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## Preface

Materials and associated technology developments have influenced humanity's cultural evolution and have made a significant impact on improvements of life quality. The names given to historical epochs, e.g. Stone Age, Bronze Age and Iron Age, make evident the importance and significance of the materials and associated technologies. Since its inception in the 1940s as an effective method to purify refractory metals, chemical vapour deposition (CVD) has evolved into the key technology to manufacture very large-scale integrated circuit chips. This has created revolutionary computer technology for modern society and led to the arrival of the information technology era. Over the last two to three decades, CVD technology has been further developed as an advanced technology to manufacture high-performance materials. One of the most representative and commercially valuable developments is the manufacture of fibre-reinforced ceramic composite materials (including carbon/carbon composites).

With the rapid development of CVD technology and applications in the aforementioned areas, it became imperative to produce a general-purpose reference book about this technology with a particular focus on advanced materials. Whilst there are a number of books introducing CVD in micro-electronic applications, there are no books about CVD applications in high-performance materials; this book aims to fill this gap.

In recent years, the interdisciplinary approach has had a profound influence on materials science and engineering, which are being transformed from a passive trial-error approach-based engineering into fields with a more proactive methodology than they previously had. Materials science and associated engineering technologies have become an advanced interdisciplinary field, which is closely related to physics, chemistry, engineering and so forth. In the 1990s, a well-known statement was made to indicate interdisciplinary nature of the aforementioned fields and to define the discipline: an outstanding material scientist should be a chemist in front of a physicist and a physicist in front of a chemist. At the same time, he should be a scientist in front of an engineer and an excellent engineer in front of a scientist. This identifies the knowledge and skill set for a good material scientist, who should possess broad and in-depth knowledge in physics, chemistry and engineering. Only equipped with the above knowledge can a material scientist innovate and develop new materials and products. At the same time, it also implies that an engineer must have a good understanding of these disciplines in order to develop innovative products. Above all, an innovator needs to have all the above essential knowledge and pursue and investigate interdisciplinary research and development areas in order to discover new materials, develop novel products and design new manufacturing systems for new and advanced products to meet ever increasing market demands.

Physics, chemistry and physical chemistry are the foundations of materials science and engineering. Materials researchers are also required to possess the sensitive vision and active thinking necessary for developing new materials based on innovative ideas. It is important for them to possess engineering ability to establish new prototype equipment for any research investigation. Many past experiences, both successful and unsuccessful, demonstrate the importance and necessity of the above qualities.

An understanding of the above characteristics and requirements for materials science and engineering forms the basis of the structure of this book, as it summarises precisely the essential knowledge requirements for CVD technology. Whilst the authors tackle a wide range of theoretical topics, the focus of the book is on the fibre-reinforced ceramic matrix composites used by the CVD or chemical vapour infiltration (CVI) processes. Based on the requirement of a systematic understanding of CVD processes, the related materials by some special CVD techniques and their potential applications, the book is structured as follows.

Starting with an introduction to the CVD process, Chapter 1 introduces basic features, historical developments, perspectives and literature of the CVD processes. A compendium has been compiled consisting of all key publications in the fields broken down into journals published in the field, books and handbooks produced, as well as proceedings of some of the most key conferences. Chapter 2 is concerned with the physical fundamentals involved in CVD processes. These include the theory of gas kinetics, vacuum technology, gas transport characteristics and so forth. As a key chapter for CVD processes, Chapter 3 explains the working principles, functional behaviours and design procedures of a CVD system. Furthermore, this chapter introduces a concurrent design and process modelling approach and associated design and analysis of the equipment used. In addition, some special techniques, such as continuous CVD and fluidised bed CVD, are introduced in this chapter. Chapter 4 explains the thermodynamics of chemical reactions of a CVD process and the methods of calculating CVD phase diagrams. It goes further by analysing some typical CVD phase diagrams. CVD kinetics is also discussed for homogeneous reaction, heterogeneous reaction and surface kinetics. Focusing on fibre-reinforced ceramic matrix composites, Chapter 5 introduces some typical CVI processes, their developments and applications. Physical and mathematical models are also established in the chapter to analyse the densification behaviour of the composites. Using the carbon fibre-reinforced silicon carbide composite as an example, the mechanical properties of these composites manufactured by CVI processes are also discussed in detail. Chapter 6 describes the theory of the microstructure evolution of the deposits, the control methods of a CVD process and the relationship between microstructures and the processing parameters. Computational fluid dynamics is introduced as an effective scientific method to simulate the velocity field of the gas flow within the CVD chamber and to optimise the processing parameters.

A substantial collection of CVD reaction systems and CVD phase diagrams has been compiled and included in Appendixes 3 and 4. This book is meant to be used as a reference and to serve as a rich information source for those who are interested in exploring and investigating further other CVD processes.

With the above information, it is also important to emphasise that the development of advanced materials requires innovative thinking and a visionary philosophy. As an example, when ceramics attracted much research interest and wide spread attention as a potential structural material in the 1970s, researchers explored different ways of overcoming its intrinsic weakness – brittleness. Among many methods tried, it was difficult to imagine that the brittleness of ceramic materials could be overcome by compositing several brittle constituent materials together. These radical approaches and results were pioneered by Professor Naslain in Bordeaux University, France, and Professor Fitzer of Karlsruhe University, Germany. It has been proven that carbon fibre-reinforced silicon carbide composites and silicon carbide fibre-reinforced silicon carbide composites exhibit excellent toughness. Of course, the interphase (also a brittle material) between the fibre and matrix plays an important role in this feature. This combination of brittle materials resulting in a new, strong and tough composite could be considered analogous to the mathematical principle of “a negative number multiplied by a negative number gives a positive number”. With the inspirational and innovative development of high-performance materials detailed in this book, it is the hope of the authors that new materials will be further developed based on CVD technology to benefit humanity in the future.

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Shortly after the authors jointly finished the most of the contents of this book and wrote the above text for this preface, Yongdong passed away suddenly at the young age of 43. He still had so much to work for and so much potential to contribute to the field. He was even hoping and planning to revise this text for

further editions. Sadly this will not be possible with his inputs. The second author would like to dedicate this book to Yongdong for his contribution, dedication and hard work in writing the relevant chapters of this book and his scholarly work in the field for the last 20 years.

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