The Spin Polarization of Palladium (Pd) on Magneto-Electric Cr_2O_3

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Abstract:

The electronic structure, especially spin polarized band structure, are essential to the implementation of spintronic materials. In addition, the surface/interface is a key to the device. The tool of spin polarized inverse photoemission spectroscopy (SPIPES) combined with spin polarized photoemission (SPES) is the most complete approach for developing a full understanding of magnetic materials in electronic structure point of view.

Furthermore, SPIPES is hugely surface sensitive, which is an advantage for characterizing boundary polarization. We have developed angle-resolved SPIPES [1, 2], the time reversed process to SPES, specifically to characterize the unoccupied state band structure. Here, we present several results of SPIPES and the value of complementing PES, Angle Resolved PES, leading to the next step to Spin polarized PES, including the latest on-going Pd covered Cr_2O_3 investigation.

The Pd/Cr_2O_3 results show evidence of magnetic behavior in Pd suggesting that Pd on Cr_2O_3 is more than just a paramagnetic with an induced polarization arising from the chromia boundary polarization. This be leading to the voltage controlled spintronic memory devices.

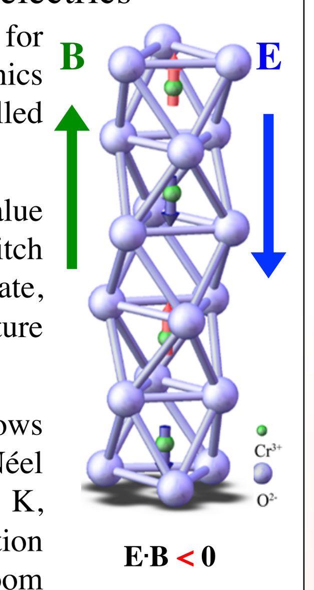
Symple Overview of Cr_2O_3

Cr_2O_3 Antiferromagnetic Magnetoelectrics

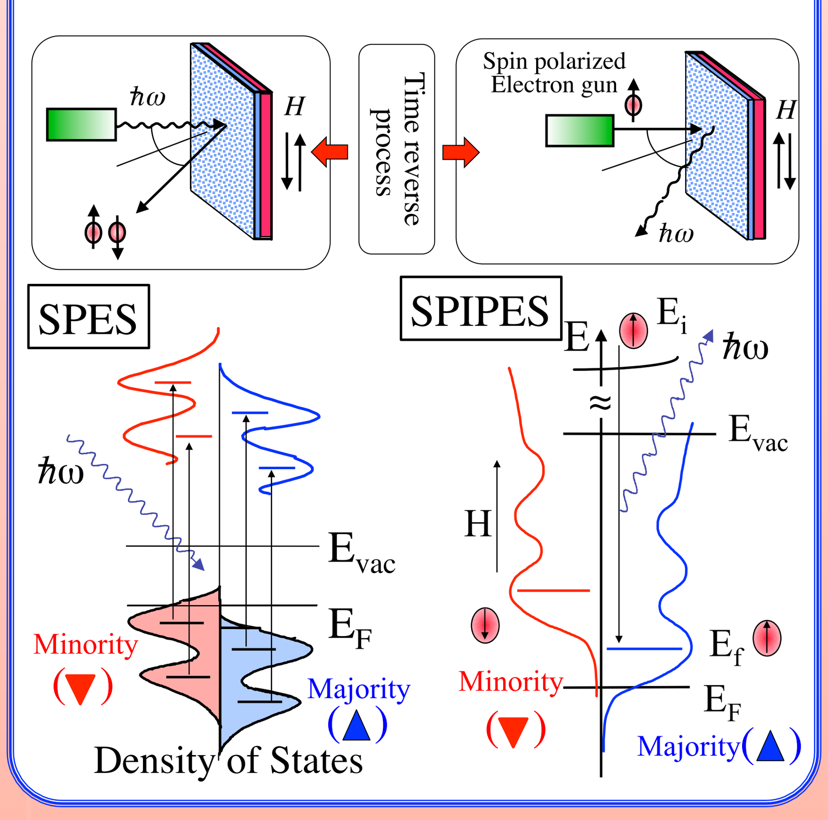
★Attracting great interest for voltage controlled spintronics devices: voltage controlled switching of magnetism.

★There exists threshold value for the product |E·B| to switch the surface domain state, below Néel temperature (307K).

★Boron doped Cr_2O_3 shows an evidence of higher Néel temperature, T ≈ 423 K, meaning higher polarization asymmetries at room temperature.

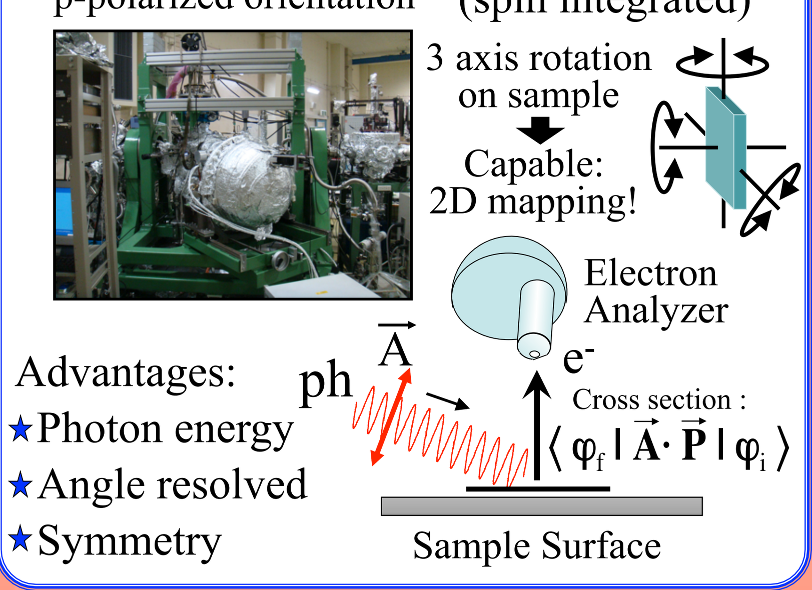


Schematic Diagram of SPES and SPIPES



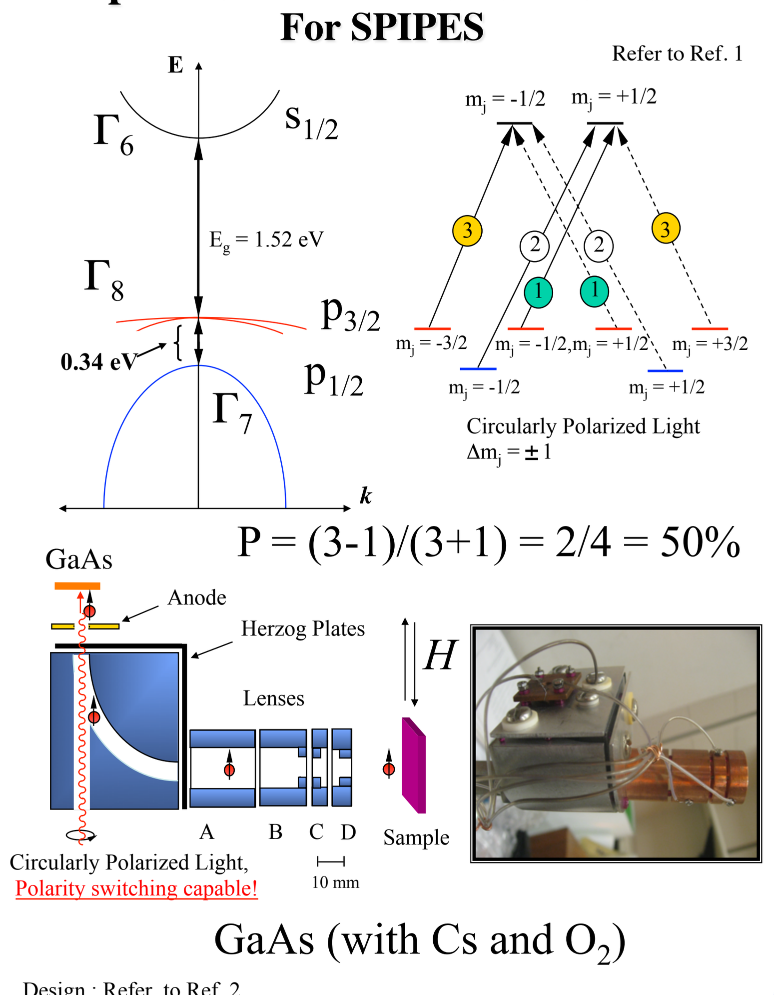
Experimental Set Up at HiSOR BL-1 for Angle Resolved PES (ARPES)

p-polarized orientation (spin integrated)



Advantages:
★Photon energy
★Angle resolved
★Symmetry

Spin-Polarized Electron Source For SPIPES



$P = (3-1)/(3+1) = 2/4 = 50\%$

GaAs (with Cs and O_2)

Design : Refer to Ref. 2

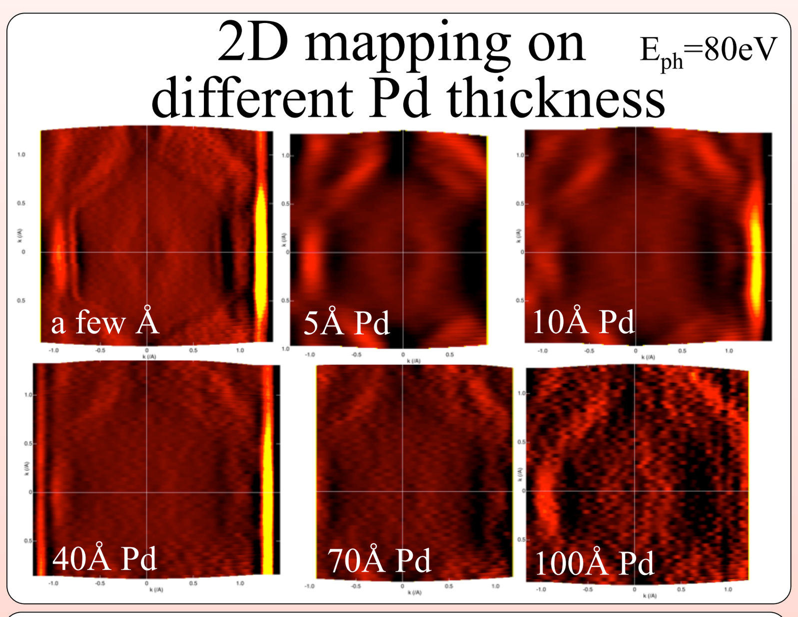
Reference:
1 Daniel T. Pierce and Felix Meier, PRB **13**, 5484(1976)
2 F. Ciccacci, et al., Rev. *Sci. Instrum.* **63**, 3333 (1992)

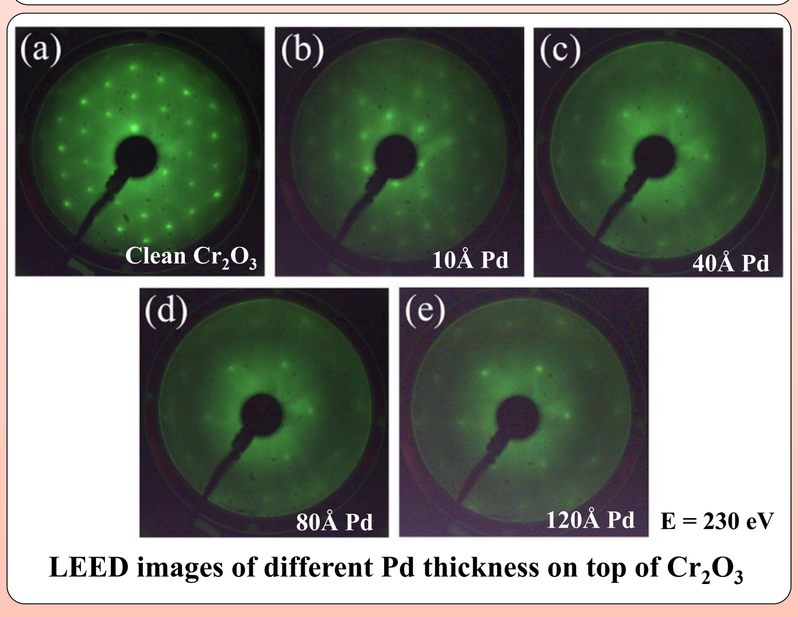
On Going Research

Angle Resolved PES

Palladium (Pd) on Cr_2O_3

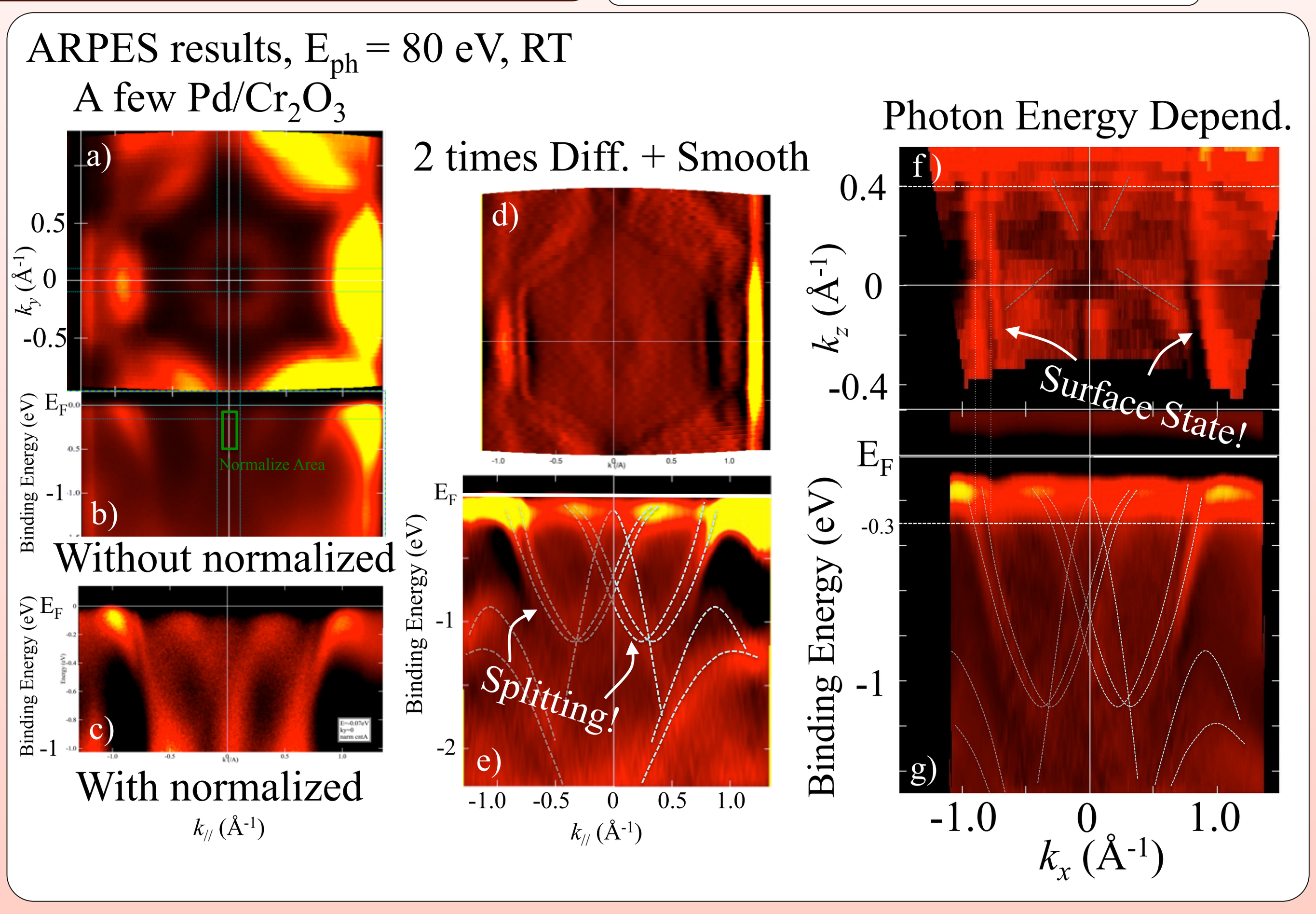
2D mapping on different Pd thickness, E_{ph}=80eV





LEED images of different Pd thickness on top of Cr_2O_3

ARPES results, E_{ph} = 80 eV, RT



Above Fig.: a) and b) are the row data of ARPES at HiSOR. c) is the simple normalized data of b) in Igor function. d), [E at -0.2eV below E_F] and e) are smoothed and 2 time differentiated result of raw data, a) and b), showing band splitting on those bands near E_F, as indicated with arrows. f) and g) are the experimental results of photon energy dependent measurement on the different sample with similar Pd thickness on Cr_2O_3, with showing none dispersing features, in f), as surface states, [f) E at -0.3eV below E_F].

SPIPES

SPIPES results of Pd doped Cr_2O_3

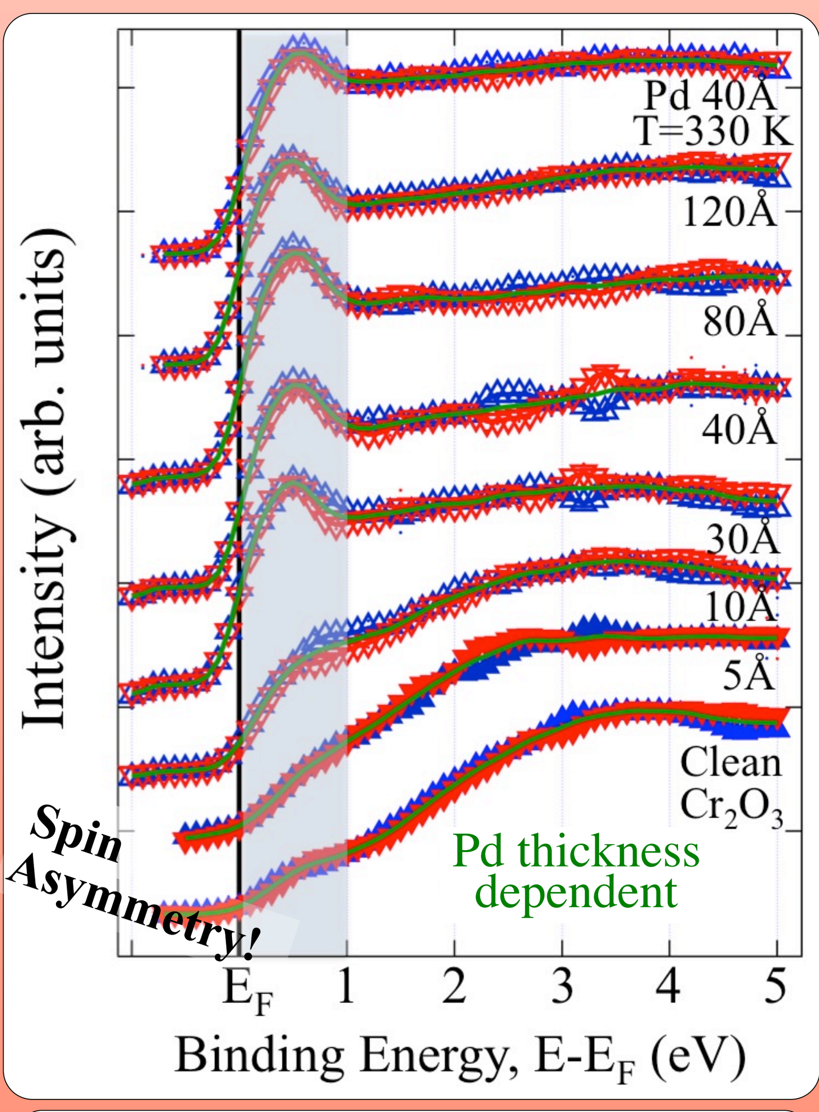


Fig. above: Experimental SPIPES results for clean Cr_2O_3, at bottom, and variety of Pd thickness on top of Cr_2O_3, at room temp. The very top feature is for T ≈ 330K with 40Å, for comparison.

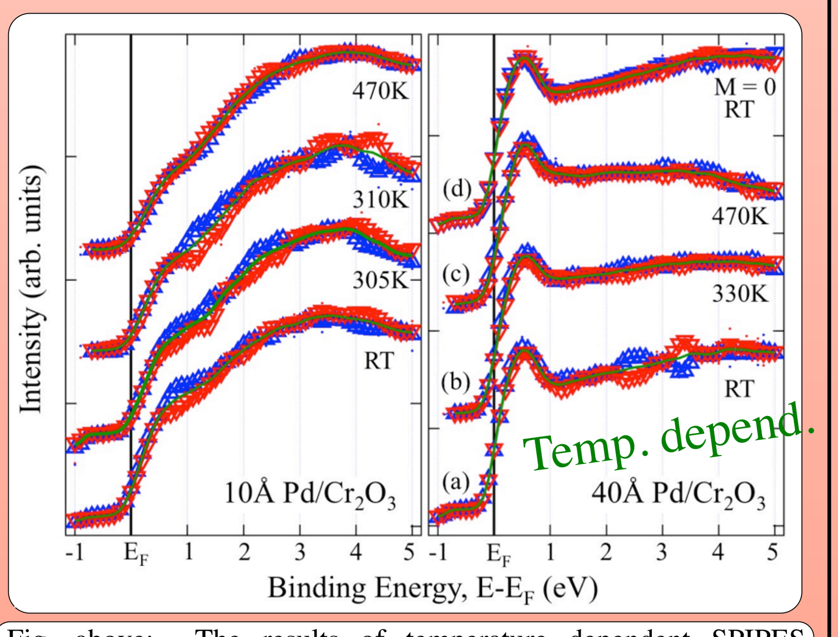


Fig. above: The results of temperature dependent SPIPES measurement of Pd thickness of 10Å (left) and 40Å (right) on Cr_2O_3 (0001). The feature on right panel on the top, is for the result for zero external magnetic field applied on the 40Å Pd on Cr_2O_3 (0001) single crystal, at room temperature, for comparison.

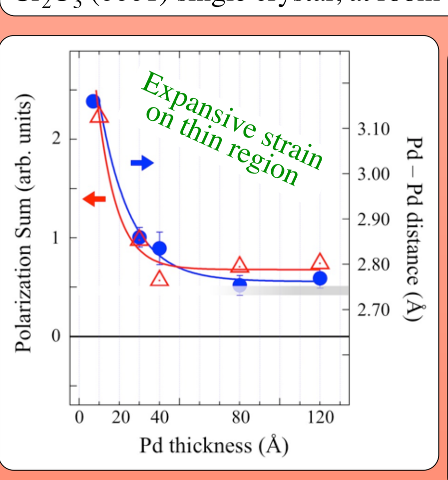


Fig. at left: The blue carve is the extracted values for Pd-Pd distance figured out from LEED images, and the red curve is the summed value of spin polarization of the range between E_F to 1eV, as graded on SPIPES results, referring to Pd thickness. The horizontal gray strap around thick Pd thickness is refereeing to the bulk Pd-Pd distance.

k value comparison of LEED and ARPES on Pd doped Cr_2O_3

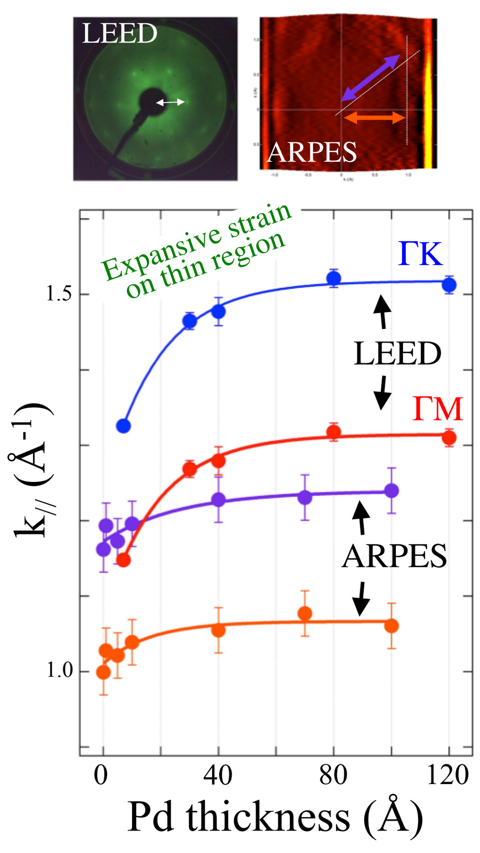
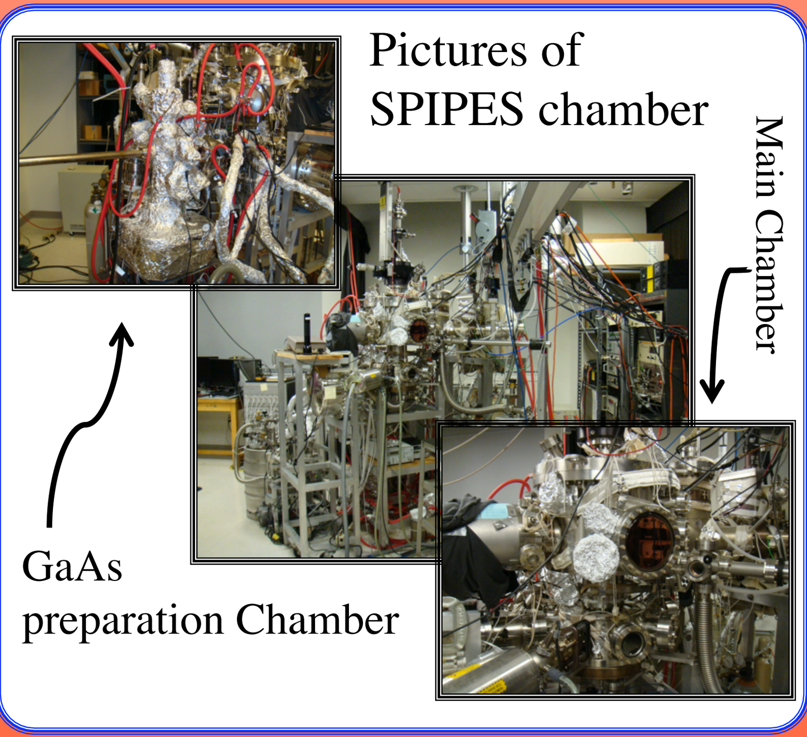


Fig. above: Those features are extracted value of $k_{//}$, depending on Pd overlayer thickness, in 2 dimensional electronic structure from LEED (upper one is for ΓK and lower one is for ΓM point, from geometrical position of spots), and ARPES (for 2 direction of symmetry lines as indicated arrows, from band dispersion and 2D mapping).

Pictures of SPIPES chamber



Conclusion

- Experimentally we have measured occupied electronic structure of Pd covered Cr_2O_3, coverage depended, with using Angle resolved Photoemission Spectroscopy (ARPES) at HiSOR, to reveal band splitting and surface states of valence region.
- PES and LEED results show a clear evidence of thickness dependent strain effect on Pd, related to magnetic character of Pd thin layer on Cr_2O_3.
- With such established Spin Polarized Inverse Photoemission Spectroscopy (SPIPES), we reveals evidence of spin asymmetry of unoccupied electronic structures on Pd covered Cr_2O_3, temperature and thickness dependent.

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