Effect of crystal defects on diamond morphology during dissolution in the mantle

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ABSTRACT

The influence of three-dimensional defects on the morphology of diamond dissolution in water-containing carbonate melts was studied at a pressure of 5.7 GPa and a temperature of 1300 °C, using a BARS multi-anvil apparatus. Experiments on stage-by-stage dissolution were performed for four blocky synthetic diamond crystals. Initial crystals had polycrystalline structure of the faces, strong strains, block structure, numerous microtwins, and microinclusions. It has been established that the main relief features of partly dissolved diamond crystals are shield-shaped laminae and negative trigons on remnants of {111} faces, deep etch channels, rectilinear steps on microtwins, and hillocks on rounded surfaces. The produced dissolution forms have shagreen or block-type rounded surfaces. The main element of the relief are hillocks. Their shape is controlled by the orientation of the surface on which they are localized. For natural rounded diamonds it is found that the dissolution drop-like hillocks on the surfaces are also related to strong lattice strains occurring in the crystals. The established relation between the dissolution hillocks and diamond deformation can be used for the reconstruction of the post-growth history of natural diamonds as well as for the preliminary evaluation of their quality.

Keywords: Diamond dissolution, crystal morphology, defect of crystals, dissolution hillocks

INTRODUCTION

Natural rounded diamonds demonstrate a wide variety of surface structures. Some crystals have macroscopically smooth, glossy surfaces. Others show on their surfaces specific features, including serrate and shield-shaped laminae, drop-like hillocks, striations, ruts, and many other patterns (Kukharenko 1955; Orlov 1977; Robinson 1978). There is no doubt that the rounded form of natural diamond crystals is a result of dissolution in water-containing kimberlitic melt (Moore and Lang 1974; Orlov 1977; Robinson 1978; Gurney et al. 2004; Kozai and Arima 2005; Khokhryakov and Palyanov 1990, 2007; Fedortchouk et al. 2007). Therefore the details of the micro-relief of natural diamond crystals reflect first of all the conditions of dissolution in natural processes. At the same time, diamond characteristically contains various structural imperfections ranging from point to three-dimensional defects. The dissolution of the defects outcrops proceeds in a different way than for perfect surfaces (Heimann 1975). As a result, the micro-relief elements may form, which to a greater extent reflect the features of the real structure of diamond crystals rather than the dissolution conditions. This question has not been adequately explored so far. Only for some micro-relief elements of natural rounded diamonds, their relation to the real structure has been determined. It is established that trigons on {111} faces are located at the dislocation outcrops (Lang 1964). It is shown that the intersecting striation is related to the bands of plastic deformations (Robinson 1978) and rhomic patterns of the etching channels to the surface cracks (Orlov 1977). The nature of many other widely abundant micro-relief elements and surface sculptures has not been clarified yet. The scarcity of experimental data on this subject is partly due to the fact that in most cases only high-quality diamond crystals were used in the dissolution experiments (Kozai and Arima 2005; Khokhryakov and Palyanov 2007; Fedortchouk et al. 2007). Furthermore, most of previous experimental works on diamond dissolution were focused mainly on the effect of conditions and composition of the medium on dissolution morphology.

In the present study we have explored the dissolution of synthetic diamonds of block structure. The specific features of dissolution surfaces of mosaic crystals are established. It is shown that the origin of the drop-like hillocks on diamond tetrahedra is related to the occurrence of strong local strains in the diamond lattice.

EXPERIMENTAL METHODS

In the experiments we studied stage-by-stage dissolution of four blocky crystals of synthetic diamond weighting from 1.2 to 5.92 mg (Fig. 1). The diamond crystals were grown by the temperature gradient method in the NiFe–C system with nitrogen content from 0.25 to 0.3 at% (Palyanov et al. 2010). A detailed investigation of these crystals was performed in (Palyanov et al. 2010). It was shown that the crystals had a polycrystalline structure of the faces, strong strains, block structure, numerous microtwins and microinclusions. Such characteristics are typical for many natural diamond crystals. Crystal no. 1 (5.92 mg) has small {100} faces (Fig. 1a). Approximately one third of the crystal has flat faces, and the rest surface is blocky with numerous microtwins. Crystal no. 2 (2.47 mg) has only {111} faces (Fig. 1d). The surface exhibits large blocks and twinning intergrowths. Crystals no. 3 (1.51 mg) and no. 4 (1.20 mg) are of octahedral habit. These crystals have a rough relief with numerous trigonal blocks and depressions (Figs. 1g and 1j). All crystals contained microinclusions of metal catalyst. The amount of microinclusions in the crystals increases with the degree of their blockiness from crystal no. 1 to crystal no. 4. From the infrared absorption measurements it was found that...