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book reviews

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Crystallography of Quasicrystals. By Walter Steurer and Sofia Deloudi. Springer Series in Materials Sciences No. 126. Springer, 2009. Pp. xiv + 384. Price (hardback) EUR 128.35. ISBN 978-3-642-01898-5, e-ISBN 978-3-642-01899-2, doi 10.1007/978-3-642-01899-2.

Since the discovery of quasicrystals in the early 1980s, the literature on this fascinating class of solids has constantly increased (a search for 'quasicrystal(s)' in the *title* gives 156 articles in the IUCr journals as of May 2010). Furthermore, a monograph on a related subject (*Aperiodic Crystals: from Modulated Phases to Quasicrystals*, by T. Janssen, G. Chapuis and M. de Boissieu) was published in the IUCr/OUP series only two years ago. The analysis of this new text, although necessarily synthetic and limited in space, has therefore to give an account not only of its content but also of its originality with respect to the previous monograph.

Crystallography of Quasicrystals is composed of three parts: *Concepts* (three chapters, pp. 1–188), *Methods* (three chapters, pp. 189–242) and *Structures* (five chapters, pp. 243–371), followed by a (short) glossary and the index. A useful list of acronyms is given at the beginning (pp. xi–xii). Grey boxes throughout the whole text provide the reader with definitions and explanations.

The structure of the book aims clearly at giving a complete overview of quasicrystals, through a journey that starts on the abstract (geometrical) side, becoming more and more concrete when exploring experimental techniques for structure analysis, and finally arriving at a panoramic view of the known structures characterized by quasiperiodicity in one or more dimensions and to a discussion of the stability of quasicrystalline phases and their formation mechanism. A large number of examples of real quasicrystals are given, and everybody interested in the field will certainly be grateful for the effort of collecting all this information in a single text. On the other hand, one could regret the absence of solved exercises, which would have made it easier to follow the theoretical presentation.

The first part of the book, *Concepts*, starts with a presentation of the d-dimensional (dD) approach (d being the number of dimensions of the physical space) and culminates in an extensive treatment (138 pp.) of the n-dimensional (nD) description of quasiperiodic structures, where $n > d$ is the number of dimensions of the embedding space necessary to show structural correlations (such as the occurrence of discrete Bragg diffractions and the presence of noncrystallographic symmetry operations) that are hidden in the dD approach. The first chapter introduces tilings and coverings (the latter admitting overlaps) in one-, two- and three-dimensional space, starting with the Fibonacci and octonacci sequences. Several drawings help the reader to follow the mathematical treatment, which is kept at a reasonable minimum. The second chapter, consisting of only 11 pages, gives a rapid introduction to polyhedra and their cubic and icosahedral packings. These first two chapters would serve well for a self-study approach.

The third chapter, dedicated to the nD approach, starts with a very clear and informative introduction of the concepts of parallel and perpendicular spaces. The nD space is separated into two orthogonal subspaces, the parallel (physical) space (par) and the perpendicular space (per) spanning the $n - d$ dimensions, par and per being invariant under the n-dimensional point group. The nD embedding of 1D, 2D and 3D quasiperiodic structures in the three settings of incommensurately modulated structures, composite crystals and quasicrystals is introduced geometrically, *via* the cut-and-project method and the strip-projection method, leading to the introduction of the rational approximants and periodic average structures. This part, which occupies only eight pages, is probably the weakest of the whole book, in the sense that the density of information and notions presented here makes it hard to follow for a newcomer to the field. More space, with examples and solved exercises, would have been useful; as it stands this part serves mainly as a short guide and a journey through the literature results remains necessary (fortunately, useful references are given in the text).

The calculation of the structure factor of a quasicrystal in the nD approach is then introduced as the Fourier transform of an electron-density-distribution function which consists of two parts corresponding to the dD par space and the $(n - d)$D per space, the latter corresponding to the 'geometrical form factor'. Here some more details about the phason modes and phason flips would have been welcome, considering that the term 'phason' has been introduced (but not really defined) at p. 61, although the example in Fig. 3.4 is quite clear. The concept is reintroduced and explained later (Chapter 6, p. 235): a reminder here would have been useful.

The rest of the chapter is devoted to a detailed analysis of 1D, 2D and 3D quasiperiodic structures; despite the richness of figures and examples, it is tough reading for self-study, whereas it would be an excellent companion text for a school on the topic.

The second part of the book is devoted to *Methods* and consists of three chapters which target experienced users who are familiar with the concepts treated but not necessarily with their application to quasicrystals. Chapter 4, *Experimental Techniques*, gives a quick panoramic view of electron microscopy, diffraction methods and spectroscopy for the investigation of quasicrystals. Chapter 5, *Structure Analysis*, presents a clear summary of the concepts and ideas behind data

collection and treatment, structure solution, and refinement, up to data publication. Although targeting specifically quasicrystals, this chapter is a remarkable compendium of the fundamental concepts and clear reading for everybody approaching structural crystallography. Last but not least, Chapter 6, *Diffuse Scattering and Disorder*, is a short but extremely clear exposition of the effects of static and dynamical defects on the diffraction pattern, in particular on the diffuse scattering: as for the previous chapter, the usefulness of this part goes well beyond the application to quasicrystals.

Part III, *Structures*, could be considered as being in two sections: a review of known quasicrystalline structures (Chapters 7–9) and a discussion of the physics of quasicrystals (*Phase Formation and Stability*, Chapter 10; and *Generalized Quasiperiodic Structures*, Chapter 11). The first part constitutes a reference for investigators in the field, while the second part gives fundamental insights on the specific properties and characteristic of quasicrystals and their potential applications. In Chapter 10 the challenging problem of how quasiperiodicity is achieved at intermediate cooling rates (between those for metallic glass formation and crystallization of periodic structures) is presented. The preservation of the local structural ordering present in liquid alloys does not explain the quasiperiodic long-range order, and the role of entropy as a decisive factor remains unclear. Instead, the presence of polyhedral structural motifs (clusters) with noncrystallographic symmetry crossed by low-energy internal surfaces is called as a cause of quasiperiodicity. Unfortunately, the figure (Fig. 10.2) illustrating this point is barely understandable. Finally, a survey of known phase transitions is given followed by the presentation of microscopic models of the transitions, based on the nucleation of ordered domains. This applies directly to 1D quasicrystals, which are supposed to play the role of intermediate states between quasicrystals and periodic structures. Other mechanisms are mentioned with far fewer details.

The last chapter gives an overview of soft quasicrystals (liquid crystals, polymers) and of metacrystals (photonic and phononic crystals) and their applications as devices for electromagnetic and acoustic waves. Despite the limited extent (the whole chapter counts only 13 pages), the fundamental concepts are explained in a remarkably clear way and several references are given for further study.

Crystallography of Quasicrystals complements well the previous monograph, where the treatment of quasicrystals was definitely shorter because they were considered in the more general frame of aperiodic crystals. Quite obviously, some overlap exists, for example in the mathematical models, while the presentation of phasons and phonons is more detailed in the previous monograph. This new text does cover a gap in the literature not only for the in-depth analysis of the higher-dimensional approach to quasicrystals, but also because of the detailed presentation of quasiperiodic phases collected in the third part of the book. Online access, where figures in colour are accessible, is recommended, because the greyscale versions that, with a few exceptions, replace them in the printed edition are not always easy to follow. Some more breadth on the physical properties of quasicrystals would perhaps have been useful, although the authors have succeeded in concentrating the fundamental concepts in an extremely clear synthetic presentation. But this would perhaps have meant to go well beyond the editorial limits in a book that already counts almost 400 pages.

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