Temperature Dependence of the Work Function of Nickel

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The variation of the work function of nickel with temperature was measured with clean (111) and (100) surfaces between 25 and 320 °C and up to 430 °C with Ni(110). In all cases the work function decreases linearly with temperature by 1.7×10^{-4} eV/°C. No anomaly (neither a jump nor a change of the slope $d\varphi/dT$) was found at the Curie point.

A series of investigations of electronic properties of nickel [1–3] revealed hints for the occurrence of anomalies at the Curie temperature ($T_c = 358$ °C). The work function is an interesting quantity in this connection in particular due to its surface specifity.

In an earlier work Comsa et al. [4] found a slight variation of the slope $d\varphi/dT$ in the region of the Curie temperature. Pierce and Spicer [5] reported the work function of polycrystalline Ni at 405 °C to be about 0.1 eV smaller than at 22 °C.

Since the work function is highly sensitive towards surface impurities (e. g. 1% of a monolayer of adsorbed CO causes a variation by more than 10^{-2} eV) extreme care has to be taken with respect to the surface cleanness. The present measurements were performed within a UHV system with a base pressure of 4×10^{-11} Torr. Ni single crystal surfaces were cleaned by extended argon ion bombardment and subsequent annealing. The cleanness of the surfaces was monitored by means of Auger electron spectroscopy, but the reproducibility of the work function data was even far more sensitive with respect to the presence of impurities adsorbed from the residual gas atmosphere. The variation of the work function was determined with an accuracy of $\pm 3 \times 10^{-3}$ eV by means of a self-compensating vibrating capacitor (Kelvin) method using oxidized tantalum as material of the reference electrode. No corrections were made for the variation of the thermoelectric emf since this effect is expected to be much smaller than the measured voltage changes [6].

Measurements with Ni(110) were performed between 25 and 430 °C. The results are shown in Fig. 1 together with some earlier data obtained from Ni(100) and Ni(111). (For experimental reasons the latter were unfortunately not performed up to the Curie temperature.) All data fit well a straight line with a slope of -1.7×10^{-4} eV/°C.

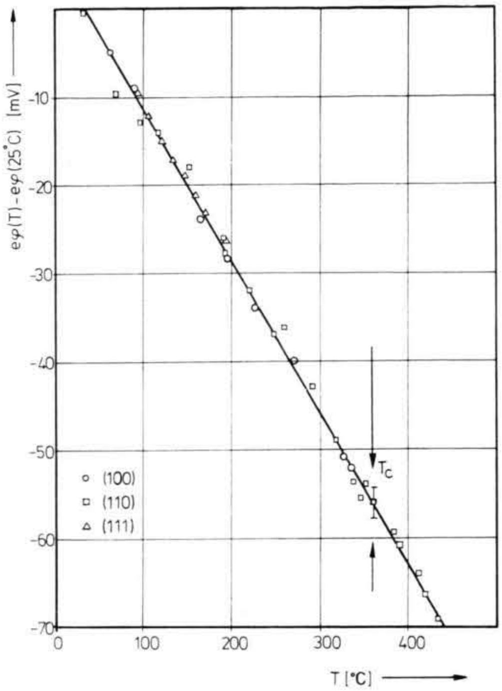

Fig. 1. Variation of the work function, $\Delta\varphi = \varphi(T) - \varphi(25\,^\circ C)$, of Ni(111), (100) and (110) surfaces with temperature. $T_c = 358$ °C denotes the Curie point of nickel.

This value is in good agreement with that of about -2×10^{-4} eV/°C as extracted from measurements by Tracy [7] with Ni(100). Similar preliminary observations were made with polycrystalline Ni films in a work still in progress [8].

The observed decrease of the work function with increasing temperature may be caused by a series of different factors like thermal expansion, internal effect of atomic vibrations, variation of the chemical potential etc. [6]. No attempt for a quantitative analysis is made here. It is interesting, however, that no influence of the surface orientation was observed.

An important point is that no measurable anomaly occurs at the Curie temperature – neither a jump nor a variation of the slope $d\varphi/dT$. Using an extension of the theory of Hohenberg and Kohn [9], Pant and Rajagopal [10] estimated that the work function of Ni should change by 0.135 eV when going from the ferromagnetic to the paramagnetic state, which is not in agreement with the present findings. The conclusion is that within our limits of accuracy the work function of Ni is not affected by the magnetic transition.

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