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Unveiling novel temperature scales at the surfaces of 4f-materials by ARPES measurements

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For a long time, rare-earth (RE) intermetallic materials have attracted considerable interest because of their rich and exotic properties including complex magnetic phases, valence fluctuations, heavy-fermion and Kondo behavior and non-Fermi-liquid properties. At the heart of the involved physics is the delicate interplay between itinerant electrons and the lattice of localized 4f states.

In that regard, the class of RE compounds RE_2Si_2 (T is transition metal atoms) of the $ThCr_2Si_2$ type structure attracts considerable attention. Besides their unique bulk properties evolving from an interplay of 4f and itinerant electrons, these materials serve the models for studying exotic physics within the non-centrosymmetric Si-T-Si-RE four-layers surface-silicide block. Within this block, the strength of spin-orbit coupling (SOC) can be tuned by choice of suitable transition metal (T) atoms. It gradually increases by exchanging Co (3d) for Rh (4d) and further for Ir (5d). As a competing ingredient, exchange magnetic interaction may be exploited by inserting elementary 4f magnets like Gd as the RE component. Because the orbital moment of the Gd 4f shell vanishes ($L = 0$), the pure and large spin moment of Gd will be a strong and robust source of magnetic phenomena. A rotation of the 4f moments to a certain angle relative to the surface normal may be achieved by coupling to a crystal electric field (CEF). To make use of notable CEF effects, a non-vanishing orbital moment L is needed, like for instance in Ho or Dy. Then, this option allows to implement an exchange magnetic field with different strength and orientation at the surface, which competes with the Rashba SOC field and creates additional possibilities to manipulate the properties of the 2D electrons within the considered Si-T-Si-RE system. As the next ingredient, the Kondo effect can be introduced by inserting elements with unstable 4f shell as Yb or Ce. This gives the opportunity to explore the interplay of the 2D electrons with 4f moments within a 2D Kondo lattice in the presence of spin-orbit coupling and a non-centrosymmetric environment.

Our recent experiments have realized the most of such scenarios and demonstrated quite nicely that the Si-T-Si-RE surfaces of the RE_2Si_2 materials serves as a versatile playground for studying the fundamental properties linked with 4f magnetism and f-d interactions at reduced dimensionality. It represents a kind of construction kit with spin-orbit coupling, Kondo interaction, crystal-electric fields and magnetic exchange with different strengths as building blocks. Their mutual combination gives the opportunity to design systems for different scenarios and to study the physics of 2D electron states in the presence of these competing interactions. The obtained results create a solid platform for the time-resolved studies that are of particular importance for the physics and applications of magnetic materials. The most interesting experimental results, which unveil the novel temperature scales at the surfaces of RE_2Si_2 as well as of $RECo_2P_2$ materials and which are linked with the aforementioned scenario will be presented.

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