

INFLUENCE OF HYDROGEN ADSORPTION ON THE ELECTRON SPIN POLARIZATION (ESP) AT A FERROMAGNETIC (110)-NICKEL SURFACE

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Received 3 May 1977

The ESP determined through electron capture by small angle reflection of deuterons at well oriented Ni(110) surfaces is found to be influenced by H₂ adsorption. A coverage of one monolayer reduces the ESP from $-96 \pm 3\%$ to $-8 \pm 3\%$. The – sign indicates predominance of minority spin electrons. Desorption of hydrogen from the nickel surface restores the original polarization measured at a clean (110) nickel surface.

1. Introduction

The electronic structure of ferromagnetic surfaces changes by chemisorption [1]. In [2–4] we reported on measurements of the ESP with the electron capture spectroscopy at ferromagnetic single crystalline surfaces. The ESP is determined through electron capture in 150 keV deuterons which are small angle reflected at a surface of a ferromagnet. The distance of closest approach in such a small-angle reflection of incidence angle $\alpha = 0.2^\circ$ is 0.2 nm or larger.

Here we report on the influence of hydrogen adsorbed at a (110)-nickel surface with coverages up to one monolayer. The ESP is found to be reversibly reduced from a high value at a clean surface to a low value measured at a covered surface. The sign of the polarization (–, i.e. predominance of minority spins), however, does not change by hydrogen adsorption.

2. Experimental

The experimental set-up and the technique of the electron capture spectroscopy are described in [2–4]. During reflection of 150 keV deuterons at well oriented surfaces of ferromagnetic nickel electrons are captured, thus partially neutralizing the deuteron beam. The electrons are polarized and transfer their polarization to the nuclei by hyperfine interaction. The nuclear

polarization is then a measure of the ESP and is determined from the asymmetry in the angular distribution of the α -particles emitted in the reaction $T(d, n)\alpha$. The crystal is magnetized to saturation, with its axis of magnetization parallel to the surface and perpendicular to the direction of the incoming beam. The experiment is performed in a vacuum of 8×10^{-10} mbar where the hydrogen partial pressure is 7×10^{-10} mbar.

3. Results and discussion

Fig. 1a shows the experimental results measured on Ni(110) at $T = 300$ K. The various values of P belong to the different hydrogen partial pressures p , plotted in fig. 1b for the same time scale. At $p = 7 \times 10^{-10}$ mbar we obtain $P = -96\%$. The hydrogen pressure p is increased step by step up to 2×10^{-5} mbar where the surface coverage is approximately one monolayer H₂ [5]. At each step the pressure is kept constant for 60 min, taking 40 min to reach the equilibrium coverage and the subsequent 20 min for the measurement of the ESP. At $p = 2 \times 10^{-5}$ mbar we observe the least negative $P = -8\%$. Reducing p to the initial low value restores the original P measured at the clean surface. At such low hydrogen pressures the contribution of beam desorption which helps to produce a clean surface is not negligible. Therefore, in this experiment equilibrium values for hydrogen coverage as a function

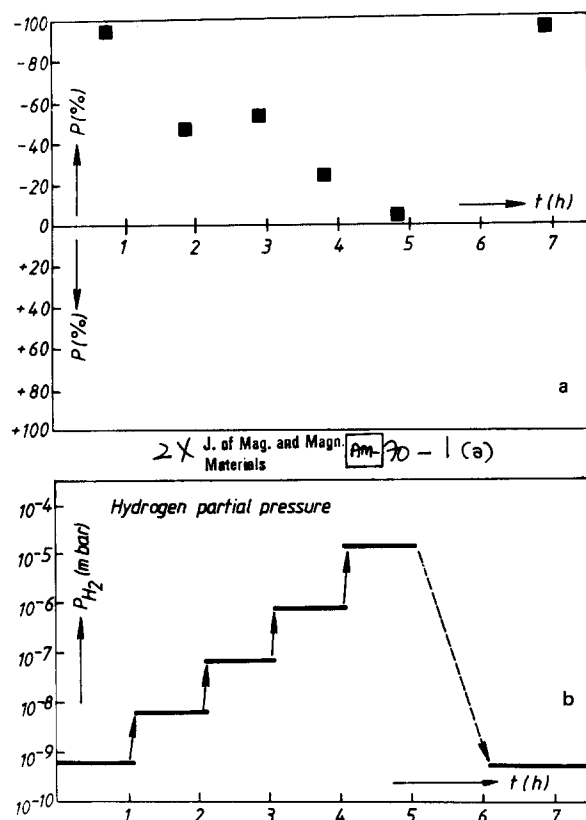


Fig. 1. (a) Electron spin polarization P (■) at Ni {110}, and (b) hydrogen partial pressure p_{H_2} ; t = time scale in hours (see text); $p_{H_2} = 2 \times 10^{-5}$ mbar is equivalent to one monolayer of chemisorbed hydrogen at $T = 300$ K.

of the hydrogen pressure (cf. [5]) are considered to be the upper limits during the ESP measurement, where the deuteron beam is reflected at the crystal surface.

It is known that hydrogen chemisorption changes the charge distribution at the surface [6]. At present, however, there are no calculations available which relate the surface density of states of electrons at single crystalline nickel surfaces with the fractional coverage by chemisorbed hydrogen [6]. We proceed in discussing the present experimental results in the context of various models [7,8].

(1) In the model where additional electrons merely fill the bands of nickel, the Fermi level is raised with increasing hydrogen coverage. Fig. 2 shows the variation of the electron spin polarization P for Ni(110) in dependence on the position of the Fermi level. The P values are extracted from recent band structure calculations

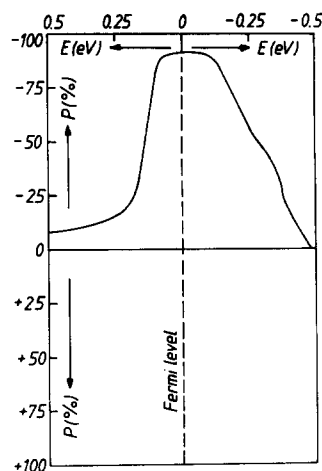


Fig. 2. Electron spin polarization P at the nickel {110} surface as a function of electron density energy relative to the Fermi level of nickel (extracted from [9]). $E > 0$ corresponds to a raise of the Fermi level.

tions by Marschall [9], thereby neglecting any change of the bands by the chemisorption of hydrogen. We observe that the variation of P is at least qualitatively in agreement with the experimental results (see fig. 1).

(2) In other models describing chemisorption of hydrogen, modifications in the density of the metallic states at the surface are allowed for. The formation of new states connected with the chemisorbed hydrogen is also considered [8]. Such states can be near the Fermi level and hybridize with the nickel band states. The filling of these states with increasing H_2 coverage might result in a reduction of the electron spin polarization at the surface as observed in the present experiment.

Electron density calculations for metal surfaces without and with adsorption are of actual interest [6]. In transition metals the electron density of states is connected with many other properties. The experimental investigation of the electron spin polarization at surfaces is considered to provide a valuable contribution for the analysis and applicability of such theoretical models.

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