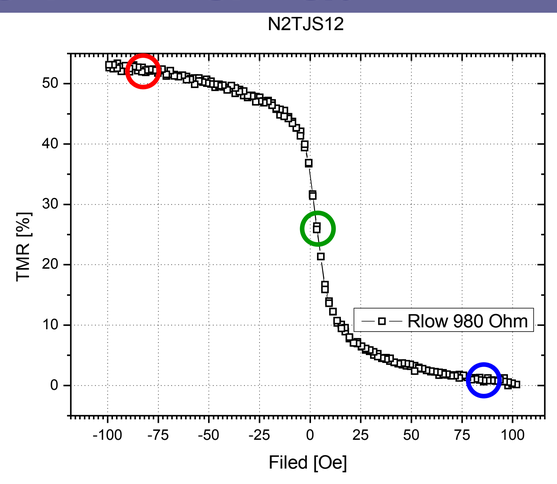


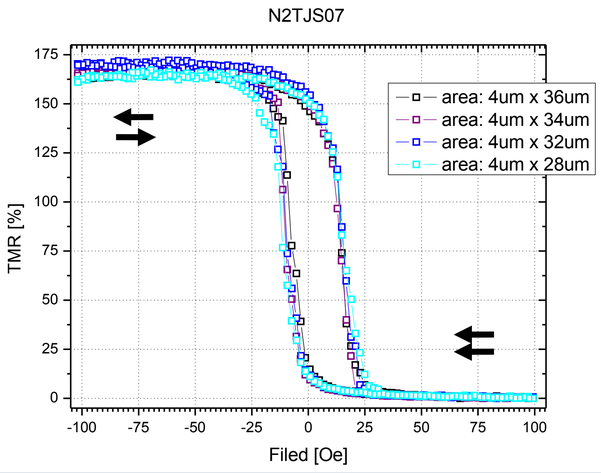
Fabricated at INESC, MTJs samples constitute so called exchange bias spin valve (**EB-SV**). Junctions with different upper electrode thickness were measured:

- N2TJS12 : t = 15.5 Å
- N2TJS07 : t = 30 Å

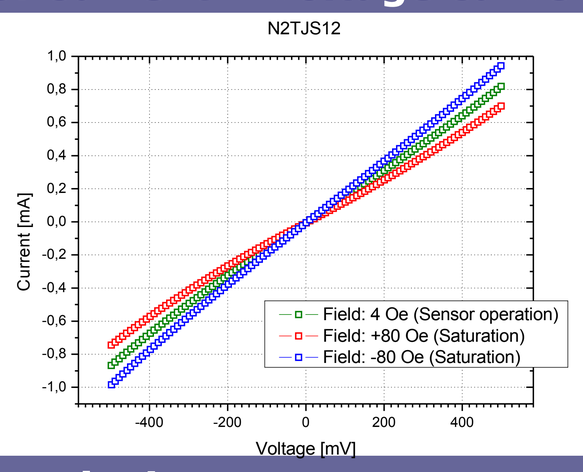
Both samples were annealed at 330 °C for 1 hour in 5kOe magnetic field.

C2. TMR vs. Field





C3. Current – Voltage curve



C4. Results

Sample N2TJS12 manifests lack of **hysteresis**, and very high **sensitivity** in linear range, therefore it has perfect advantages of magnetic field sensor [3].
Sample N2TJS07 has typical hysyeresis loop and can be used as MRAM memory cell. TMR value is reaching 170% and it is independent on junction area.
Current-voltage characteristics were measured for Sensor sample in three operating points:

- in the highest sensitivity point
- in saturation regions, simultainously for both magnetic field directions

Conclusions

Universal setup for MTJs measurement was built.
Created in LabVIEW application enables not only characterisation of samples but also management and presentation of measured results.
Designed mechanical parts makes possible investigation of samples patterned to nano size without necessity of bonding.
Measurement performed on test samples show main capabilities of the setup.

[1] - J. Hayakawa, S. Ikeda, Y. M. Lee, F. Matsukura, and H. Ohno, *APL,* vol. 89, 232510 (2006), *APL*, vol. 90, 212507 (2007)

[2] - J. Hayakawa et al. *Jpn. J. Appl. Phys*., vol. 45, L1057 (2006)

[3] - P.Wiśniowski, J.M.Almeida, S.Cardoso, N.P.Barradas, and P.P.Freitas, *J. Appl. Phys.*, vol. 103, 07A910 (2008)

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