DP-05

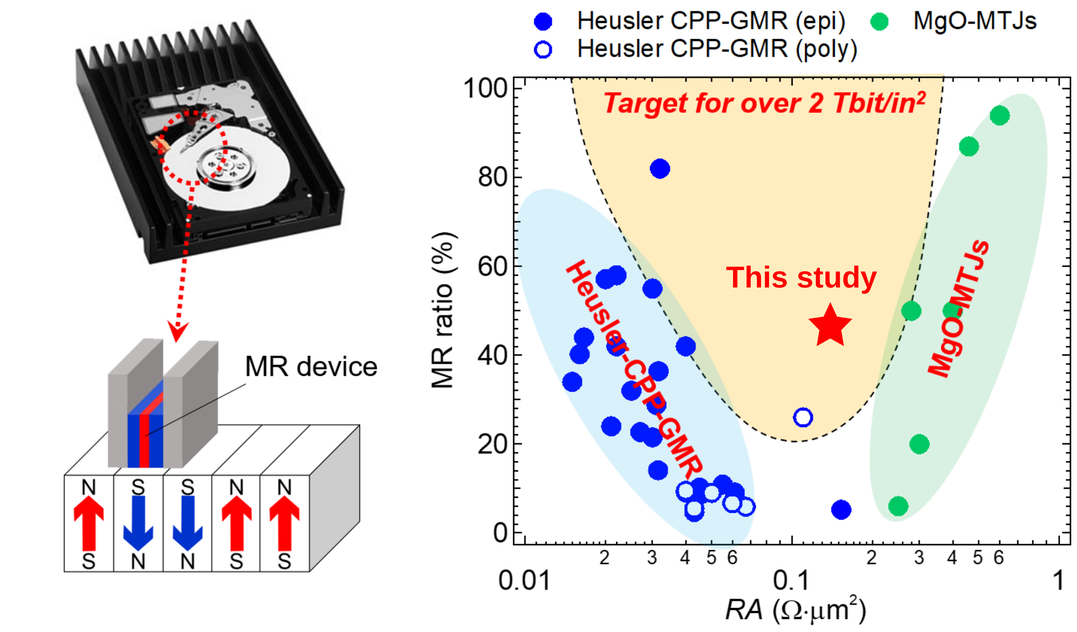
Investigation of magnetotransport properties of Heusler-alloy-based magnetic tunnel junctions with a $Cu(In_{0.8}Ga_{0.2})Se_2$ semiconductor barrier with a low resistance-area product

Koki Mukaiyama[1], S. Kasai[1, 2], Y. K. Takahashi[1], P-H.Cheng[1, 3], Ikhtiar[1], K. Masuda[1], Y. Miura[1,4], S. Mitani[1, 3], and K. Hono[1, 3]

[1] NIMS, [2] RIKEN, [3] Univ. of Tsukuba, Kyoto Institute of Technology

Introduction

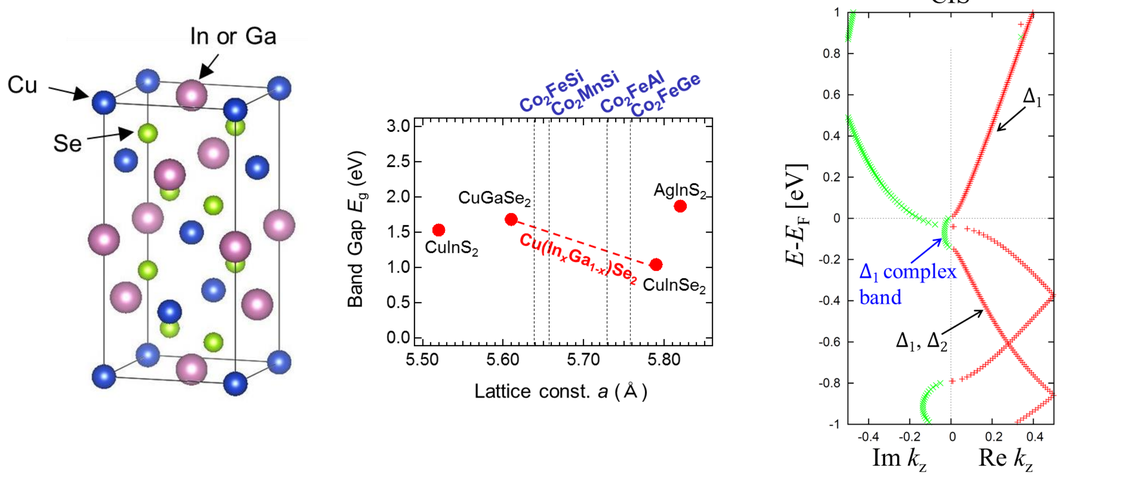
- Requirements for a read head of HDDs over 2 Tbit/in^2



In order to realize a read sensor head of HDDs over 2 Tbit/in^2, a large MR ratio with a low RA ~ 0.1 Ω·μm^2 is desired. However, this requirement is still a great challenge for both the MgO based MTJs and the Heusler-alloy based CPP-GMR devices. So, we have focused on semiconductor barriers because their lower band gaps may result in an adequate RA value without degrading an MR ratio.

- $Cu(In_xGa_{1-x})Se_2$ semiconductor barrier

  - Chalcopyrite structure
  - Low band gap; E_g = 1.0 ~ 1.6 eV (*cf.* MgO : 7 eV)
  - Good lattice matching with Co-based Heusler alloys
  - Δ_1 state propagates dominantly.



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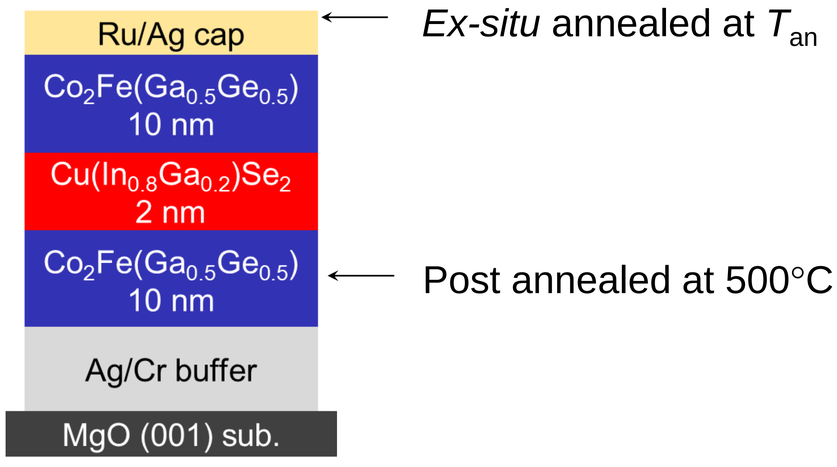
$Cu(In_{0.8}Ga_{0.2})Se_2$ is expected to be grown epitaxially on Heusler alloys and can result in a large MR ratio due to the Δ_1 coherent tunneling.

Objective

Fabrication of the MTJs with a $Cu(In_{0.8}Ga_{0.2})Se_2$ semiconducting barrier and demonstration of a large MR ratio at a low RA ~ 0.1 Ω·μm^2.

Experimental method

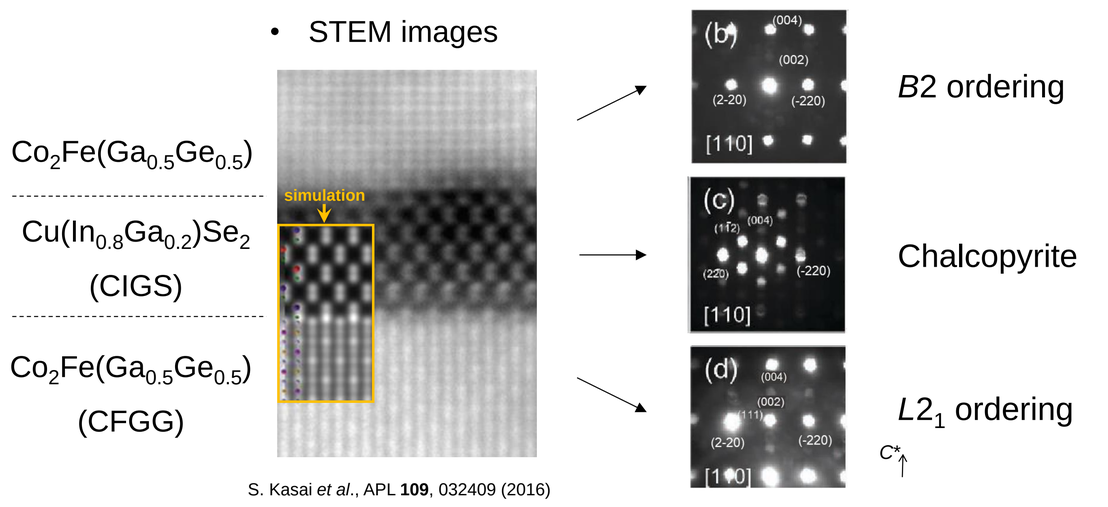
- Deposition : DC/RF magnetron sputtering



- Microfabrication : E.B. lithography & Ar ion milling
- Evaluation
  - Structural analysis : TEM
  - Transport properties : DC-4-probe method

Results & Discussion

- Structural analysis by TEM
  - STEM images



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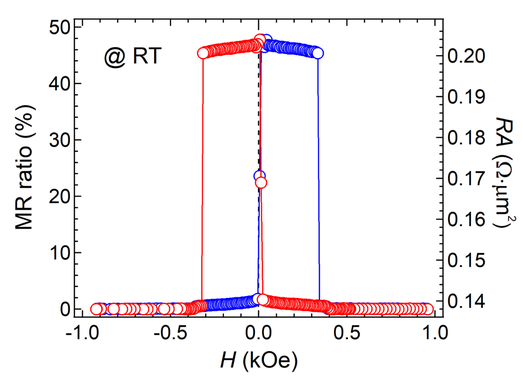
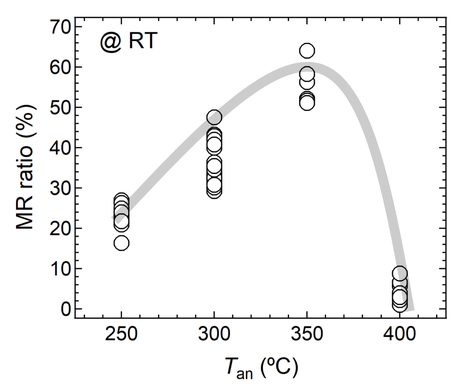
✓ CIGS was epitaxially grown on CFGG with $(001)[110]_{CFGG}//(001)[110]_{CIGS}$.

- Magnetoresistance effect
  - MR curve (T_{ann} = 300 °C)



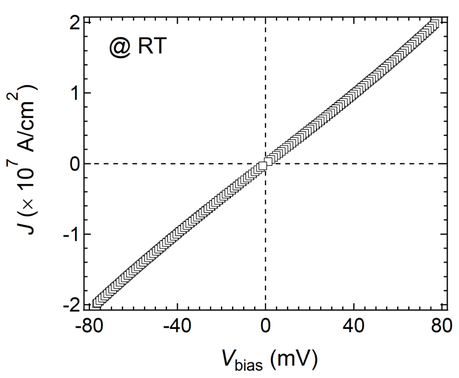
✓ MR = 43 %, RA = 0.14 Ω·μm^2, (ΔRA = 0.157 Ω·μm^2)

  - Dependence on T_{an}



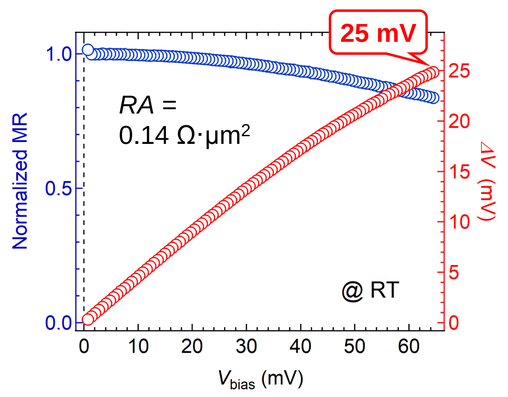
✓ MR ratio reached 64% at maximum.

- Bias voltage dependence
  - *J-V* characteristics



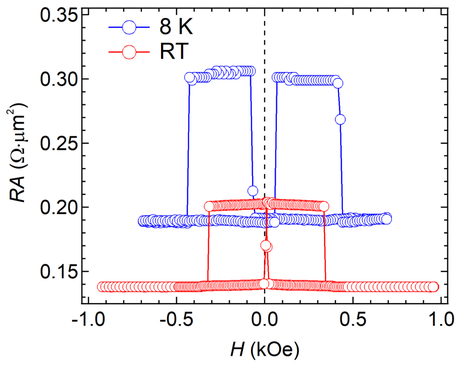
✓ Nonlinear behavior

  - MR ratio & Output ΔV (= MR × V_{bias})



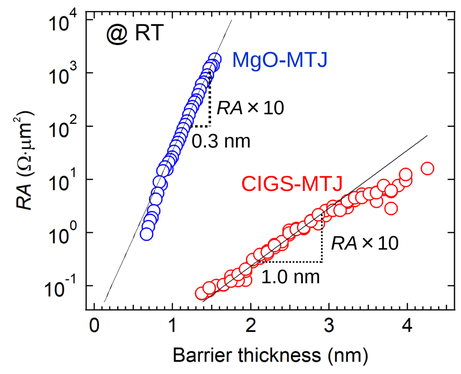
✓ Large ΔV of 25 mV.

- Transport mechanism
  - Temp. dependence of RA



✓ RA increased at low temperature.

  - CIGS thickness dependence of RA



✓ Log RA ∝ CIGS thickness.

Dominant transport mechanism is ‘‘Tunneling’’.

Summary

- $Cu(In_{0.8}Ga_{0.2})Se_2$ semiconducting barrier was successfully fabricated on a $Co_2Fe(Ga_{0.5}Ge_{0.5})$ Heusler-alloy electrode.
- Large MR ratio of 47 % and high output voltage of 25 mV were achieved at low RA of 0.14 Ω·μm^2. K. Mukaiyama *et al.*, Applied Physics Express **10**, 013008 (2017)

Acknowledgement

This work was supported by the ImPACT program.