Book Reviews

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X-ray Scattering and Absorption by Magnetic Materials. By S. W. Lovesey and S. P. Collins (Oxford Series on Synchrotron Radiation, No. 1). Pp. 390. Clarendon Press, 1996. Price (hardback) £70.00. ISBN 0-19-851737-8.

For once, there is a book on magnetism that does not disclose how long ago lodestone was discovered. Neither does it recount applications ranging from personal stereos to computer drives and medical scanners. This is a book that provides a contemporary sketch of a modern field of research made possible by the exploitation of synchrotron radiation. The work serves two principal objectives. Firstly, it is suitable for anyone who would like to become acquainted with a new field of spectroscopy that has made sensational progress over the past decade and, secondly, it is a valuable reference book for those who are already familiar with the techniques.

Stephen Lovesey from the Rutherford Appleton Laboratory, who is the author of several text books on neutron scattering and magnetism, has joined forces with Steve Collins, who has first-hand experience in the development of magnetic diffraction and Compton scattering at Daresbury Laboratory. They have 'opened their notebooks' thereby providing the growing community of researchers with accounts of experimental methods, instrumentation and data analysis, representative examples of successful investigations, and a theoretical framework, based on single atoms and unit cells, to interpret the measured signals. The result is a very impressive account on synchrotron radiation techniques applicable to magnetic materials. The authors have focused on scattering and absorption, while other areas, such as photoemission, Auger spectroscopy and resonant Raman scattering, have been deliberately omitted. This book clearly has been composed with great enthusiasm and is roughly divided into two parts, one with an experimental and the other a theoretical emphasis. The first part incorporates a great deal of recent work along with many useful tips for the experimentalist and will be readily appreciated by the non-specialist reader. The second part is intended to offer a fuller understanding of the theoretical framework of this subject. The strength and merit of this book is that both experimental and theoretical issues have been addressed and have been skilfully interwoven. In addition, although magnetic scattering is in the early stages of development, the book establishes a foundation on which further research can be built.

The introductory survey incorporates the principles of the relevant techniques, namely absorption (dichroism), and elastic (diffraction) and inelastic (spectroscopy) scattering. Subsequent chapters expand on these topics, ranging from experimental methods and the properties of synchrotron radiation and instrumentation up to a theoretical interpretation of the data. Magnetic scattering is some four orders of magnitude less than charge scattering and for a plane-polarized primary beam it is 90° out of phase. Without this phase factor there could be a significant interference term in the scattering. Fortunately, the phase shift can be modified in at least three different ways: (i) through the use of a circularly polarized beam; (ii) by using crystals with unit cells that lack a centre of symmetry, represented by complex unit-cell structure factors; and (iii) through the use of resonant or anomalous charge scattering. The charge scattering does not cause polarization mixing, which allows for the possibility of the construction of a sensitive filter for magnetic diffraction. Perhaps the most important aspect of the polarization dependence is not the contrast with charge scattering, but the fact that magnetic orbital and spin scattering exhibit a different polarization dependence. A quantitative analysis of the secondary-beam polarization makes it feasible to determine separate spin and orbital magnetization distributions, which is a great advantage over neutron scattering where spin and orbital magnetism are treated in an identical way.

In ferromagnets the magnetic and charge Bragg reflections overlap. However, the interference term, which is linear in the scattering length, is much stronger than the pure magnetic scattering term. Reversing the magnetization of the target causes the interference term to change sign. To avoid the magnetic amplitude being completely out of phase with the charge scattering, a non-centrosymmetric lattice is required to allow magnetic charge interference. Alternatively, the photon energy can be tuned close to an absorption edge of one of the ion species. The role of the resonance is to give the charge scattering a complex structure factor, effectively mimicking a non-centrosymmetric crystal structure and so permitting magnetic charge interference. Resonant diffraction is essentially a probe of local magnetic phenomena. Since the excitations involve a highly localized initial core state, resonant scattering can take place only in regions close to the nucleus where the core level density is high. There is no magnetic form factor except possibly a very broad one from the core electron density, and the precise relationship between magnetic diffraction intensities and the magnitudes of local moments is not straightforward.

Scattering is closely related to X-ray absorption through the optical theorem which relates the attenuation coefficient to the imaginary part of the forward scattering length. Among the various techniques discussed, magnetic X-ray dichroism – surely to become the most popular one – has generated hundreds of scientific papers within the decade following the discovery of the effect. Sum rules relate the integrated dichroism to the spin and orbital parts of the magnetic moment. X-ray absorption has the advantage that it is not affected by the broad real resonant tails which tend to obscure the more subtle features in the scattering. The authors explain the absorption phenomena with the use of a simple two-step picture. This makes it easy to understand, but there is a price to pay for this. Only a single-step model is able to provide a complete picture that includes effects due to the magnetic dipole term in circular X-ray dichroism and the spin-orbit coupling in the isotropic spectrum and linear dichroism. The inclusion of these relevant issues could easily have further enhanced the book's usefulness.

The final experimental chapter deals with Compton scattering, which has in the past played a vital role in the demonstration of quantum mechanics. Its magnetic companion is at least as important, especially in relation to band structure models. Furthermore, an entirely separate theoretical framework with appendixes is incorporated in the last 90 pages of the book. Those who are searching for a rigorous mathematical treatment might still be disappointed. Nevertheless, the objective of the book, which is to provide clear insight into the subject, is achieved. This, combined with the many suitable citations from the original literature, make the book all the more readable.

The field of magnetic scattering is growing at a tremendous pace and indeed has continued to expand even since the preparation of the book! However, the book will retain its value and has drawn together those contributions to the published literature that have proved to be most fecund. It must surely play a part in raising the awareness of researchers in magnetism to the potential value of synchrotron-based techniques. The book is suitable for graduate students and researchers with an interest in magnetic materials and for professionals who wish to consider the use of synchrotron radiation in their research. At £70 the book will stretch the pockets of many of those younger scientists to whom it is directly addressed; nevertheless, it is surely an indispensable item for the university and the institutional library.

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