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Wilhelm Kulisch

Deposition of Diamond-Like Superhard Materials

With 60 Figures

Springer

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Preface

Modern key technologies such as microelectronics and micro system technology, but also automobile, aircraft and space technology, and in addition even the fabrication of every-day articles (especially for recreational purposes) place an ever increasing demand on the materials involved. This is true not only for the work pieces and components produced (such as active or passive devices in microelectronics, or parts of cars and planes) but also for the tools used to fabricate these elements, and for components of the analysis tools used to characterize them. An example for the importance of material selection can be found in the automobile industry where harder cutting and spaning tools result not only in prolonged life of the (often very expensive) tools but also in smaller tolerances of the dimensions of motor components and thus to less expensive and less polluting motors. In the field of analytics, the recently developed scanning probe microscopies may be used as an example of tools which allow material characterization with regard to a variety of physical and chemical properties but which rely to a large extent on the material properties of the sensors used [1].

Thereby, it is sufficient for many (but not for all) applications to optimize not the bulk properties of a material but just its surface properties. In many cases this is more economical and often also leads to even better results. Such a surface optimization can be achieved either by chemical or physical surface treatments (plasma oxidation, plasma nitridation, ion implantation), or by deposition of a thin film with the desired properties.

For these reasons materials sciences in general, and especially thin film technology, experienced a rapid development in the two preceding decades. In this context, even actual physical topics gain more and more importance for materials sciences; the deposition of diamond films and the synthesis of high-temperature supraconductors, fullerenes, and nanotubes may serve as examples. In its initial phase, the development of thin film technology was closely related to that of semiconductor electronics; meanwhile, however, the fields of application have been extended widely and now cover areas such as optics, tribology, information storage, and many others.

A very important material property currently the center of intensive multifaceted research is hardness, which is the resistance against the intrusion of another body. Possible areas of applications again include work pieces and components (e.g. parts for aircrafts and boats), tools (e.g. drills, cutting tools), and components of analysis tools (e.g. resistant tips for AFM measurements) alike. It is further of special importance that the material property hardness correlates in many cases with other extreme mechanical and non-mechanical properties.

There are two general concepts in the design of superhard materials. The conventional way is to prevent the movement of dislocations and the propagation of cracks within the material. This approach, which has been known for several thousand years, today leads in the form of composite materials or – by thin film technologies – of multilayer and multiphase systems to new, successful solutions.

The second way consists of the synthesis of ideal materials (almost) free of dislocations and cracks. Therefore, besides the realization of such materials the question of importance is which compounds possess, due to their bond structure, an 'intrinsic' hardness that is as high as possible. In this context the prediction of material properties by means of ab initio calculations plays an ever increasing role [2]. The discussion in this book will show that superhard materials are to be found in the B/C/N system, and that they possess properties similar to those of diamond even if they do not exceed them. In addition to diamond, we also have tetrahedral amorphous carbon (ta-C) and cubic boron nitride (c-BN) in the class of diamond-like superhard materials. Currently, however, intensive work is going on in the race to synthesize diamond-like superhard carbon nitride modifications and – although this is still in its infancy – to realize ternary $B_xC_yN_z$ compounds.

This book summarizes the present state of the art of the deposition of diamond-like superhard materials in form of thin films. The experimental and theoretical work performed by the Thin Film Technology Group of the Institute for Technical Physics at the University of Kassel is used as a basis. In particular I discuss whether there is a common route to the deposition of such thin diamond-like superhard films which can be easily transferred to further compounds from this class, thus allowing the design of a family of superhard materials with many additional extreme properties.

Much of the content of this book comes from my German habilitation thesis, which was submitted to the Department of Physics at the University of Kassel in January 1998. Although research in the area of diamond-like superhard materials has by no means ceased, and a great number of interesting papers were published in 1998, the main conclusions of this book are not affected by this new work. I have included up-to-date references for readers who would like to investigate this field further.

Acknowledgement. Such a book cannot be written without the help and assistance of many people. Far more important is the fact that the underlaying experimental and theoretical research relies on the individual work of my coworkers and the help of and discussions with many friends and partners all over the world.

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