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Dependence of Electron Reflection on Contamination of the Reflecting Surface

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Measurements of the reflection of electrons from a tungsten target have been made using electron energies from 3 to 1000 volts. It was found that the reflection of electrons changed considerably during the formation of the first monolayer of contamination on the surface and thereafter remained constant. Whether the change was an increase or a decrease depended on the energy of the electrons.

IN the course of measurements of the energy distribution of secondary electrons from tungsten targets,[1] it was found that the elastic reflection of primary electrons depended on the amount of contamination present on the target surface. Furthermore, it was found that the entire observed change in primary electron reflection beginning with a clean target, occurred during the formation of the first monolayer of contamination on the surface. The length of time involved was of the order of 100 seconds at a pressure of 5×10^{-8} mm of Hg. Subsequent changes in primary reflection over a period of one hour were negligible.

A few measurements of the type on which the foregoing statements are based are shown in Fig. 1. Seven different curves labeled (a) to (g) are shown, some being measurements of reflected primary current I and the rest being measurements of pressure in the vacuum system, P. The horizontal axis is time in seconds and has the same scale for all curves. I was measured using an energy analyzer having a resolution of one percent and adjusted to accept only elastically reflected primary electrons. Observations were made at several values of primary voltage, V. At time zero the tungsten target was heated, or flashed, at 2400°K for one second (by passage of a high current). As can be seen in curve (c), this caused a high momentary rise in pressure. Following the flash, the clean target acted as a pump, adsorbing gas and lowering P. After formation of the first monolayer of contamination, the pumping action ceased and the pressure returned to normal. Thus the pressure record indicated the monolayer adsorption time. The reflected primary current I was recorded at the same time. Curve (a) shows I *versus* time for the case with $V=800$ volts. The value of I increases as the result of flashing the target (point X) and returns to its previous value (point Y) in a time comparable to the monolayer adsorption time. The total change in I is indicated as ΔI. A second flashing of the target either during the interval between X and Y or after point Y had been passed would always result in a return to point X. After the point Y had been reached, the value of I remained constant even when the pressure in the vacuum system was increased by a factor of 100.

A second measurement of I was made immediately following that shown in curve (a) and with the pressure record shown in (c) still applicable, but with $V=700$ volts. The result is given in curve (b); it can be seen that changing V has changed the shape of the curve. It was subsequently observed that not only the shape of the I curve but also the direction of ΔI depended on electron voltage V. Curves (d) and (e) show simultaneous measurements of I and P respectively for the case of $V=100$ volts. This time the change in ΔI was

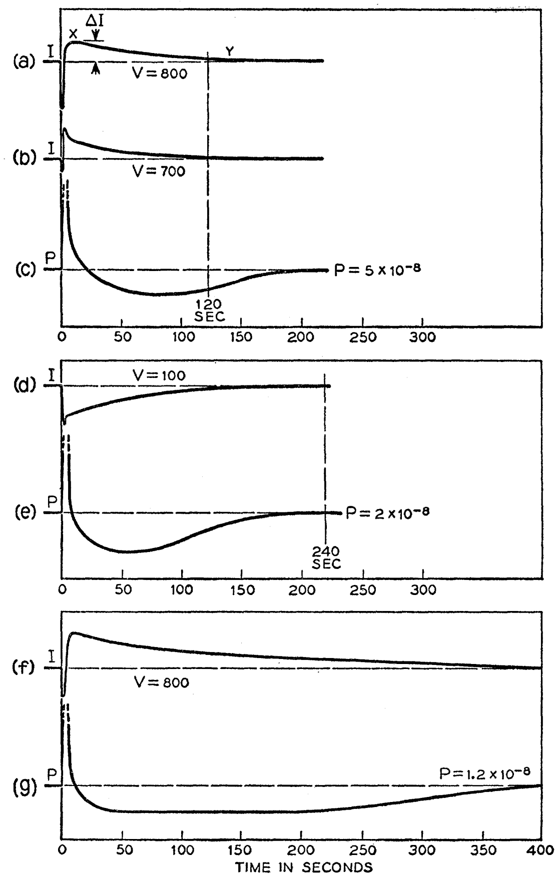

FIG. 1. Measured curves for a tungsten target, showing elastically reflected electron current I and pressure in the vacuum system P, both as functions of time. Values of electron voltage V and of pressure P are indicated.

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negative. Similar observations made at several different values of V from 3 to 1000 volts are shown in Fig. 2. Evidently both the magnitude and direction of ΔI depend on V. The fractional change in reflected primary current expressed as $\Delta I/I$ was sometimes rather large, lying between $+20$ and -45 percent.

The time required following a target flash, for I to return to its pre-flash value, was always roughly proportional to the monolayer adsorption time. This can be seen in all the curves of Fig. 1, including the last two, (f) and (g), where a lower pressure resulted in a measurement interval of 400 seconds.

These observations serve to point out the necessity of providing an atomically clean surface for measurements of electron reflection coefficient and of making such measurements in a relatively short time and under good vacuum conditions.

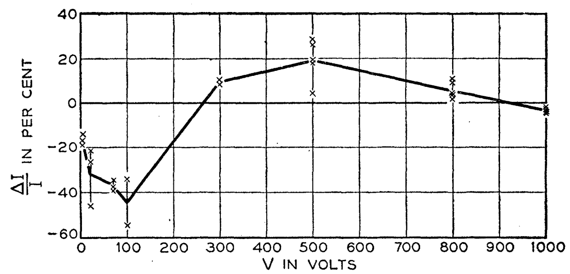

FIG. 2. A plot of the fractional change in reflected primary current, expressed as $\Delta I/I$ in percent, as a function of electron voltage V.

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Magnetic Properties of Colloidal Nickelous Oxide

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Magnetic susceptibility measurements by the Faraday method have been made in the temperature range 4–550°K for a series of iron-free nickelous oxide samples prepared by the heat-treatment of hydrous nickelous hydroxide in a current of nitrogen at temperatures of 250–1300°C, the crystal size as given by electron diffraction methods varying from 80–2000 A. Samples (crystal size $\sim$2000 A) prepared at 1200–1300°C exhibit susceptibilities typical of an antiferromagnetic material, the observed Néel point of 523°K agreeing with the results of earlier investigators. In samples (crystal size $\sim$100–200 A) prepared at 300–500°C the susceptibility agrees with that for the larger crystals above the Néel point, but exhibit maxima at lower temperatures. The temperatures, T_c, at which the maxima appear, decrease regularly and the amplitudes of the maxima increase regularly, with decreasing crystal size. In the range studied, linear plots $[10^{-4}T_c=1.090f-1.037]$ are obtained for T_c as a function of f, the ratio of the average number of next nearest magnetic neighbors per nickel atom to the number of next nearest magnetic neighbors in an infinite crystal, as computed from the observed crystal sizes. Neutron diffraction patterns demonstrate that the magnetic structure is antiferromagnetic at temperatures both above and below T_c, and hence the maxima do not correspond to shifted Néel points.

The magnetic susceptibility curves for the colloidal crystals of nickelous oxide resemble those obtained by others for certain iron and chromium sulfides. In iron sulfide, FeS_x, the susceptibility increase to the maximum is attributed by Néel and others to a ferrimagnetic structure, analogous to certain ferrites. In view of the "active" oxygen (Bunsen test) contents of the nickelous oxide samples which vary from 0.36 to 0.00% as the crystal size increases from 80 to 2000 A, it is possible to attribute the ferrimagnetic behavior to the ordering of a sublattice of defects, as Néel does for FeS_x. However, the subsequent decrease in susceptibility at temperatures below T_c cannot be readily explained for either FeS_x or NiO.

In view of the linear relationship between T_c and f, it is concluded that the unusual magnetic properties of colloidal nickelous oxide is attributable to the small size of the crystals and the accompanying enhanced specific surface and the decreased number of next nearest magnetic neighbors which results in an altered magnetic environment.

Nickelous oxide prepared at 250°C contains a small amount of undecomposed nickelous hydroxide detectable by electron diffraction methods. The magnetic susceptibility of pure nickelous hydroxide follows a Curie-Weiss law $[\chi_m=1.07/(T-36)]$ from about 300° to 90°K. Below 90°K, the susceptibility increases more slowly to a value of $\sim 2000\times10^{-6}$ emu at 4°K, and some field dependence was observed, suggesting the desirability of additional studies concerning possible ferromagnetism.

INTRODUCTION

NICKELOUS oxide, as normally prepared, consists of crystals larger than the colloidal range of particle size, and exhibits a transformation at approximately 523°K, detectable by back reflection x-ray diffraction,[1,2] magnetic peaks in neutron diffraction patterns,[3] and the appearance of a Néel point in magnetic susceptibility measurements.[4] Below 523°K nickelous oxide is rhombohedral and antiferromagnetic, whereas above 523°K it is cubic and paramagnetic.[5] The rhombohedral structure results from only very small distortions from the cubic form. In the antiferromagnetic form, Shull *et al.*[3] found that of the 12 nearest neighbors surrounding any Ni ion, 6 are oriented parallel to the central ion and 6 are antiparallel. However, the number of next nearest neighbors for an infinite

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