k-resolved electronic structure of bulk crystals, buried heterostructures and impurity systems by soft-X-ray ARPES

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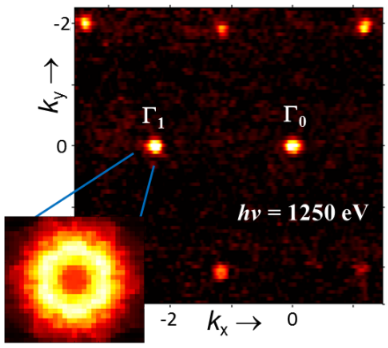
Knowledge of fundamental characteristics of solid-state systems such as electron dispersions, Fermi surface, electron-boson coupling, etc. resolved in electron momentum **k** is essential for synthesis of materials tailored to particular applications. Whereas for crystalline surfaces such information is delivered by angle-resolved photoelectron spectroscopy (ARPES), pushing this technique to soft-X-ray photon energies around 1 keV adds up large probing depth, sharp definition of three-dimensional **k**, and chemical-state specific resonant photoexcitation. These spectroscopic advantages allow access to 3D bulk materials, buried interfaces/heterostructures and impurity systems actual for electronic, spintronic and quantum devices.

Bulk materials. – Applications of soft-X-ray ARPES to bulk materials are based on a sharp definition of three-dimensional **k** resulting from the enhanced photoelectron delocalization. Examples include 3D-nested Fermi surface of VSe_2 forming exotic charge-density waves [1], 3D band dispersions and band-dependent electron-phonon interaction in complex oxides [2], 3D topological structures such as Weyl cones and chiral fermions [3], etc.

Buried heterostructures. – Semiconductor systems are illustrated by AlN/GaN high-electron-mobility transistor (HEMT) heterostructures, where soft-X-ray ARPES resolves the anisotropic Fermi surface (Figure) and band dispersions of the interfacial quantum-well states [4]. An example of superconductor/semiconductor interfaces is NbN/GaN, where a **k**-space separation of the Fermi states in NbN from the valence states in GaN protects their superconductivity [5]. A paradigm example of oxide interfaces is $LaAlO_3/SrTiO_3$. Resonant photoexcitation at the Ti *L*-edge resolves here the interfacial subbands, whose peak-dip-hump spectral function identifies a multiphonon polaronic nature of the charge carriers intrinsically limiting their mobility [6].



Impurity systems. – An example of impurity systems is Ga(Mn)As the dilute magnetic semiconductor. Resonant photoexcitation at the Mn *L*-edge identifies energy alignment and hybridization of the Mn impurities with host GaAs, disclosing the mechanisms of the ferromagnetic electron transport [7]. Other cases include magnetic V impurities in topological Bi_3Se_2 competing with the quantum anomalous Hall effect, etc.

References

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