

Epitaxial cobalt-based Heusler alloys for spintronic applications: Elaboration, structural and magnetic investigation

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Half-metallicity and ultra-low damping investigation

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Outline

- I. Co₂MnX Heusler alloys & spintronics
- II. In situ SR-PES on the Cassiopée beamline
 - Elaboration of Co₂MnX
 - Spin-Resolved Photoemission Spectroscopy

III. Ferromagnetic resonance

- Out-of-plane geometry
- Low magnetic damping results

IV. Summary

Heusler alloys

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Exp. 1996 % H. Liu *et al, App. Phys. Lett.* **101**, 2012

Interest for spintronic devices :

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Spin transfer torque (STT) and STT – MRAM :



 α = magnetic damping η = spin polarization rate

high (~7.10⁸ A/m²) [S. Mangin et al, App. Phys. Lett. 94, 2009]

Motivations

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Co₂MnX Heuslers good candidates for STT-MRAM :

- ✓ Predicted HMM (ab initio calc.)
- ✓ Ultra-low damping materials (down to 10^{-5})
- ✓ Appreciable T_C & M_S
- ✓ Lattice parameter close to MgO (tunnel barrier)
- ✓ (Perpendicular magnetic anisotropy ??)

Our strategy :

- Elaboration of epitaxial Co₂MnX thin films by MBE
- To confirm the predicted HMM behavior of Heuslers and tune the electronic structure (by switching X_{IV} by X_{III} , X_V etc.)
- Measurement of the Gilbert damping by VNA-FMR
- Link the HMM behavior and damping value

$J_c = \frac{2e\alpha M_S V}{\hbar\eta} \left(M_S + H_k \right)$









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The Cassiopée Beamline

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Mott detection SR-PES



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SOLEIL : 2,75 GeV storage ring, Saint Aubin, Fr.



MBE growth

MgO(001) [100] // Co₂MnX(001) [110]

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Growth by co-evap. Controled by QCM (error : 5%)

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MBE growth The [110] RHEED patterns

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Co_2MnX with $>$	X =	Si	Sn	AI
		\checkmark	\checkmark	X Low chemical order
		Ge	Ga	Sb
		\checkmark	\checkmark	X Growth along (111) 2 Hex. domains

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MBE growth XRD : the (111) asymmetric peak

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Spin Resolved Photoemission

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Spin Resolved Photoemission

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Results on Co_2MnX_{III} (X_{III} = AI, Ga)



 Co_2MnAI 60% spin polarization at E_F

hv = 37 eV

 $hv = 37 \, eV$

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 Co_2MnGa 100% spin polarization at E_F

not yet published

For the $Co_2MnX_{III,}$ the Fermi level slides down since there is one less valence e⁻ Spin gap at E_F for Co_2MnGa







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Ferromagnetic resonance

Perpendicular magnetic field VNA-FMR





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Low magnetic damping on Heuslers





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- Epitaxial Co₂MnX thin films can be grown by MBE
 → Why low chemical order for Co₂MnAl or (111) growth for Co₂MnSb ?
- High spin polarization for almost all of them
 → HMM confirmed for Co₂MnSi and Co₂MnGa !
- Ultra-low magnetic damping also confirmed \rightarrow In the 10⁻⁴ range for Co₂MnX_{IV}
- How does the chemical disorder impact the physical properties ?
- Link the SR-DOS with the calculated band structures
- Find connections between the magnetic damping and the spin polarization (and the electric conductivity)









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