Alloying and interface properties of (Fe/V) multilayers

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Scope of the multilayer studies

Aim of this HAXPES work has been to investigate the roughness, intermixing and alloying of different interfaces/multilayers.

Ni/Cu

- Repeated $[Ni_5Cu_X]_n$ bilayer unit:

X=2 ML, n=15
X=5 ML, n=21

- MgO substrate
- Fe/Pt/Cu buffer layer
- Pt cap

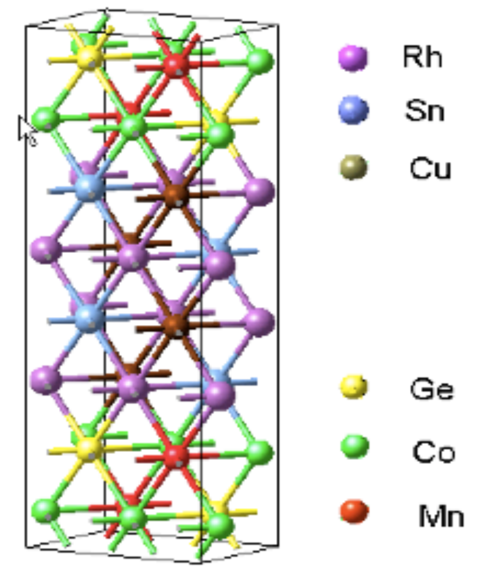
Fe/V

- Repeated $[Fe_A V_B]_n$ bilayer unit:

A=6 ML, B=2 ML, n=20
A=6 ML, B=6 ML, n=20
A=2 ML, B=5 ML, n=20

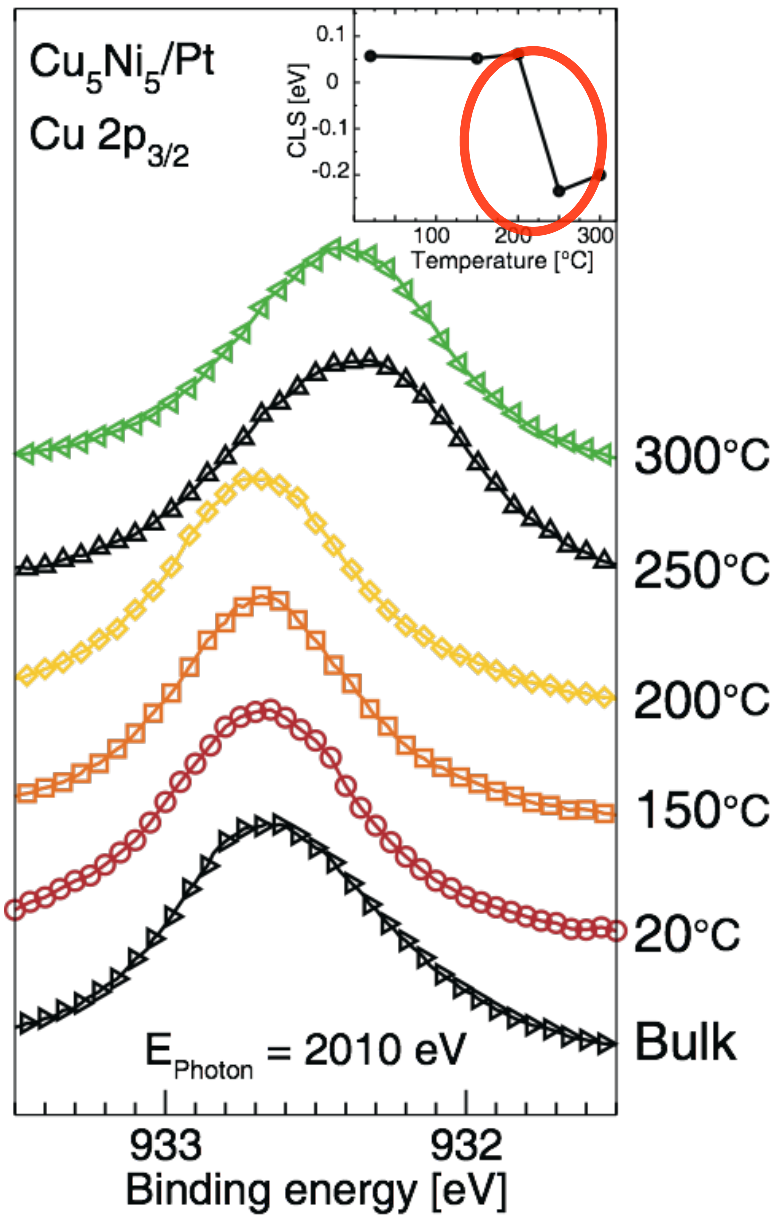
- MgO substrate
- Pt or Pd cap

Heusler alloys



$Co_2MnGe/Rh_2CuSn/Co_2MnGe$
(CMG/RCS/CMG) sandwich

Ni/Cu multilayers - part 1



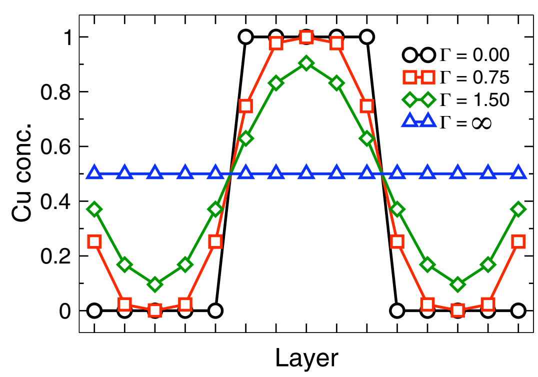
The very first Ni/Cu HAXPES results:
Phys. Rev. Lett. 97, 2006, 266106

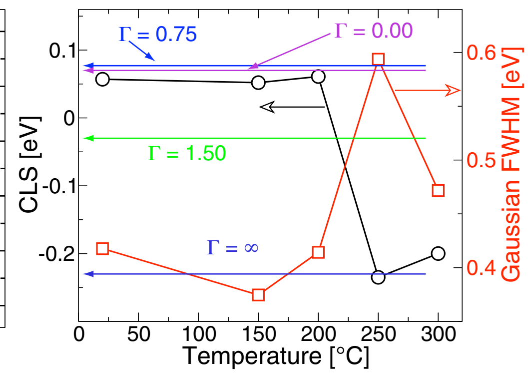
- Broadening of the Cu 2p core-level and a -0.2 eV shift between 200 and 250 ºC

- Shift backwards at 300 ºC

- Interface quality theory: Γ represents the quality of the interface

The interfaces are clearly destroyed but what exactly happens between 200 and 250 ºC?

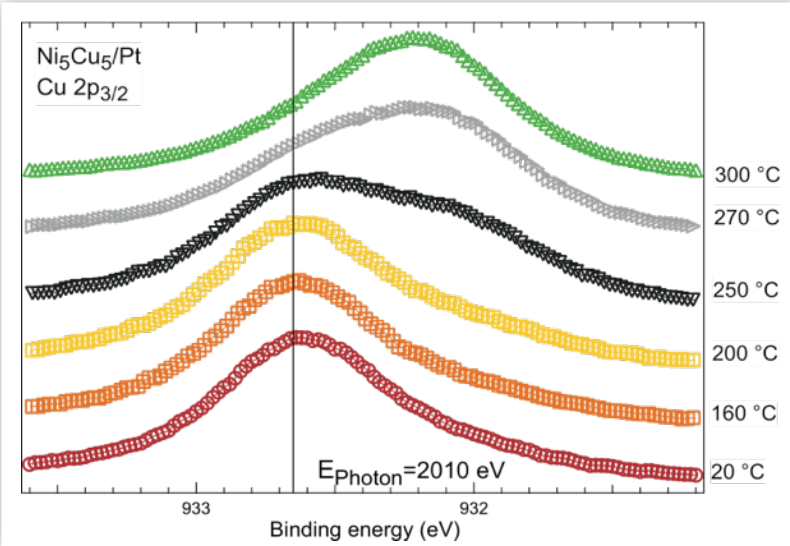


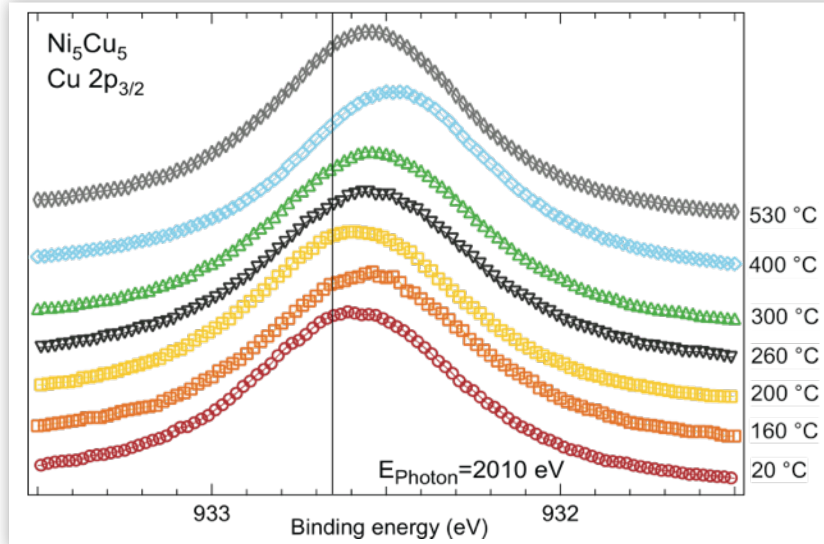


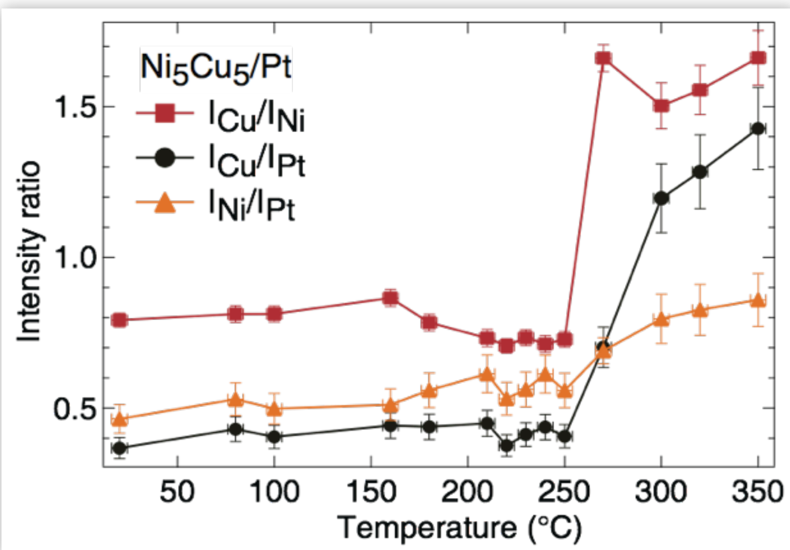
- Core-level shifts calculated from first principles calculations (DFT)

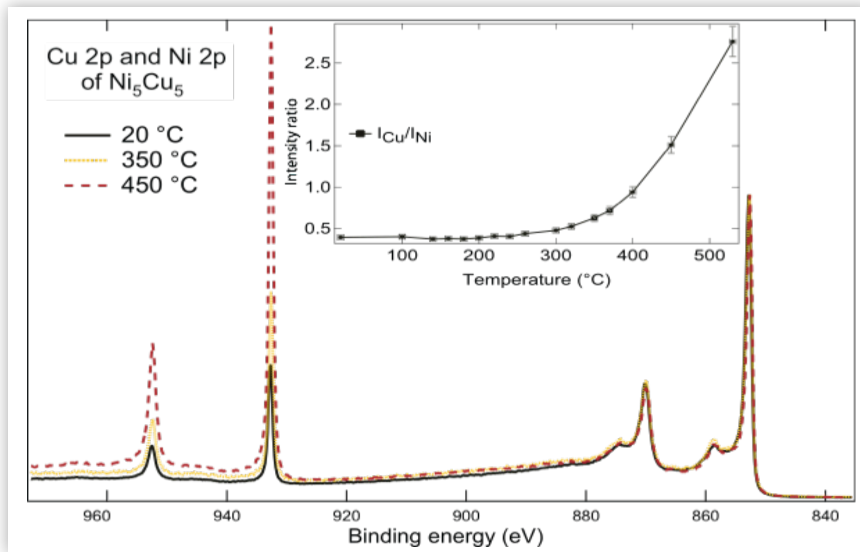
- Complete screening picture including both initial (ground state) and final (relaxation due to core-hole screening) state contributions in the same computation scheme

Ni/Cu multilayers - part 2





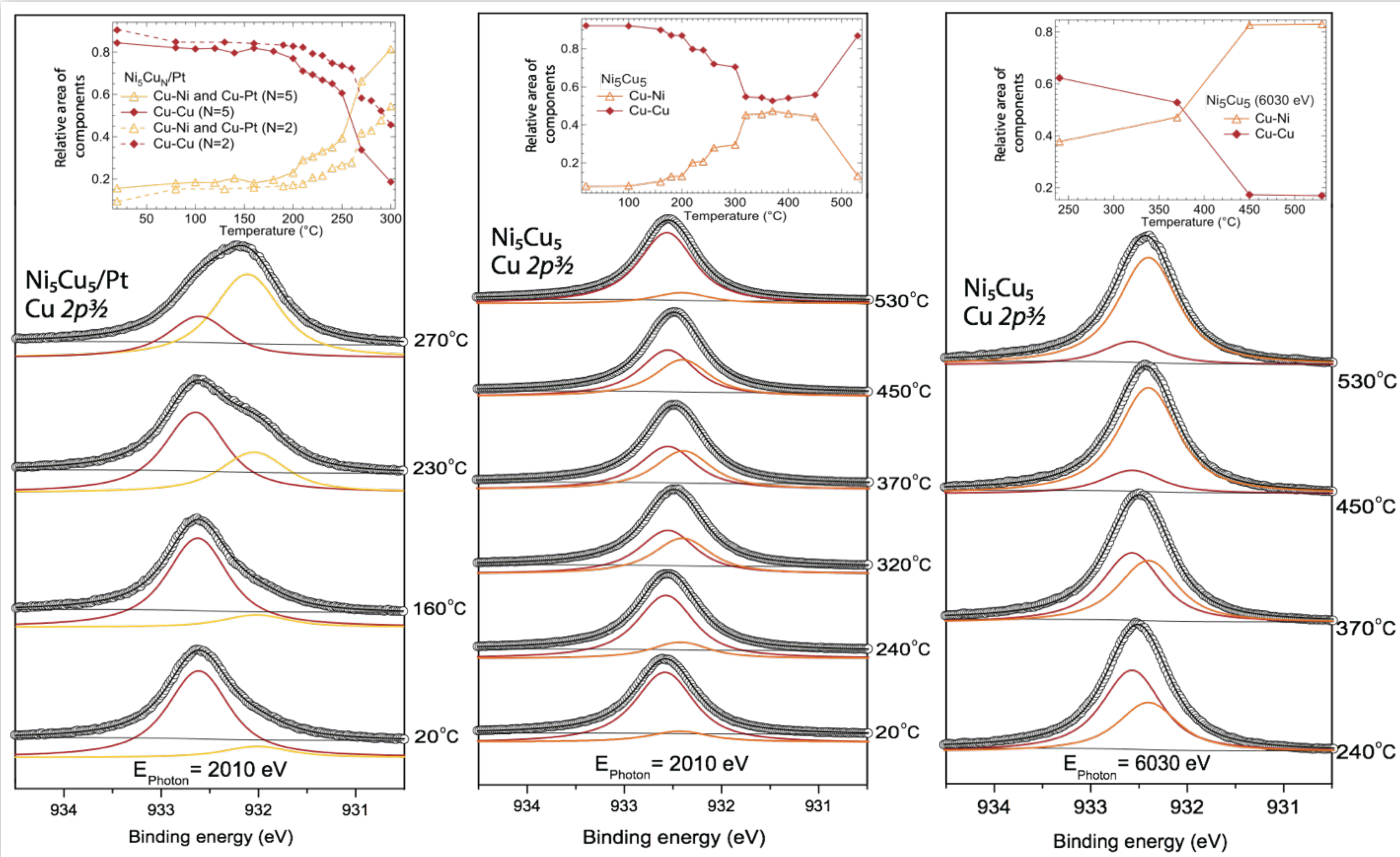




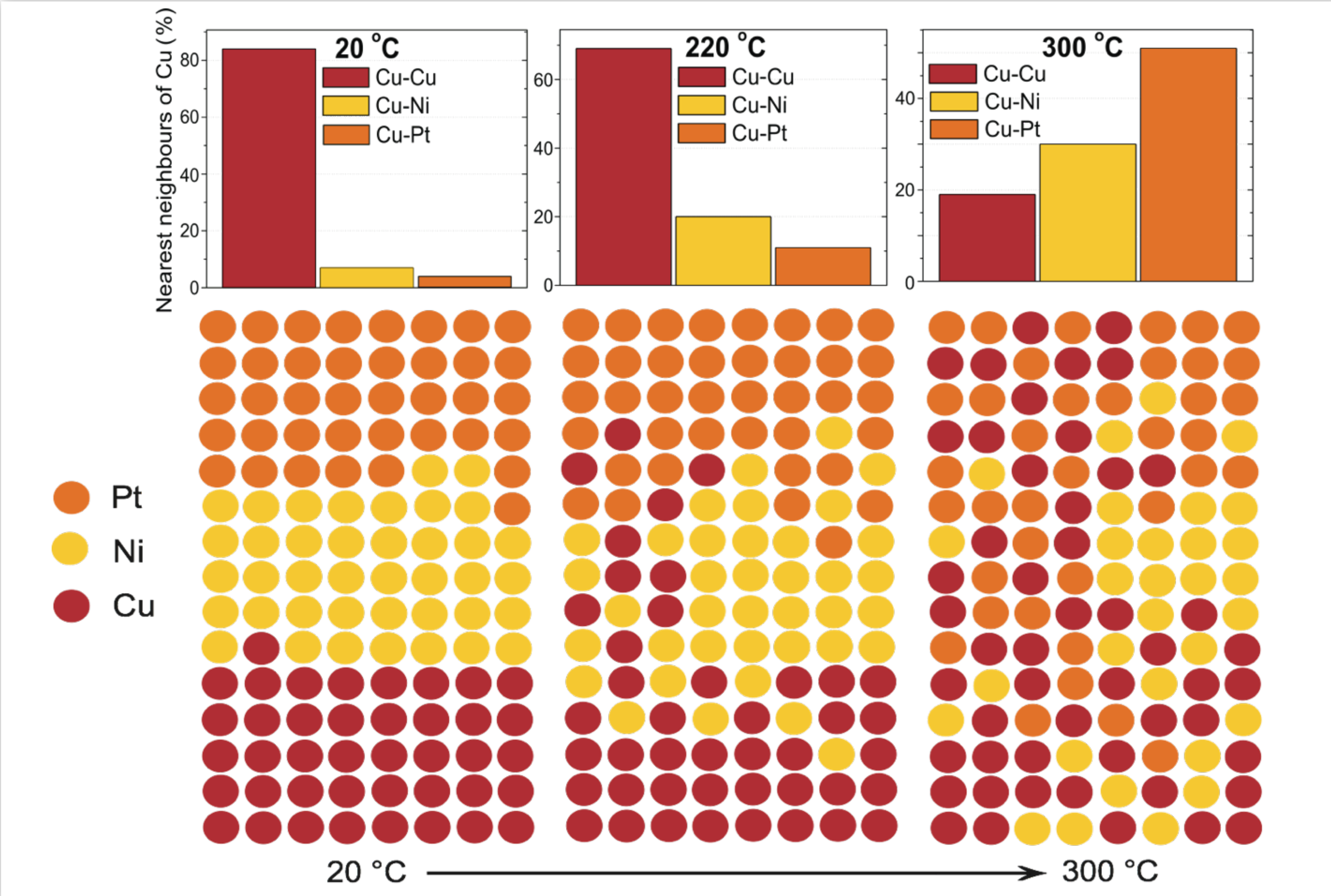
Pt cap diffusion

Cu segregation

More quantitative information → two-peak-fit model



Phys. Rev. B 80, 2009, 94104

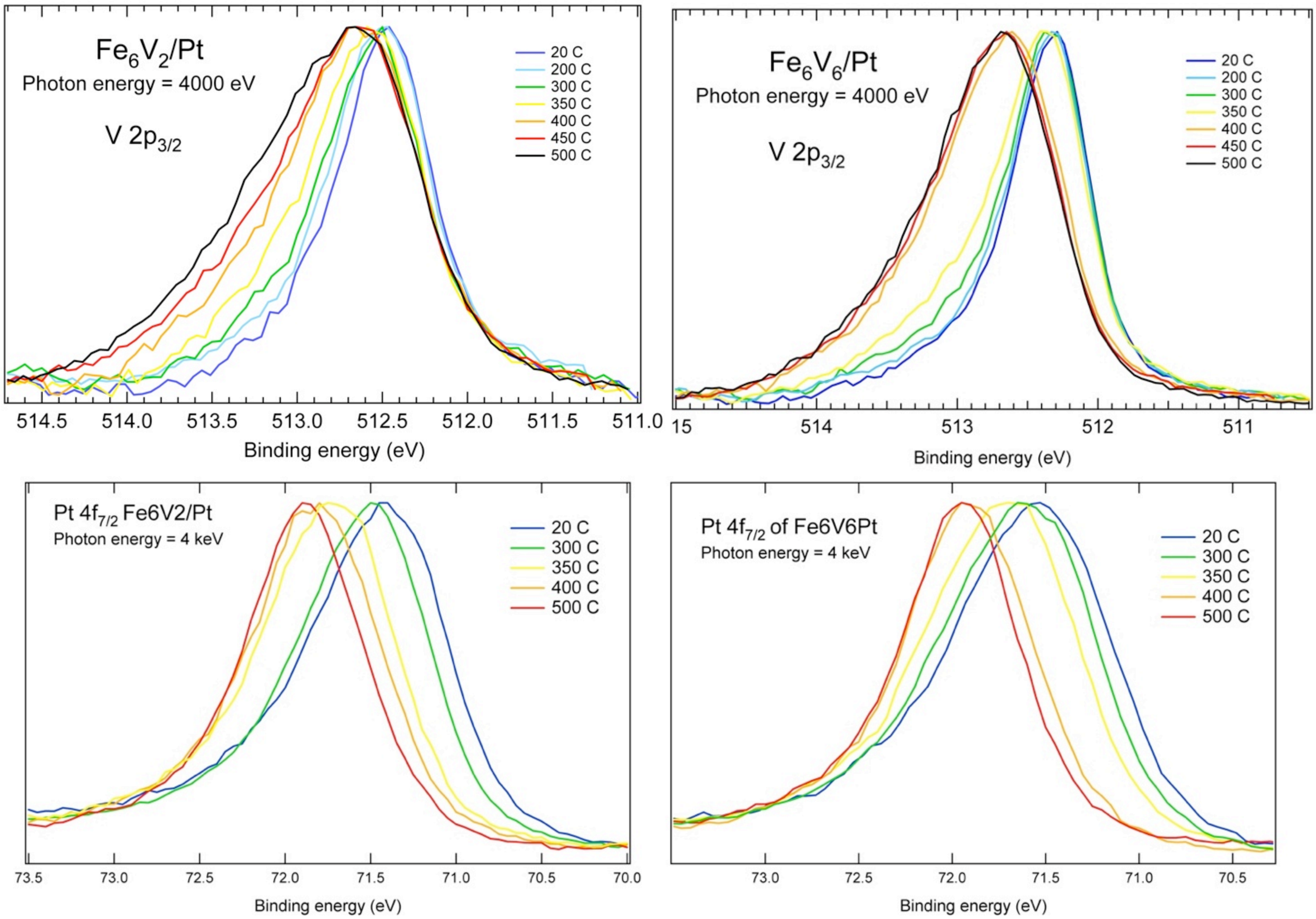


Phys. Rev. B 80, 2009, 94104

Summary of Ni/Cu study:

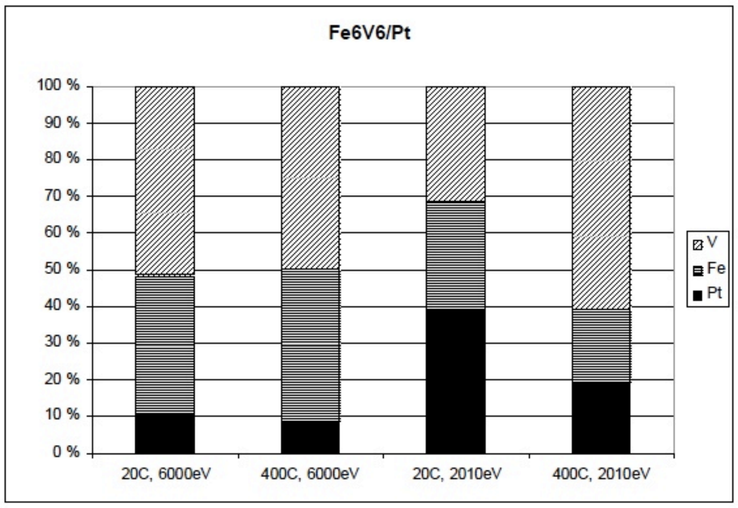
- The bulk sensitivity and nondestructive character of HIKE method were exploited to observe interface roughening and alloying as a function of heating temperature.
- Destroying of interfaces and first signs of alloying were seen already at low temperatures which brings valuable information related to sample preparation.
- Another important result connected especially to multilayer fabrication process is the diffusion of protective Pt capping layer into the sample.
- The relative intensity variations of core-levels of Cu, Ni and Pt and the compounds of two-peak-fit model of Cu 2*p* as a function of temperature give indicative information about the kinetics of the compound atoms.
- Quantitative idea of intermixing can be formed by comparing the intensities of the Cu-Cu and Cu-Ni/Pt components of Pt capped and Ni capped Ni/Cu multilayers in the two-peak-fit model.

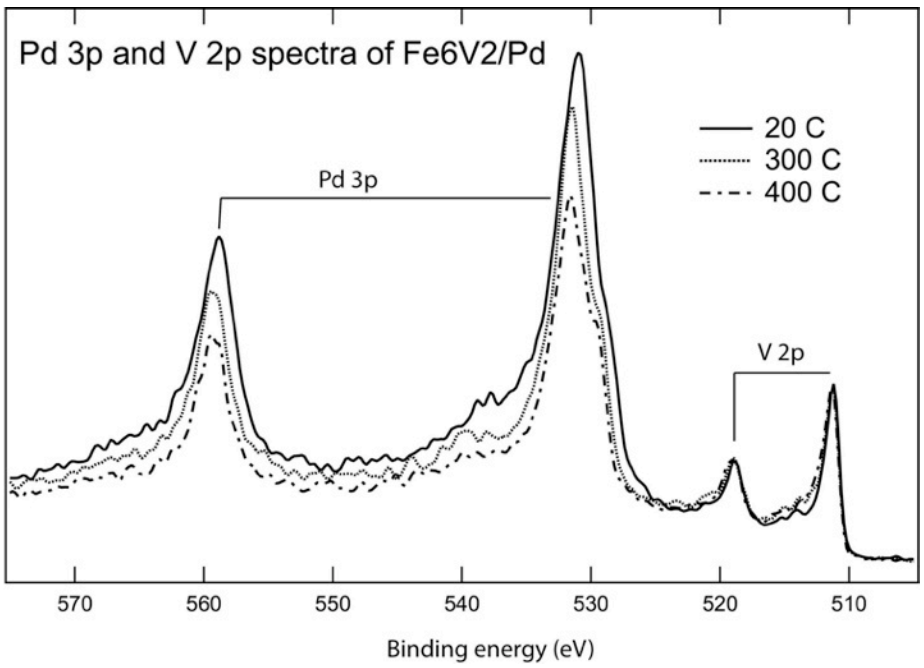
Fe/V multilayers



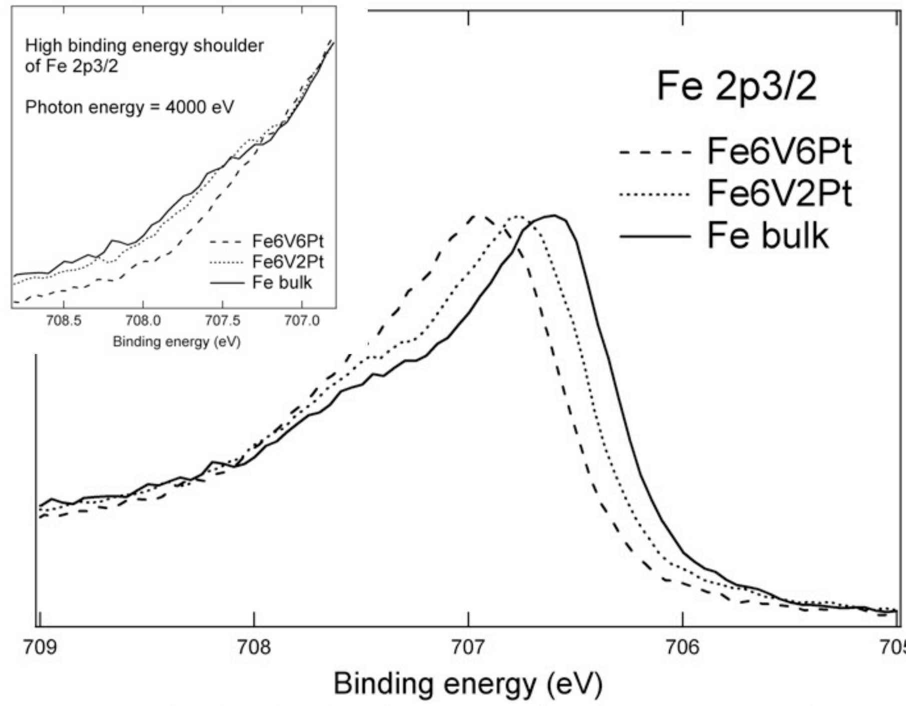
- V 2p of Fe6V2/Pt is shifting gradually as a function of heating whereas almost the entire shift of V 2p in Fe6V6/Pt takes places between 350 and 400 C. This is due to the thin V layer with only interface V atoms in Fe6V2/Pt. Same kind of effect can be observed in Pt 4f. -> Pt diffusion occurs easier in V environment (in Fe6V2/Pt where V layers have alloyed at lower temperature and V segregation can be faster).

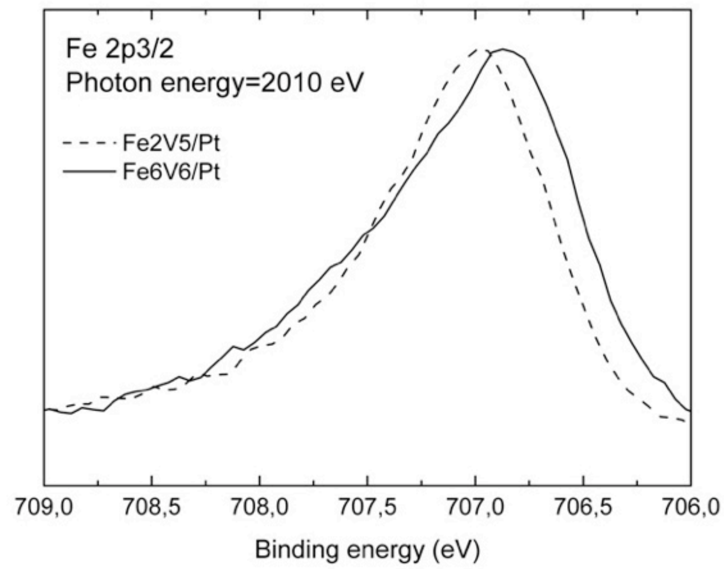
Diffusion of Pt and Pd cap





Fe 2p





- Diffusion of Pt cap is stronger than diffusion of Pd cap.
- High binding energy shoulder in Fe 2p is dependent on the Fe concentration in the sample.

Heusler alloys

- The use of highly spin-polarized Heusler alloys as ferromagnetic electrodes has long been considered to be a promising avenue for achieving higher MR ratios.
- Spin polarization is in reality limited due to defects and specific details of the interface structure regarding roughness and intermixing.
- What could be done to optimize the layered structure, i.e., minimizing disorder and interface roughness during growth and post-treatment?

→ **HAXPES of**

<u>(CoMn2Ge)6/(CuRh2Sn)18/Ru</u>

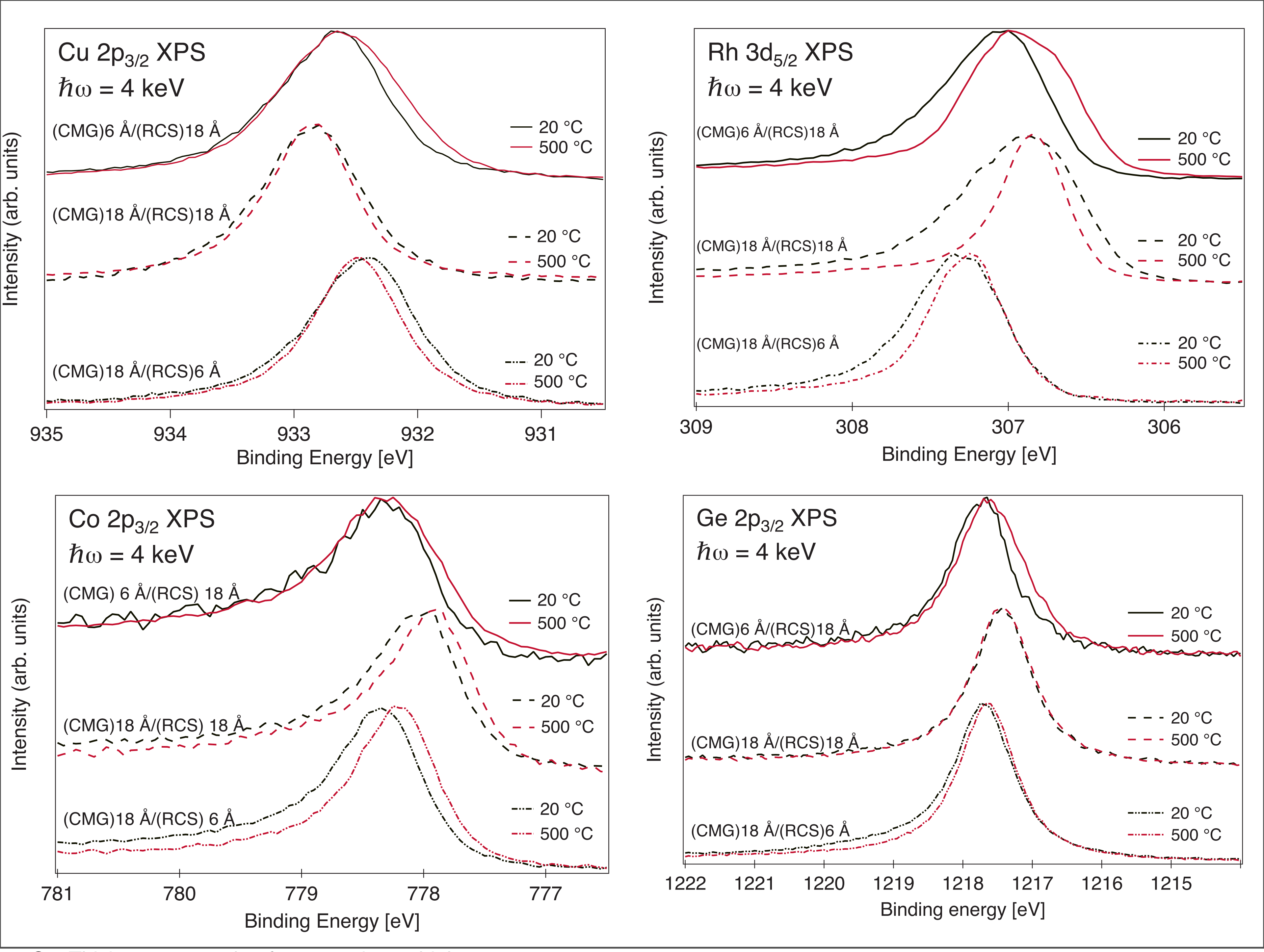
<u>(CoMn2Ge)18/(CuRh2Sn)18/Ru</u>

<u>(CoMn2Ge)18/(CuRh2Sn)6/Ru</u>

The use of highly spin-polarized Heusler alloys as ferromagnetic (FM) electrodes has long been considered to be a promising avenue for achieving higher MR ratios. Spin polarization is in reality limited due to defects and specific details of the interface structure regarding roughness and intermixing.

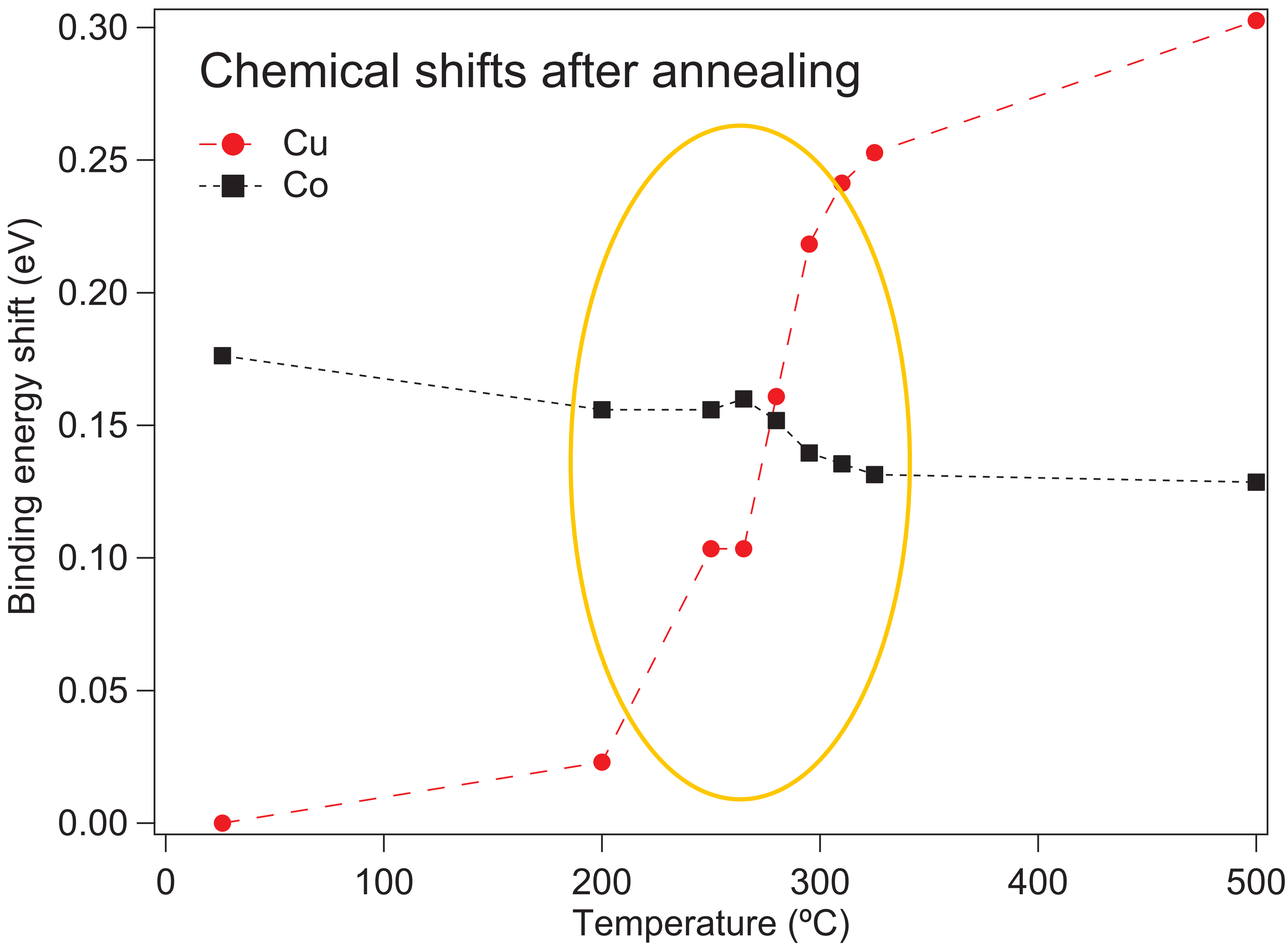
T. Ambrose and O.Mryasov, Half-metallic Alloys: fundamentals and applications, Springer Verlag Series 676, 187 (2005)

K. Nikolaev, P. Kolbo, T. Pokhil, XL Peng, YH Chen, T. Ambrose, and O. Mryasov, Appl. Phys. Lett. 94, 222501 (2009)



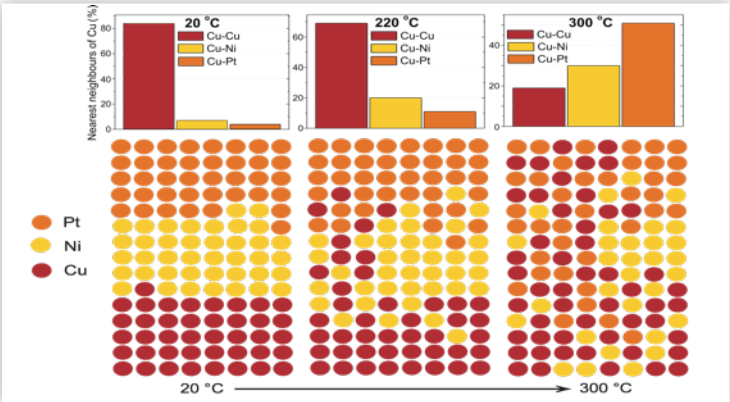
- Cu: Thicker layers stable for annealing at higher temperatures
- Rh: Thick CGS Thick CMG appears stable again.
- Co: Seems to be moving for all thicknesses
- Ge: Again seems quite stable at higher temperatures when the individual layers are thicker.

(CoMn2Ge)/(CuRh2Sn)/Ru



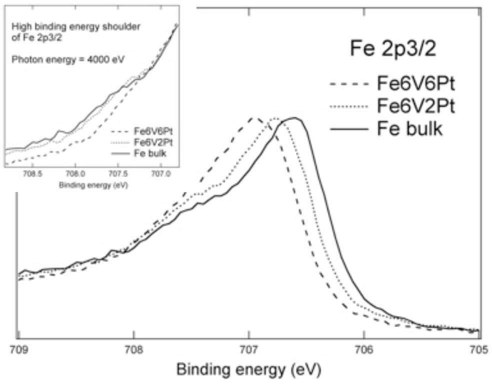
- Intermixing occurs in a very narrow temperature range. Note that 250 C annealing is needed to prepare the samples.

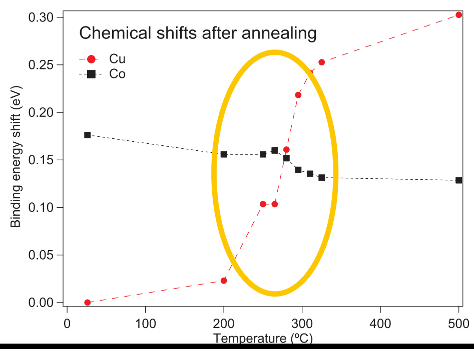
Summary



Ni/Cu
- Pt cap diffusion, formation of ternary alloy
- Cu segregation
- Two-peak-fit model for more quantitative information

Fe/V
- Pt cap diffusion, not so strong Pd cap diffusion
- V segregation
- Change in Fe 2p peak shape as a function of Fe concentration





Heusler alloy multilayers
- Interface intermixing already at temperatures that are used in sample preparation

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