

Preface

Based on a theory of differential equations approach, the first edition presented an analytical one-electron non-spin theory of electronic states in some simple and interesting low-dimensional systems and finite crystals. The essential understanding obtained is that different from that all electronic states are Bloch waves in a crystal with translational invariance as in the conventional solid state physics, a two boundary truncation of the translational invariance may produce two different types of electronic states—boundary dependent or size dependent—in some simple and interesting cases. The size dependent states are stationary Bloch waves due to the finite size of the truncated system, which properties and numbers are determined by the size. The boundary dependent states are a different type of electronic states which properties are determined by the very existence of the boundary. Such an understanding was first learned in one-dimensional crystals and later archived in multi-dimensional crystals as well. Since it was first published more than ten years ago, the existence of such two types of confined states or modes has been confirmed by subsequent investigations of other authors in various low-dimensional systems. The very presence of the boundary dependent confined states is a unique distinction of the quantum confinement of Bloch waves. Whether this is the origin of many unusual properties of low-dimensional systems remains to be understood.

The current Chap. 2 is a summary of basic theory of periodic Sturm–Liouville equations, as a part of the mathematical basis of the book. The author recently learned that this mathematical theory could treat more general one-dimensional systems in physics, such as one-dimensional layered photonic crystals and phononic crystals. Therefore, the wave equations of those crystals can be treated in the same way as the Schrödinger differential equation for a one-dimensional electronic crystal. By the theory, eigenmodes of those different one-dimensional crystals have similar properties. As a result, eigenmodes of two types will be obtained if the modes are completely confined to the finite size. The general theory of periodic Sturm–Liouville equations straightforwardly gives many equations or theoretical results previously obtained on layered crystals in the literature. It can further treat more complicated thus previously untreated cases without much extra effort and

provide theoretical understandings on results observed in previous numerical calculations but may not be explained. These problems are discussed in Appendices C–F.

The primary focus of this book is still on the electronic states in crystals of finite size. Various substantial revisions, improvements, and corrections are made, in particular, in Chaps. 3, 5, and 8. All main scientific conclusions presented in the first edition remain valid or receive improved understandings, such as the differences between multi-dimensional cases and one-dimensional cases. *In general*, a surface state in a multi-dimensional crystal does not have to be in a band gap, since that in the physical origin, a surface state is closely related to a permitted band rather than a band gap. That a surface state is always in a band gap and decays most at the mid-gap is merely a unique distinction of one-dimensional crystals.

Some readers feel that examples are helpful for understanding the mathematical theory in the book. An advantage of the Kronig–Penney model is that its solutions—in both permitted and forbidden energy ranges—can be analytically obtained and simply expressed. The model provides a concrete example for illustrating the theory presented in Part II. The newly added Appendix A serves this purpose.

Periodicity is one of the most fundamental and extensively investigated mathematical concepts. Many periodic systems can be truncated. The truncations of periodicity do present new issues. In comparison with the periodicity, the investigations and general understandings of the truncated periodicity are much less. The existence of two types of confined states is a preliminary understanding of the simplest cases and is only the beginning. This new edition of the book is a continuing and further effort of the author trying to understand the truncated periodicity in physical systems based on the mathematical theory of periodic differential equations.

This edition is devoted to Professor Kun Huang and Professor Xide Xie, two leading founders of modern solid-state physics in China. The author was fortunate to be personally educated by them, as a human being and as a physicist.

It is a pleasure of the author to take this opportunity to thank Prof. Walter A. Harrison for his guidance and help, leading the author into modern solid-state physics again after he had to stop doing physics for more than ten years during the disastrous Cultural Revolution in China.

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Last but not least, the author is grateful to his family members. The work presented in the book could not have been completed without their continuing understandings, selfless love and supports in many ways and many years.

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