Synchrotron X-ray Measurement of the Femi Surface in Disordered Alloys

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The Femi surface plays a central role in the electronic properties of all materials. It represents the maximum energy of the electrons in the material. In particular, disordered metallic alloys have presented an enormous problem in defining and measuring this constant energy surface. Theory is very dependent on experimental data which is extremely tedious to accumulate. In this work we use a technique, developed by Dr. H. Reichert at the Max Planck Institut für Metallforschung – Stuttgart. In this method very high energy synchrotron x-rays are measured in transmission and an entire plane of reciprocal (momentum) space can be examined in 10 seconds using a two dimensional detector. The diffuse scattering shown on the right is for the alloy Cu_3Pd in the disordered state.

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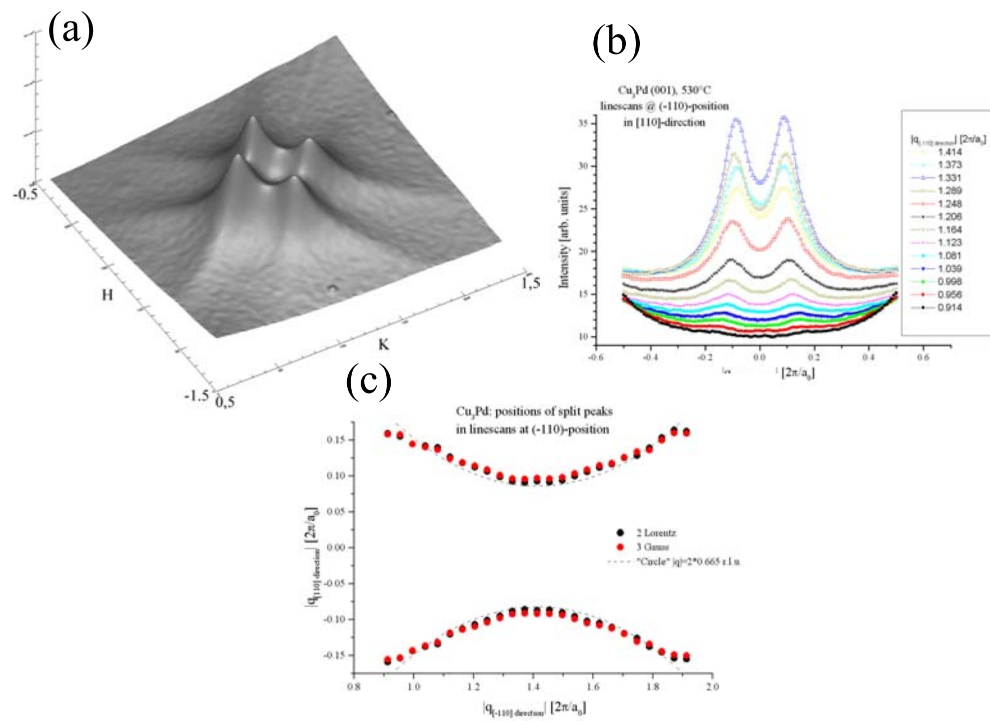

Fig. (a) shows a three dimensional plot of diffuse intensity from disordered Cu_3Pd. The asymmetry is due to atomic size difference between Cu and Pd. There are clear ridges of diffuse intensity that peak at the center of the figure; (b) scans through symmetrical ridges showing the extension of the intensity over a large area; (c) plots the maxima of these ridges of diffuse scattering with a dotted line representing a circle (note scale change). In other words, the position of the maximum energy surfaces is essentially spherical, which defies current theory and is being analyzed in Houston and Stuttgart. These are extremely provoking results that have never been seen before.

In all text books of solid state physics, the Femi energy (E_F) and Femi wave vector(k_F) play a crucial role in the determination of the optical, transport, magnetic, and thermal properties of materials. In metals, in particular, k_F is the defining quantity for the metal in question. For metallic alloys, it is especially of interest to understand the stability of alloys and the values of their band gaps (unallowed energies), through an understanding of the shape of the Femi surface, and thus of the value of k_F as a function of orientation in the crystal. Access to this basic information is extremely difficult to obtain and it is only through positron annihilation methods and photoelectron spectroscopy, both of which are very tedious to carry out, that any information on the Femi surface of disordered alloys can be ascertained. The present technique, initially discussed in 1969 by the PI, is only now being fully realized using third generation synchrotron x-ray sources with disordered alloy crystals. The information obtained is remarkable as one would not expect k_F to be circular in the above plot, but rather show flat or nesting regions. In other words, one must examine the theory very carefully to extract this result, and this is in progress.

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Education:

Two Houston graduate students (Jose Rodriguez and a new student, Cesar Ricardez) are contributing to this work. Both students are from Mexico and are pursuing a Ph.D. in Physics.

Collaboration:

Professor Moss is working closely with the Max Planck Institut für Metallforschung – Stuttgart, in particular, with Dr. Harald Reichert, Prof. Vladimir Bugaev, and Prof. Helmut Dosch, director of the institute.

Societal Impact:

A basic understanding of metal physics and the stability of a variety of technologically important alloys depend on an understanding of the underlying theory and band structure. This in turn is intimately connected to the behavior of the Femi surface of the alloy. Modern metallurgy and materials science require such an understanding.