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Book Review

ION BEAM MODIFICATION OF MATERIALS '90

Ed. D.B. Poker & S.P. Withrow. North-Holland, Elsevier, Amsterdam, 1991.

What have a diamond transistor, a surface hardening treatment that causes no change in the dimensions of a component, optical waveguides integrated on a wafer, and a totally new strain of rice got in common? The answer is that they can all be prepared by ion implantation, in which the accelerator technology familiar to nuclear physicists is used to inject selected impurity atoms in a layer just under the surface of a solid.

Ion beam modification of materials, or IBMM as it is commonly called, has become a recognised discipline in the preparation of materials with exotic surface or near- surface properties. The above pair of volumes contains the Proceedings of the seventh biennial conference in the IBMM series, held in September 1990 in Knoxville, Tenn. with strong involvement from nearby Oak Ridge National Laboratory.

These conferences generally attract some 400 participants from all the industrialised countries, and a comparable number of scientific presentations. Most are given in poster form. Manuscripts for inclusion in the Proceedings have to pass the refereeing scrutiny for the journal Nuclear Instruments and Methods B, and in this case there are 313 of them. The standard is generally high, and the volumes are essential reading for anyone with an interest in the materials of tomorrow.

Historically, it was the semiconductor industry which first took advantage of the penetration of accelerated ion beams into solids on order to achieve highly controllable electronic doping. Research still continues apace, and silicon is the subject of many of the papers in these two volumes, with gallium arsenide not far behind.

Several such papers are concerned with the new processes opened up by the development of high-energy ion- implanters, operating at MeV rather than the more usual hundreds of keV, enabling layers to be implanted underneath others.

In particular, progress in the synthesis of deep isolating layers of silicon oxide or nitride below the device layer, using high current implants of oxygen or nitrogen, is reported. There are many papers on the damage or recrystallisation of silicon under conditions of ion irradiation. The formation of metal silicide interconnects layers, either by high energy implantation or by ion-beam mixing - irradiating a metal layer on a substrate by heavy inert-gas ions - also merits several papers.

One of the most interesting new developments is that of diamond-based semiconductors (Prins et al.) using ion doping combined with the defect engineering to achieve the necessary substitutionality of the dopant atoms. There are also papers on deposited diamond-like coatings with a view to mechanical applications.

Increasing the surface hardness and wear resistance, and decreasing the friction coefficient, of engineering materials by ion implantation, is already a commercial proposition in several countries. The ability to treat formed components with no dimensional change, and to enhance the surface of a cheap substrate, are the great advantages. The section on ion beam modification of metals is the largest in these Proceedings, with 56 papers.

Nitrogen implantation into steel is the classic combination, but papers are also presented here on a great variety of others: co-implantations of nitrogen with boron, titanium or carbon into steel, pure carbon implants into steel, nitrogen implants into aluminium etc. Buried nitride or oxide nanoprecipitates have been seen in some cases. It is becoming clearer that effects depend very much on individual implant-substrate chemistry or physics. Various degrees of benefit are reported, in the form of increased micro-hardness, reduced wear or friction, and in some cases enhanced resistance to corrosion. Yttrium and tantalum implants have been the most successful for the latter.

Of interest in this connection is the first report (Nielsen et al.) by a a seven-way collaboration, including the Rolls-Royce Company, who have embarked on a comprehensive study into the reduction of corrosion in aero- engine bearings, with future field tests planned. Preliminary results show improvements after chromium and tantalum implantations into the bearing steel.

A somewhat eclectic section on insulators, ceramics and polymers contains the second highest number of papers, 50. Some of the subjects meriting several papers each are the implantation of metal ions in alumina to enhance the mechanical properties, changing the refractive index of electro-optic crystals by radiation damage to produce light-waveguides for solid-state optical signal processing, and irradiating polymer films with a view to increasing their electrical conductivity.

IBMM was amongst the earliest attempts to improve the properties of high-T_c superconducting films, often with detrimental results. However, IBMM's ability to introduce a controlled degradation towards a normal resistive state has contributed valuable insights into the conduction mechanism; a review of this work is provided by Chu et al. Other papers report some success in increasing the critical current density and the transition temperature, and in the synthesising of high-T_c films by ion-assisted techniques.

Ion beam assisted deposition, as distinct from ion implantation, includes ionised cluster beam deposition and ion beam mixing. In a powerful variant reviewed by Wolf and Ensinger, ion irradiation during the deposition of an evaporated or sputtered layer leads to improved and controllable adhesion, stress and texture of the film. There are many papers dealing with specific electrical, tribological or other systems in detail.

A section on theory and fundamentals is concerned with the bread-and-butter issues of ion ranges and damage (together with the important related topic of sputtering) on which IBMM as an exact science depends. Although there is a separate but related conference devoted to IBMM equipment and techniques, a few papers comprise a short experimental techniques section here.

Finally, there are two papers on new biological applications. High-quality colour photographs of operation illustrate the paper by Suzuki et al. on the reduction of the blood-clotting propensity of silicone rubbers by implanting various ions therein; and the introduction of beneficial mutations in rice by this technique is the subject of a paper authored jointly by the Chinese Institute of Plasma Physics and the Chinese Institute of Rice (Yu Zengliang et al.).

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