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STUDY OF MAGNETISM AT SURFACES BY SCATTERING OF NEUTRONS AT GRAZING INCIDENCE*

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Scattering of x-rays at grazing incidence is providing exciting new information on the composition and density fluctuations at surfaces. The measurement of the intensity reflected for different angles of incidence θ_i gives the depth profile of the scattering density.[1] The diffuse scattering around the specular beam determines the critical fluctuations at surface phase transitions, as in smectic/nematic liquid crystals.[2] The measurement of surface Bragg reflections under conditions of grazing incidence provides the structure at the surface and its relation to that of the bulk.[3] For all these problems, the great advantage of x-rays in comparison with more surface-sensitive radiation is the capability of interpreting accurately and unambiguously the intensities measured. The sensitivity of x-rays to surface phenomena is enhanced in the grazing incidence geometry. Even so, the scattered intensities are weak, because the number of scattering centers in the surface layer is small: hence powerful sources are needed.

Neutrons can provide parallel information on magnetic phenomena at surfaces. The simplest experiment involves the measurement of the reflectivity of a well-collimated beam from the surface, as a function either of the neutron wavelength or of the angle of incidence θ_i. Using polarized neutrons, the spin-dependent reflectivity of a magnetically-active material can determine the depth profile of the magnetic induction B. A prototype instrument at the Intense Pulsed Neutron Source at Argonne has already demonstrated the feasibility of this technique in determining the penetration depth of an external magnetic field in superconductors.[5] This provides a crucial test of the extent of the electronic correlations predicted by current theories of superconductivity. Further experiments are being planned to study the magnetic disturbances close to the surface of ferromagnets; a first experiment on films of iron oxides showed a remarkable change of the magnetic depth profile with increasing oxidation.

This new technique is demanding a considerable amount of technical development. In regard to the sample, the reflecting area has been reduced to the practical dimensions of 15 x 50 mm; this surface views the neutron beam at a typical angle $\theta_i \approx 0.3°$. The surface should be flat within one optical fringe; the best results were obtained by vapor depositing 1 μm layer of the sample material on a polished substrate of weakly reflecting silicon. New area counters are being tested, with a resolution better than 0.5 x 0.5 mm. Much research remains to be done to attain the optimal focussing conditions which would given good intensity and yet good resolution ($\Delta\theta_i \approx 0.01^0$).

With the present state-of-the-art, intensities as low as 10^{-3} that of the incident beam can be measured. This corresponds to the reflectivity at an angle θ_i which is approximately twice the value for total reflection θ_c. Since the depth profile of the magnetic induction, B(z) is a distorted Fourier transform of the reflectance, the truncation of the

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measurements at $\theta_i \sim 2\theta_c$ causes a smearing of B(z) over thicknesses on the order of 30 Å.

The next generation of neutron sources should provide enough flux to study the depth profile B(z) in much greater detail, and at the same time open the possibility of studying the lateral fluctuations of magnetism alongside the surface. Indeed, the intense theoretical effort presently being aimed at a better understanding of the critical phenomena of magnetism[6,7,8] at the surface gives a strong stimulus to attempt to observe experimentally the related fundamental quantities.

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