PLASMA-RESONANCE EMISSION OF POTASSIUM, EXCITED BY LIGHT

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An electron plasma of a crystal enclosed in a thin slab can be excited in its eigenfrequency ω_p (volume plasma frequency) by irradiation with light, if the electric vector $\vec{E}$ of the light has a component in the direction of the foil normal; see Fig. 1. Since this plasma mode is a radiative one, this excitation should be recognized by the emission of light of the plasma frequency. This radiation has been detected from silver foils.[1]

It is now of special interest to make this experiment on a metal with a plasma of nearly free electrons rather than in a metal such as silver, in which the plasma frequency has been changed by band-band transitions (transition of 4*d* electrons into the Fermi band at 3.9 eV) from $\hbar\omega_p = 9.2$ to 3.7 eV. There are a number of metals available, but most of them have a very high volume-plasma oscillation energy (10-15 eV) and thus need for the irradiation experiment linearly polarized light of very short wavelength which is available only in synchrotron radiation. Therefore, these experiments were carried out on potassium which behaves like a metal with quasifree electrons and whose volume plasma oscillation lies at a relatively low energy (3.7 eV). Also, plasma-resonance absorption experiments have shown that the plasma of potassium can be described fairly well by the concept of free electrons.[2]

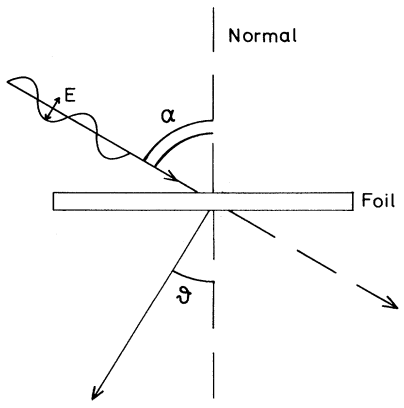

FIG. 1. A polarized light beam is incident on a thin potassium foil at the angle α. The light emitted from the excited plasma is detected at the angle θ.

For this purpose, thin potassium films (300-1000 Å) were evaporated on a SiO_2 substrate and irradiated with light containing the plasma frequency of potassium; see Fig. 1. The emitted radiation was registered with a photomultiplier after having passed through a monochromator. Figure 2 shows the measured intensity for the incident light polarized parallel or perpendicular to the plane of incidence. In the case of irradiation with light polarized perpendicular to the plane of incidence, no plasma emission is observed since the electric vector of the incoming electromagnetic radiation has no component in the normal of the potassium foil. Taking into account the spectral distribution of the incoming intensity, one obtains the maximum of the emitted radiation at 3300 Å, corresponding to 3.76 eV. This is in agreement with the value corresponding to the volume energy loss of potassium, as measured from characteristic energy losses of electrons.[3]

If one irradiates the potassium foil with a line of a measured half-width of 3 Å, neither

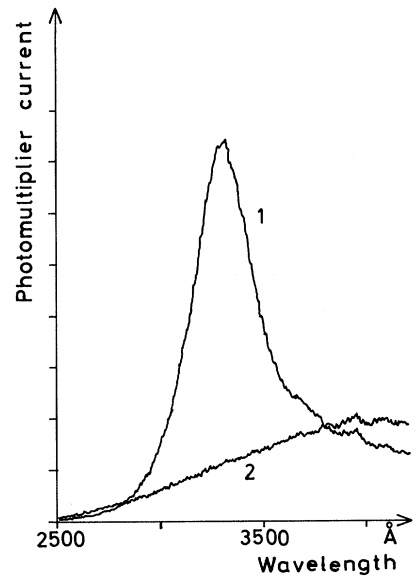

FIG. 2. Recorded traces of the light emission from potassium foils at $\alpha = 60°$ and $\theta = 30°$. Curve 1, incident light polarized parallel to the plane of incidence. Curve 2, incident light polarized perpendicular to the plane of incidence.

a shift nor a broadening of the emitted line with respect to the incident line has been observed within the limits of error of ±3 Å given by the resolution of the monochromator. Furthermore, the intensity of emission obtained by irradiating the foil with light of a narrow spectral width has been found to be the same as that obtained at the same frequency by irradiating the foil with a large frequency band (>1000 Å). These results are in good agreement with the emission experiments made on silver.[4] Obviously, the plasma behaves like a resonator.

The half-width of the emitted line is 400 Å or 460 meV in good agreement with the energy-loss measurements. (However, these two values are not directly to be compared, since the width of the emitted line is dependent on the observation angle θ. It needs to be extrapolated to $\theta = 0$ in order to be compared with the half-width of the electron energy loss. For this purpose, the half-width has to be measured as a function of θ. These experiments are in preparation. This correction, however, is not of great importance.)

It may be added that the maximum of the emission can be found at longer wavelengths than 3300 Å, depending on the conditions of evaporation; the minimum of the transmission (plasma-resonance absorption) is displaced in the same way.

These experiments show that the plasma of free electrons, excited by light, also shows the phenomenon of plasma-resonance emission.

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OBSERVATION OF NAGAOKA'S BOUND STATE FOR CONDUCTION ELECTRONS IN DILUTE MAGNETIC ALLOYS*

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Recent theories differ as to whether a negative s-d exchange interaction between a localized-impurity moment in a dilute alloy and the conduction-electron spins will result in the formation below some critical temperature T_C of a quasibound state analogous to the Cooper pair in the theory of superconductivity,[1-3] or will merely cause a strongly temperature-dependent scattering of conduction electrons at low temperatures.[4]

Electrical resistivity measurements over the three-decade temperature range from 40 mdeg to 40°K reported here for dilute alloys of iron in copper permit a clear choice between the two predictions. Preliminary susceptibility measurements on the same material also tend to support the bound-state model. Quantitative agreement below T_C between Nagaoka's theory and the resistivity data permit T_C and hence Kondo's exchange coupling constant J to be determined. Above T_C serious disagreement is found with the predictions of perturbation theory, heretofore considered by most authors to be valid in the region sufficiently far above this temperature. The high value of T_C (16°K) and the observed absence of impurity-impurity interactions make dilute Cu-Fe a nearly ideal system for studying the quantitative features of the low-temperature state.

The alloy samples were vacuum cast in alumina-coated spherical graphite molds 11 mm in diameter, using high-purity copper combined with a suitable quantity of a Cu-0.5%Fe master alloy to create the very dilute samples needed. The larger susceptibility sample was prepared from the same master in a similar mold of different shape. All samples were chemically etched before use. The resistivity ratio at room temperature to helium temperature of a pure-copper sample prepared using the same techniques was greater than 900. Absence of a resistivity minimum in this sample indicates that it contained less than 2 ppm iron. The samples were supported below a He^3-He^4