viscosity, vary from 463 at $\dot{q}_c$ to 2057 at 20 mW cm^{-2} using the hydraulic diameter,[14] and from 1620 to 7200 if we use the large dimension of the channel cross section. Ladner, Childers, and Tough[3] have found the breakdown of Poiseuille flow in small diameter tubes at $R_c = 1320$ at this temperature. Since our channel is short, and in addition, is penetrated by the five cavities, it is likely that the normal fluid is always turbulent. It is thus reasonable to compare our value for $\delta\beta/\beta_0$ to measurements on pipe flow of turbulent classical fluids. Very few data exist; however, one experiment[17] on water found $\delta\beta/\beta_0 = 0.043$ for $R/R_c \simeq 1.5$, approximately constant up to $R/R_c \simeq 2.5$, and decreasing to 0.038 at $R/R_c = 5$. Though the magnitudes of $\delta\beta/\beta_0$ are not comparable, the dependence on R is qualitatively similar. Our measurements of the temperature dependence of $\delta\beta/\beta_0$, as well as a more complete discussion of the experimental details are reported in forthcoming papers.[18]

We acknowledge valuable discussions with R. J. Donnelly and J. T. Tough. Support was provided by the National Science Foundation, through Grant No. DMR-75-01252.

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Demagnetization of the Ni(100) Surface by Hydrogen Adsorption

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(Received 18 May 1977)

The spin polarization of field-emitted electrons from the (100) plane of field-evaporated Ni single-crystal tips is observed to decrease from $-(3.0\pm 1)\%$ to $(0\pm 1)\%$ upon hydrogen adsorption (full coverage). We interpret these results as evidence for a strong reduction of the ferromagnetism of the d electrons of the Ni surface atoms upon hydrogen chemisorption.

Elastic and inelastic electron tunneling in field-emission experiments have been very useful in providing novel information concerning the electronic interactions of adsorbates on metal surfaces.[1] Changes in the field-emission energy distributions (FEED) of the clean surface upon adsorption have been successfully interpreted in terms of variations of the surface electronic structure upon adsorption. As examples, we may mention hydrogen on W,[2] hydrogen and oxygen in Ir,[3] and Au adsorbed on W.[4] The purpose of this Letter is to show that additional information on chemisorbed systems on magnetic substrates can be obtained in field-emission spectroscopy (FES) by measuring changes in the electron-spin polarization (ESP) of the emitted electrons.

The experiments were performed in the apparatus described previously.[5] Suppression of the CO in the stainless steel system was achieved by repeated exposure to hydrogen, baking, and pumping by Ti sublimation at liquid-nitrogen temperature. Single-crystal Ni[100] tips[6] were cleaned by UHV dc field evaporation at low temperature. Fifty to one hundred monolayers were desorbed to obtain the first evaporated endform. During the ESP measurement on the clean tip the total FE current, which is extremely sensitive to adsorbates, did not change within the first 15 min; and after a 5% decrease in the total FE current, occurring within about 50 min, the tip was cleaned again by field evaporation. After an ESP measurement on the clean tip, the surface was recleaned by field evaporation and subsequently exposed to about 60 L [1 L (Langmuir) = 10^{-6} Torr sec] hydrogen at about 100 K to ensure full coverage.[7] Under these conditions no hydrogen diffusion in the bulk Ni is expected. The field-emission pattern was observed to vary very little upon hydrogen chemisorption as has been reported earlier.[8] The average work function of the tip increased by 0.35 ± 0.05 eV. The polarization measurement was carried out with a pressure of 1×10^{-8} Torr hydrogen and with the probe hole selecting emission from the Ni(100) face only. The total FE current and the FE pattern remained stable for a few hours. The ESP was observed to decrease from $-(3 \pm 1)\%$ for the clean surface to $(0 \pm 1)\%$ upon adsorption.[9]

This simple result allows us to draw direct conclusions concerning the interaction of hydrogen and the ferromagnetic Ni(100) surface. The H 1s-derived bonding orbitals on Ni(100) are expected to lie several eV below the Fermi level E_F (about 6 eV according to Conrad *et al.*[10]), which is in agreement with what has been observed by ultraviolet photoemission spectroscopy (UPS) on other transition metals.[11] As a consequence resonance tunneling through H 1s-derived states is expected not to be important. In addition, changes in the d-band emission near E_F have been observed in UPS experiments from hydrogen-covered Ni(111),[10] which, however, have to be interpreted cautiously since the significance of difference spectra in photoemission is not yet clarified. The observed ESP for the clean surface is due to the small contribution of the minority-spin d states to the FE current, since s-d hybridization is very small near X in the ΓX direction in the Brillouin zone.[12] Therefore, along [100], the observed changes of the ESP of the field-emitted electrons upon hydrogen adsorption have to be related to changes of the surface density of the d states.

The chemisorption bond of hydrogen on transition metals is basically covalent. The d states on the Ni surface which take part in the covalent bond will be pulled to lower energies compared to the clean surface. This will tend to make the d shell more nearly full. As a consequence, a considerable reduction of the magnetic moment of the Ni surface upon hydrogen chemisorption is expected.

Most of the theories of chemisorption attempt to correlate the behavior of the chemisorbed system with the properties of the free adsorbate and substrate. Two different concepts have been suggested: the "induced covalent bond" scheme[13] which takes account of electron correlation effects and neglects the band character of the metal substrate, and the "molecular orbital" (Hartree-Fock) approach[14] based on the Anderson model[15] of impurities. More recently, various model Hamiltonian theories[16-19] have been presented which take correlation effects into account as corrections with various degrees of sophistication.

Self-consistent calculations of the surface electronic structure of transition and noble metals[20] including chemisorbed layers[21] are appearing in the literature, and it is likely that the system H on ferromagnetic Ni will soon be a tractable one. The experimental result we have presented can serve as a test for the ability of calculations to treat magnetic effects in chemisorption on transition metals. FES probes solely the surface of the metal. An interesting question arises: How large is the magnetism of second, third, and other Ni layers when the first one has been "demagnitized"? The range of such a perturbation can be experimentally investigated via photon-energy-dependent, energy-resolved, spin-polarized photoemission.

Additional information on the role of s-d hybridization in the Ni band structure and related influence of chemisorption on the surface magnetism will be gained by investigating H on Ni(100) and H on Fe. These studies are in progress in our laboratory.

Finally, we note that as early as 1961[22] absorption of H in Ni has been found to reduce the magnetic moment of Ni by about $0.7\mu_B$ per average atom of hydrogen adsorbed. This is consistent with our results although the H-Ni bond in bulk Ni is presumably different from the one at the surface.

We thank B. Wilkens for the excellent technical assistance, D. R. Hamann and G. K. Wertheim for enlightening discussions, and W. F. Brinkman for his continued interest in this project. One of us (M.L.) acknowledges a Fellowship from the Schweizerischer Nationalfonds.

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Critical Nuclear Magnetic Relaxation in a Strong Itinerant-Electron Ferromagnet: Ni

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Nuclear magnetic resonance has been observed in ferromagnetic Ni near the critical temperature. The nuclear spin-spin and spin-lattice relaxation rates are found to become equal in the critical region below T_C and diverge with a critical exponent $n' = 0.67 \pm 0.08$. Spin-lattice relaxation rates in the paramagnetic state exhibit only incipient spin-fluctuation enhancement within the experimental range. Measurements of the ferromagnetic NMR frequency near T_C and of the Knight shift above T_C are described.

The three-dimensional (3D) transition metals Fe, Co, and Ni are among the most familiar magnetic materials, yet experimental data on critical spin-fluctuation phenomena in these systems are few and contradictory. Ni has the lowest Curie temperature of the three ($T_C = 631$ K) and fluctuations in Ni have been investigated by inelastic neutron scattering[1] and by the method of time-differential perturbed angular correlations (PAC) in the paramagnetic state.[2] However, the temperature dependences of the spin correlation times obtained in these experiments differ from each oth-