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ELECTRON SCATTERING ON DEFECTS NEAR METAL SURFACES

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Résumé.- On a pu étudier l'effet de la surface sur les défauts du réseau en mesurant la diffusion des électrons de conduction à basse température, à l'aide de la résonance entre niveaux de Landau entre défauts de surface. L'observation a porté sur les couches très près de la surface, dans des échantillons irradiés par neutrons, et des échantillons trempés où les défauts sont créés par contrainte.

Abstract.—By measuring the scattering of conduction electrons at low temperatures with the help of surface Landau level resonance the effect of the surface on lattice defects has been studied. Defect depletion layers and stress induced defect production near the surface in quenched samples have been observed.

Using surface Landau level resonance (SLLR) the scattering of conduction electrons at low temperatures can be measured very close to the metal surface. The SLL resonances /1/ are microwave transitions between surface bound states in low magnetic fields H, which correspond classically to electrons skipping along the sample surface, reaching a depth of the order of 1000 Å. Direct measurements have been made of the scattering rates of electrons on lattice defects for a number of points on the Fermi surface (FS) of Al, corresponding to 3 different penetration depths: 400 Å, 850 Å, 2000 Å. Simultaneous measurements of cyclotron resonance could be made which probe the metal in a depth of 105 Å (figure 1).

Lattice self defects such as vacancies and interstitials or dislocations were introduced by quenching. Figure 1 shows the relative widths of the resonances as they develop during isochronal annealing (holding time 15 min). Changes in the relative width \( \Delta H/H \) of a resonance are directly proportional to changes of the scattering rate of a very small group of electrons. Practically all scattering events including small angle scattering, are effective. The measurements are made at 4.2 K where the scattering by phonons is not disturbing. At the quench temperatures (473 K) the equilibrium concentration of vacancies is 1 ppm. The increase in relative width \( \Delta H/H \) for SLLR immediately after quenching into acetone at 180 K is an order of magnitude larger than the effect of 1 ppm of vacancies. The quench induced scattering at a depth of 105 Å, quench induced scattering at a depth of 105 Å, figure 16.

![Figure 1: Relative widths of surface Landau level resonances and cyclotron resonance vs. isochronal annealing temperature for quenching from 473 K. The sample surfaces were parallel to a (110) plane (a), and a (100) plane (B). The value of \( \Delta H/H \) at the highest temperatures represent complete recovery. Experimental uncertainties are smaller than the symbols. The 4 points on the central (110) slice of the Al - FS (γ) for which measurements of SLLR were made have penetration depths of 400 Å (A and B), 850 Å (d), and 2000 Å (c & a). The cyclotron resonance L-orbit (105 Å) encloses the 2nd zone, but does not lie in the (110) plane.](http://dx.doi.org/10.1051/jphyscol:19786504)
We conclude that the defects near the surface are formed by thermal stress due to lattice contraction during the quench. The region of the metal near the surface is strained the most, and dislocations are expected to nucleate at the surface. The defects introduced by quenching into a bath at 180 K show very rapid annealing below 200 K (figure 18). This indicates that a relatively high density of sinks for defect recovery was also created during the quench since such rapid recovery is not observed in irradiated samples just below 200 K /2/. As possible mobile defects we can expect vacancies, divacancies, and interstitial clusters. The amount of quench induced scattering that recovers below 200 K appears to scale roughly with the penetration depth. This can be caused by surface depletion during the quench, when diffusion over greater lengths is possible because of the higher temperatures. Defect depletion layers of the order of 400 Å have been observed in neutron irradiated samples /2/.

Using the Al pseudopotential for the scattering potential, it can be shown /3/ that during agglomeration the total scattering rate, which includes small angle scattering, calculated per point defect increases due to the overlap of the scattering potentials. The increase is expected to continue until the agglomerates collapse into small dislocation loops. No appreciable anisotropy of scattering rates is found for small agglomerates, i.e. the scattering rate is independent of position on the FS. The hump in the annealing curves observed between 200 K and 260 K could correspond to the agglomeration of point defects, and the subsequent coalescence of small agglomerates into dislocation loops, or their annealing at sinks. Since the probability of agglomeration increases rapidly with defect concentration, a drop of defect concentration closer to the surface can explain the ratios between the magnitudes of the hump for points c, d and A.

In summary, the unusual annealing curves of electron scattering rates in quenched samples are consistent with the creation of point defects by thermal stress during quenching, and their subsequent agglomeration at temperatures below 240 K. A surface defect depletion effect is clearly observable.

References

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