Soft X-Ray ARPES at Swiss Light Source: From Bulk Materials to Buried Heterostructures and Impurities

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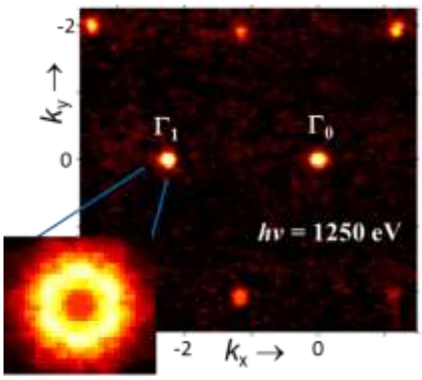
Soft-X-ray ARPES, operating in the energy range around 1 keV, benefits from enhanced photoelectron escape depth, concomitant sharp resolution in 3D electron momentum **k**, and resonant photoexcitation delivering elemental and chemical-state specificity. High energy resolving power (>30000) and photon flux (>10^{13} ph/s/0.01%BW) delivered by the ADRESS beamline of Swiss Light Source allow expansion of this novel experimental technique from bulk materials to buried heterostructures and impurities [1] which are in the heart of electronic and spintronic devices.

Bulk materials. – Applications to 3D electronic structure of bulk materials are illustrated by the layered chalcogenide VSe_2 where we discover 3D-nesting of its Fermi surface stabilizing exotic charge density waves [2]. Other examples include lattice-distortion effects in manganates connected with their magnetoresistance [3], 3D topological states in Weil semimetals, etc.

Buried heterostructures. – Semiconductor systems are illustrated by AlGaN/GaN high-electron-mobility transistor heterostructures, where soft-X-ray ARPES finds anisotropic band structure and Fermi surface (figure) of the interfacial quantum-well states, resulting in anisotropic non-linear electron transport [4]. For the "drosophila" oxide interface $LaAlO_3/SrTiO_3$, resonant photoexcitation of the Ti-derived interfacial charge carriers resolves their multiphonon polaronic nature, fundamentally limiting their mobility [5]. Further cases include EuO/Si spin injectors, EuS/Bi_3Se_2 topological interfaces, etc.



Impurity systems. – Applications to diluted magnetic semiconductors are illustrated by Ga(Mn)As, where resonant photoexcitation of Mn-derived impurity states identifies their energy alignment and hybridization with the host GaAs states, elucidating the nature of the ferromagnetic electron transport [6]. Other cases include magnetic V impurities in the topological Bi_3Se_2 competing with the quantum anomalous-Hall effect, etc.

Further prospects of soft-X-ray ARPES are connected with the multichannel spin detector iMott [7]. Boosting the detection efficiency by few orders of magnitude, this detector will deliver previousy unthinkable information about **k**-resolved spin texture of buried heterostructures and impurities. Furthemore, in 2023 the Swiss Light Source will be upgraded to the diffraction-limited source based on multibend achromats, promising an increase of the coherent fraction and reduction of the horizontal emittance by a factor of >30. The ADRESS beamline will receive an Apple-Knot undulator to reduce on-axis thermal load by two orders of magnitude. This source and optical elements with ultra-low slope errors of ~0.1 μrad will push the beamline resolving power above 100'000, allowing access to electronic structure and electron-boson interactions on the few-meV energy scale.

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[5] C. Cancellieri et al., *Nature Comm*. **7** (2016) 10386
[6] M. Kobayashi et al., *Phys. Rev. B* **89** (2014) 205204
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