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Application of Double-Crystal X-Ray Difractometry Methods and Topography for Characterization of Isotopically Modified CVD Diamond Films

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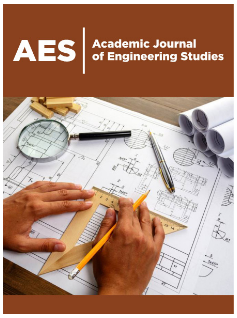

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Abstract

The case of studying isotopically modified CVD diamond films the high efficiency of using of double-crystal x-ray diffractometry and topography methods for characterizing crystals while improving the technology for their growth has been demonstrated. The main structural defects (dislocations, stacking faults, second-phase inclusions, etc.) that occur in synthetic diamond crystals during their preparation have been identified.

Keywords: Double-crystal x-ray diffractometry; X-ray topography; Defects in the crystal structure; Epitaxial films; Isotopically modified films

Abbreviations: XRD: X-Ray Diffractometry; MDs: Misfit Dislocations; ES: epitaxial structures

Introduction

Crystals are the basis of numerous instruments and devices of modern technology. All real crystals contain a variety of structural imperfections that strongly, sometimes cardinally change the properties of crystals and have a direct impact on the operational characteristics of devices made on their basis. To study the laws of formation and control of the real structure of crystals a wide range of physical research methods are currently used. Double-crystal X-Ray Diffractometry (XRD) and topography methods are widely used in laboratory practice as the most accessible and relatively simple from a technical point of view. The use of these methods in the study of epitaxial structures makes it possible to determine: structural perfection of the substrate and film; the mismatch in the interplanar spacings of the crystal lattices of the substrate and the film and their mutual misorientation; thickness of the epitaxial film over the period of the intensity oscillation (Pendellösung); lattice mating coherence; the curvature of the plate and, accordingly, the level of elastic stresses in the system, and also the change in the thickness composition and the structure of the interphase boundary when processing the swing curve using mathematical modeling methods.

In this research the capabilities of the XRD and topography methods are analyzed by the example of the study of isotopically modified CVD diamond films, which, due to their unique properties: high hardness, chemical and radiation resistance, low coefficient of thermal expansion and high thermal conductivity, are increasingly used in various fields of science and techniques [1,2]. The main structural defects (dislocations, stacking faults, micro segregation growth bands, second phase inclusions, etc.) arising in crystals during their preparation were identified. The formation of dislocation beams originating at the film-substrate interface was discovered due to possible near-surface disturbances of the substrate and relaxation of elastic macrostresses, which arise due to the mismatch between the periods of the crystal lattices of the substrate and the film. In isotopically modified diamond films ^{13}C(99.96%) grown on diamond Ib substrates, the XRD method revealed a significant decrease in the crystal lattice period $(\Delta a/a)_{relax} \sim (1.1/1.2)\cdot 10^{-4}$. Data on the features of relaxation processes in epitaxial CVD films of diamond and its crystallographic analogue of germanium are presented. Special characteristics of plastic deformation in these materials due to specific distribution of elastic stresses are revealed. The process of relaxation of elastic stresses in germanium structures at film thicknesses exceeding critical is accompanied by formation of 60-degree Misfit Dislocations (MDs) at the interphase boundary (Figure 1a); [3]. Traces of plastic deformation with the formation of MDs in Epitaxial Structures (ES) ^{13}C/^{nat}C (001) with a film thickness of ~ 80µm, almost two orders of magnitude greater than the critical value t_c~1.1µm [4], on the x-ray topogram (Figure 1b) are not visible. Only traces of mechanical processing on the reverse side of the substrate are detected, along the direction [100], which is the direction of the light polishing of diamond [5]; (Figure 1c). This seems to be connected with the low epitaxy temperature (950 °C). Compared to the melting temperature of diamond, dislocations are inactive, and the effective plastic deformation observed in ES germanium does not occur in the diamond film.

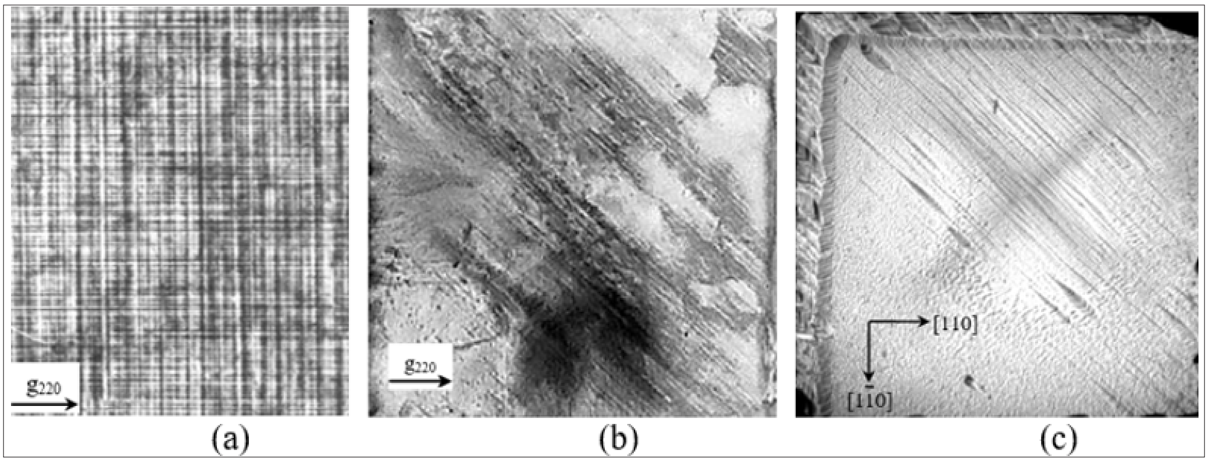

Figure 1:

(a) X-ray topograms of ES Ge(B)/Ge(001)

(b) ^{13}C/^{nat}C(001)

(c) and micrograph of ES diamond ^{13}C/^{nat}C(001)

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