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Photoemission Investigation of Ni near the Curie Temperature

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This paper is a short report on our photoemission measurements on Ni above and below the Curie temperature. We report new measurements changing the temperature in a narrow region above and below the critical point of Ni.

An attempt was made to detect the differences between the electronic structure of ferromagnetic and paramagnetic Ni by obtaining the photoemission spectra from $0.97 T_c$ to $1.03 T_c$ semi-continuously.

The photoemission investigation of Ni was pioneered by Berglund and Spicer /1/. It was followed by many experimental and theoretical papers. From our point of view the most interesting papers are those of Pierce and Spicer /2/ and of Rowe and Tracy /3/. Their experimental results show the estimated value of the difference in energy between the states of opposite spin subbands, which is frequently referred to as "exchange splitting".

Another important question is whether the photocurrent has any special temperature variation due to the anomalous temperature dependence of the d-band energy distribution curve (EDC) /3/.

We made an effort to show its similarity to the specific heat anomaly /4/ and to get a quantitative picture of the variations.

The expected difference between the electronic structure of the ferromagnetic and paramagnetic Ni is estimated by Hodges et al. /5/ and Wang and Callaway /6/. It seems that the exchange splitting gives a significant changing of the d-band peak in the EDC. If the peaks are measured during temperature variation a characteristic phenomenon may be observed.

The expected effect is a change in the intensity of the d-band peaks in EDC, i.e. a decrease in the peak characteristic of the majority spins, and an in-

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crease in the peak characteristic of the minority spins. Owing to the temperature increase up to T_c a moving of these peaks towards each other is expected, too.

For obtaining ample information a high intensity low-pressure mercury lamp with 253.7 nm wavelength was used. It is a good choice because its energy (4.89 eV) lies in the expected high sensitivity region with a narrow spectral band for exact investigations.

Our sample consisted of two pure (99.999%) 2 cm diameter polycrystalline nickel disks, 2.5 mm thick. They were mechanically and electropolished, washed in water and alcohol, and dried with a cold air blast. A sandwich was made by a heater between the disks, isolated by talc.

The sample was once more cleaned by heating in ultra-high vacuum at 800 °C for 3 h. The sample was heat cleaned at 800 °C for 1/2 h before every measurement. The chamber was pumped with IGP down to 1×10^{-7} Pa. During the heat cleaning the pressure rose, but it remained below 10^{-6} Pa.

In measuring the critical region of Ni the following method of temperature variation was used. We achieved a base temperature ($\approx 0.97 T_c$) with the sandwich stove, and during the measurement the heating current remained constant. The temperature was changed by outside heating with a high intensity halogen lamp through a suitable window in the vacuum chamber. It was carefully adjusted to the back side of the sandwich to avoid any temperature gradient, and the photoemission was carried out on the front side.

The temperature was controlled by a diaphragm.

The data and parameters were registered by an automatic data acquisition system, and evaluated by a computer. The period of the registration of one curve was several hours.

In the thermal emission spectra there must be also a singularity at $T_c/7$, so we plotted the temperature against time, too.

Our results are the following:

The critical exponents for the thermal emissivity of Ni ($w \sim |\varepsilon|^\alpha$) are

$$\text{above } T_c: \quad \alpha = -0.045 \pm 0.025 ,$$

$$\text{below } T_c: \quad \alpha' = 0.039 \pm 0.025 ,$$

and the exponents of the photocurrent ($I \sim |\varepsilon|^p$)

$$\text{above } T_c: \quad p = 0.91 \pm 0.1 ,$$

$$\text{below } T_c: \quad p' = 0.91 \pm 0.1 .$$

From other measurements /8/ the critical exponent of magnetisation of Ni is
($M \sim |\epsilon|^{\beta}$)

$$\beta = 0.43 .$$

On the basis of an approximately precise picture we assume the critical exponent p to be equal to 2β , because of the moving of the d-peaks and their intensity has also the exponent β .

In our results the effects of other critical properties (anomalous thermal emissivity /7/, critical expansion /9/, anomalous optical constants /10/, etc.) also make a contribution, but their exponents and amplitudes are substantially smaller than the exponents of magnetic properties.

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