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Fullerene journal

Fullerene Science and Technology An International and Interdisciplinary Journal (Basel and New York: Marcel Dekker)

Fullerenes represent a new allotropic form of carbon in which the atoms form closed surfaces. This class of compounds includes closed molecules of both spherical and spheroidal shape, such as C_{60}, C_{70}, and others, as well as extended carbon configurations with a surface structure (nanotubes). Although fullerenes have only a short history, this branch of science is growing rapidly and attracting continuously new investigators. The subject of fullerenes can be subdivided into three branches: the physics, chemistry, and technology of fullerenes.

The physics of fullerenes deals with the structural, mechanical, electric, magnetic, and optical properties of fullerenes and their compounds in various phase states. It includes also the nature of the interaction between carbon atoms in these compounds, the spectroscopy of fullerene molecules, and the properties and structure of systems consisting of fullerene molecules. The physics of fullerenes is the most advanced branch of the subject.

The chemistry of fullerenes comprises preparation and study of new chemical compounds based on closed carbon molecules, and the chemical processes in which they participate. The concepts and investigation methods distinguish this branch of chemistry in many fundamental ways from traditional chemistry.

The technology of fullerenes includes both the methods for the fabrication of these compounds and their various applications. The applications deserve special attention. On the one hand, there is a huge list of potential uses for fullerenes. On the other hand, it is not reasonable to expect that any of the fullerene applications will pay, in the near future, for the cost of research on the subject. The applied aspects of the problem of fullerenes thus require long-term research and tests, and the success will require painstaking and sustained efforts.

One other aspect of the application of fullerenes is the high scientific content not only at the preparatory stages of reaching a solution, but also in putting it into practice. Let us consider, for example, a medicine in which a fullerene is used as a convenient neutral base. Then, at the stage of manufacture of this compound one has to use the same fullerene detection methods as in the laboratory. The applied part of the problem of fullerenes is therefore science-intensive. For this reason the success in systematic development of fullerene applications will depend on the degree of support by the physics and chemistry of fullerenes. Therefore, in spite of the difference in approaches and in topics selected for investigation, it seems that most beneficial — from the point of view of applications — would be the simultaneous growth of the physics, chemistry, and technology of fullerenes.

This was the idea behind the launching of a new international and interdisciplinary journal, *Fullerene Science and Technology,* which took place in 1993. The publisher is Marcel Dekker Inc. in New York. The foreign editor is Prof. W. Kratschmer, one of the founders of the technology of fabrication of fullerenes in macroscopic quantities, and one of the editors is Prof. T Braun (Hungary). The journal will deal with the problem of fullerenes as a whole and publish papers on such aspects as the geometry, synthesis, structure, bond formation, chemical activity, thermodynamics, and spectroscopy of fullerenes. Various experimental methods for the detection, formation, and study of fullerenes will be included. At present, the journal is being published six times a year. Since the journal is now in its third year, some conclusions can be drawn.

The rapid growth of research on fullerenes has resulted in an avalanche-like increase in the number of scientific publications on this subject. In 1993, there were about 500 such publications, rising to over 1500 in 1994, and there were more than 1000 journal and conference papers in the first half of 1995. In this situation it is difficult to expect one small journal with under 100 pages per issue to be capable of presenting the most important trends in the research and applications of fullerenes. Moreover, the journals that began to publish work on fullerenes well before the appearance of *Fullerene Science and Technology* include authoritative and widely circulating journals such as *Nature*, *Journal of Physical Chemistry*, *Journal of Chemical Physics*, *Chemical Physics Letters*, *Physical Review B*, *Journal of Physics and Chemistry of Solids*, and others. The most outstanding results in the research on fullerenes were published in these journals and a contemporary reader interested in further progress in the subject of fullerenes would find it difficult to go beyond the customary publications.

However, *Fullerene Science and Technology* has clear advantages over the journals listed above. This is due to the manysided orientation of the journal, which has made it possible to attract specialists from different branches of science sharing the same interest in fullerenes. Although at present the papers published in this journal do not

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have the same influence on the progress in research on fullerenes as that of the papers in the leading physical and physicochemical journals in the above list, one can say that there has been a significant tendency for an increase in this influence during the relatively short period of the existence of the journal.

The topic of fullerenes is quite profound and extensive. It will continue to develop and it will not be exhausted after success in some specific practical applications. Successful growth of the topic requires a periodic journal which would bring together those working on the subject and help in exchange of information between them. This role is at present being fulfilled successfully by *Fullerene Science and Technology*. We hope that this journal will flourish in future.

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Properties of diamond and diamond films

The Properties and Grace of Diamond, edited by G Davies (London: The Institution of Electrical Engineers) 437 pages

About two years ago I reviewed in *Uspekhi Fizicheskikh Nauk* [1], the book *The Properties of Natural and Synthetic Diamond*, edited by J E Field [2]. In 1994 a new book was published and it was edited by G Davies, known for his research on optical phenomena in diamond [3]. This new book, as well as the proceedings of several conferences (see, for example, Ref. [4]), were evidence of the continuing research on the growth of diamonds and on the physical phenomena which occur in them. As in the years before the publication of *The Properties of Natural and Synthetic Diamond* [2], a specially great effort has been made by technologists to improve the methods for the growth of diamonds from a metastable gas plasma. Many of the optimistic predictions of the past decade on the reduction in the cost of diamond films have been confirmed, but unfortunately this applies only to polycrystalline films which have such valuable applications as coatings resistant to mechanical damage and to the action of chemically aggressive media. However, they are in practice not very useful as active elements for solid-state electronics.

The Properties and Grace of Diamond consists of twelve chapters and begins with a brief foreword by W Mitchell, the author of the now classical work on the optics of diamonds and identification of strongly localised states in this material. Each chapter consists usually not of one but of several short sections, written in an extremely laconic manner and containing detailed and excellent arranged tables of the main physical properties of diamonds. Each of these contributions ends with a list of references, which include work published in 1993. The authors are mainly specialists from Great Britain, Holland, and France. The first chapter describes the main physical properties of bulk diamond crystals with the natural isotopic abundance. In my opinion, however, it repeats the corresponding chapters in the book edited by Field [2], as does the third chapter dealing with the very thoroughly investigated great variety of states of the nitrogen impurity in diamonds. There is much more new material in the second chapter (on the properties of diamond surfaces), which gives data on microscopic structure, surface graphitisation, mechanisms of friction and work, diamond polishing methods, and erosion. About half the contributions to the chapter come from J E Field, who is the book editor [2].

New data on the role of impurities in the form of the elements Ni, Si, H, and O in diamond are given in the fourth chapter. Particularly interesting are the data on hydrogen and silicon impurities supplied by G Davies. The content of the fifth chapter (radiation damage in diamond) summarises in a sense the problems which have been investigated in sufficient detail and are related to ‘point’ defects, particularly vacancies and the complexes they form with chemical impurities. It is somewhat unfortunate that there is practically no information on the effects of fast neutrons on diamonds, especially since diamond dosimeters have the highest stability under the action of penetrating radiations. True, the sixth chapter dealing with the doping of diamonds by ion implantation (written by R Kalish), gives suitable attention to related topics. At present, the problem of doping diamonds with electrically active impurities is far from solved and ion implantation has long been considered one of the promising approaches [5]. The seventh chapter provides a detailed analysis of the luminescence processes in diamonds, including migration of the excitation energy and characteristic luminescence decay times. There is also the important problem of the possibility of using diamonds in lasers.

The content of the eighth chapter is very exotic, but in the good sense of the word: it is entitled “Isotopic effects in diamonds”. In fact, quite recently it has proved possible to grow isotopically pure diamond crystals, since the ^{13}C isotope exists in amounts sufficient for the purpose. It is remarkable that studies of the thermal conductivity of such a rare crystal revealed anomalies predicted long ago by R Berman.

The ninth chapter (by A T Collins) deals with topics close to problems of practical importance: it analyses the current status of the doping of diamonds with electrically active impurities, particularly with boron. One of the important conclusions reached by Collins, which he published some years ago, is that diamonds have (or will have) a fairly narrow range of applications as active elements in electronics. In particular, the problem of introduction of stable donor impurities with sufficiently shallow energy levels has not yet been solved. On the other hand, the major progress made in the growth of very large single crystals of specific silicon carbide (SiC) polytypes, which can have diameters up to 40 mm, makes it increasingly clear that SiC is at present a technologically more promising material for high-temperature semiconductor and optoelectronic devices. In particular, methods for introducing donor centres with shallow energy levels into silicon carbide have now been mastered.

The tenth chapter deals with the technology of surfaces, etching methods, and formation of stable electric contacts.

The eleventh chapter is large (35 pages) and provides detailed information on the growth of diamond films under metastable conditions, i.e. from a gaseous plasma containing the products of dissociation of organic compounds, which are carbon and usually atomic hydrogen. The initial variants of this method, involving the use of hot metal filaments and a microwave discharge, have been followed by research which has established that polycrystalline diamond films can be deposited from a plasma in a flame 'plume', i.e. under fundamentally very simple conditions. It has also been shown that laser radiation can be used to control, to some extent, the process of growth of diamond films. A separate contribution deals with the thermal conductivity of films prepared by the method just described. Such information is important because of the probability of very extensive use of diamond films as heat sinks in solid-state electronics and in computing technology.

The final (twelfth) chapter gives the current data on the method of growing diamonds at high pressures and temperatures. This chapter was prepared by Japanese specialists H Sekine and H Kanda. It is in Japan that serious effort is being made to develop the high-pressure high-temperature method which sometimes gives results which are unique to fundamental research, such as the growth of diamond crystals consisting entirely of the ^{13}C isotope. This chapter details also new data on the catalytic conversion of carbon into diamond in the presence of metals, primarily nickel.

The reviewed book will be extremely useful for Russian specialists and the publication of its Russian translation (50 – 100 copies would be sufficient) is undoubtedly justified.

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