Preface

Less is different

The development of new materials has always had a dramatic influence on the world. Consider for example the discovery of bronze, a copper-tin alloy, or of metallic iron, which have given name to their respective ages in ancient time periods. Today, the influence of new materials is not quite as dramatic but still significant, modifying many aspects of human life style. New materials are typically introduced following discoveries in fundamental science. In recent times, it has become clear that not only a new chemical composition may form a new material, but also that reduced size and dimensionality of a known compound can produce novel properties generating a new material behavior. The most recent and perhaps the most popular demonstration is provided by an ultrathin two-dimensional form of carbon, graphene: the discovery of some of its peculiar properties in 2004 has set off a revolution in materials science that is still developing. In fact, the study of two-dimensional materials has been recently hailed as "one of the hottest topics in physics."[1] Prompted by the advent of graphene, a multitude of other atom-thick two-dimensional materials have been introduced in the last decade, with big or even bigger technological payoff promise.

Oxide materials are ubiquitous on earth and in modern science and technology. They feature a huge variety of composition and structure parameters and thus of physical and chemical properties. This variety can be even enhanced by adding reduced dimensionality as a further degree of freedom, and indeed two-dimensional oxides have been actively investigated in various fields of science and technology in the last two to three decades, writing a story going in parallel with the development of carbon two-dimensional materials. This book is devoted to such oxide materials in two dimensions or at the two-dimensional limit, that is, ultrathin oxide films comprising only one or a few atom-thick layers. Typically, two-dimensional materials are derived from *van der Waals* solids, i.e., layered solids with strong

[1]See the feature article "Beyond Graphene" by R.F. Service, *Science* 348, 490 (2015).

intra-layer but weak inter-layer interactions; the latter is the result of chemical bond saturation within the layers. This means that when deposited on a substrate for applied use, the two-dimensional layers feature weak overlayer–substrate coupling. Oxides rarely belong in this category, and strong coupling to the environment is rather typical: on a substrate, strong oxide–overlayer/substrate coupling is a rule rather than an exception. The latter is particularly true for transition metal oxides grown on metal surfaces as substrates, where strong oxide–metal interactions occur. This determines the oxide–metal interface as a major descriptor of two-dimensional oxide behavior, which is of particular relevance and besides the two-dimensional confinement as a prominent factor in generating novel materials properties.

The book collects contributions addressing the physical and chemical behavior of quasi-two-dimensional oxides from a fundamental viewpoint but with a look at promising applications, trying to provide a balanced sight from both experimental and theoretical sides, and a comprehensive overview of the present status of the field. The atomic geometry and electronic structure, the influence of the support on two-dimensional oxide overlayers and the properties of oxide–metal and oxide–oxide interfaces, the phonon structure, and the catalytic chemistry are the major topics covered in the thirteen chapters of this book. The topic of two-dimensional oxide materials is relevant to many different scientific and technological areas, and one of our main goals in this book is to show how several basic concepts and physical phenomena transversally underlie such varied fields, with a belief that realizing and appreciating such common grounds can promote interdisciplinary efforts and trigger and accelerate further progress and developments.

Finally, we would like to warmly thank all our colleagues and authors for their support and efforts, for sharing the spirit of this initiative, and producing top-level chapters which perfectly fit into a common scheme; without their contributions this book could not have been realized. We are convinced that the study of two-dimensional oxide materials will continue to be an ongoing active scientific endeavor and an active area of condensed matter research. We strongly hope that this book will provide stimulus in this direction.

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