

(e,2e) electron spectroscopy of surfaces

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Abstract. In (e,2e) spectroscopy, a primary electron is scattered from a target and detected in coincidence with another electron ejected from the target. We measured such events in electron scattering from a W(100) surface by two time-of-flight electron energy analyzers based on position sensitive multi-channel detectors. We analyzed the total energy distribution of correlated electron pairs, as well as the energy-sharing distributions of electrons within a pair with a certain total energy. We found that the correlated electron pairs are created mainly by the primary electron scattering off a valence electron close to the Fermi level. An asymmetry in the energy-sharing distributions of the electrons of the correlated pair appears when the incident electron direction is off-normal. We suggest that most of the correlated pairs from W(100) are created by the specularly reflected or diffracted primary electrons and are due to a single scattering event of the primary electron with a valence electron.

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In conventional electron spectroscopy, with excitation by electrons or photons, we generally observe an integral response of the electronic system of the solid to an external excitation. There is very little information about individual electron-electron scattering events in solids. To obtain such information is difficult, both experimentally and theoretically. Experimentally, it is difficult to separate single scattering events from multiscattering processes, as well as from collective excitations of the electron charge density (e.g., plasmon). The theoretical calculation of the scattering event requires two initial and two final electron states to be calculated with a largely unknown interaction potential.

One of the most promising techniques to study electron-electron scattering is two-electron coincidence spectroscopy in the mode of one electron in-two electrons out (e,2e spectroscopy) [1,2]. Over the last twenty years, (e,2e) spectroscopy has developed as a tool for studying the electronic structure of solids and scattering dynamics of fast electrons

on solid targets [1–6]. All these studies were carried out in the transmission mode of (e,2e) experiments by using high-energy incident electrons. A fast electron knocks out a target electron and then scattered and ejected electrons are detected in coincidence. In this geometry, the scattering problem is kinematically complete: energy E_0 and momentum \mathbf{k}_0 of the incident electron are known, and energies E_1 , E_2 and momenta \mathbf{k}_1 , \mathbf{k}_2 of both time-correlated electrons are measured. One can obtain the binding energy E_b and momentum \mathbf{k}_v of the target electron by using energy and momentum conservation laws:

$$E_b = E_0 - E_1 - E_2, \quad (1)$$

$$\mathbf{k}_v = \mathbf{k}_1 + \mathbf{k}_2 - \mathbf{k}_0. \quad (2)$$

The data obtained with this mode of (e,2e) experiments concern the bulk electronic structure of a solid in the shape of a film, thin enough to transmit sufficient electrons and to justify the assumption of a single collision event.

In order to apply this technique to solid surfaces and to the study of the scattering dynamics of low-energy electrons, (e,2e) experiments in reflection geometry were designed [7–10]. In this mode, an incident electron impinges on the sample surface and two outgoing electrons are detected in coincidence. Two different modes were used in the reflection geometry experiments: (1) normal incidence and low primary electron energy [7–9] and (2) grazing angle of incidence and medium electron energy [10]. We shall focus our attention on experiments with low-energy primary electrons. In the case of the reflection geometry of the experiments, the momentum \mathbf{k}_0 of the incident electron is directed from vacuum to the solid, while the total momentum \mathbf{k}_{out} of two outgoing electrons is directed from the solid to vacuum. Thus, to describe the ionization in the reflection mode, further interactions that result in momentum reversal in addition to the electron-electron collision have to be considered. There are at least three models that describe additional elastic scattering. In the first model, the momentum normal to the surface is provided by the crystal that reflects the incident electron along the specular direction. In principle, not only the (0,0) specular beam but all diffracted beams in the back hemisphere should be consid-

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Circ Cichroic Spectroscopy 2e

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