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One of the Possibilities to Improve Optical Quality of As-Grown Shaped Sapphire Crystals

One of the possibilities to improve optical quality of as-grown shaped sapphire crystals is presented. Replacement of RF susceptor made of normal grade graphite by that made of pyrocarbon covered graphite results in increase of the optical transmission of sapphire ribbons grown by the Stepanov/EFG technique.

Keywords: shaped crystal growth, Sapphire single crystals, EPG/Stepanov method, polycarbon, optical quality

1. Introduction

It is a common place that presently sapphire single crystals due to their excellent optical and mechanical properties combined with technological availability can be widely used for many optical applications (windows for imaging systems, scanners, etc.).

At the same time it is a matter of fact, that the experimentally observed optical quality of crystals strongly depends on the chemical purity of material, structure defects etc. While growing shaped sapphire crystals (calibrated rods, ribbons, tubes) by the Stepanov/EFG technique, many technological parameters modify the real crystal structure. The aim of this paper is to find a technological opportunity to improve the optical transmission of as-grown sapphire ribbons.

2. Experimental

Sapphire ribbons 20 mm wide and 2 mm thick were grown in the [0001] crystallographic direction with the Stepanov/EFG technique. Argon atmosphere (under an excessive pressure) was applied, crucible and die were of molybdenum. All crystals were grown in a 8 KHz induction-heated growth chamber in similar technological conditions, with one except: (a) normal grade graphite or (b) pyrocarbon covered graphite were used as susceptor materials.

Both types of susceptors were primarily made of normal grade graphite with density ρ=1.63-1.67 g/sm^3, i.e. they correspponded to the variant (a). To obtain variant (b), the process of applying a coating of pyrocarbon to the surface of normal grade graphite was used. Pyrocarbon was obtained using the process of thermal decomposition of methane:

$$CH_4 \rightarrow C+2H_2 \ .$$

The reaction was realized in the temperature range 1000-1200°C using indirect heating, pressure being 700-1500 kPa. The process may be subdivided into two parts: 1) filling in the pores mainly located near the surface of parts made of graphite; 2) formation of a superficial pyrocarbon layer, basal planes of deposited graphite being arranged parallel to the susceptor surface. Pyrocarbon layers 1-12 µm thick were used in this work.

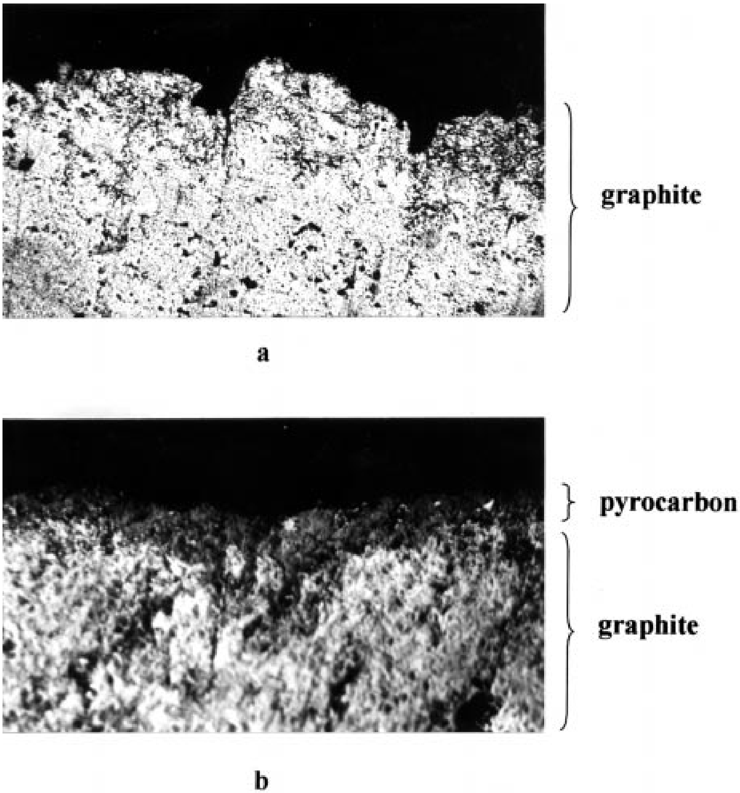

Fig. 1: The surface of susceptors after 500 hours of work: (a) - susceptor made of normal grade graphite; (b) – graphite susceptor covered by pyrocarbon layer 10-12 μm in thick; × 800.

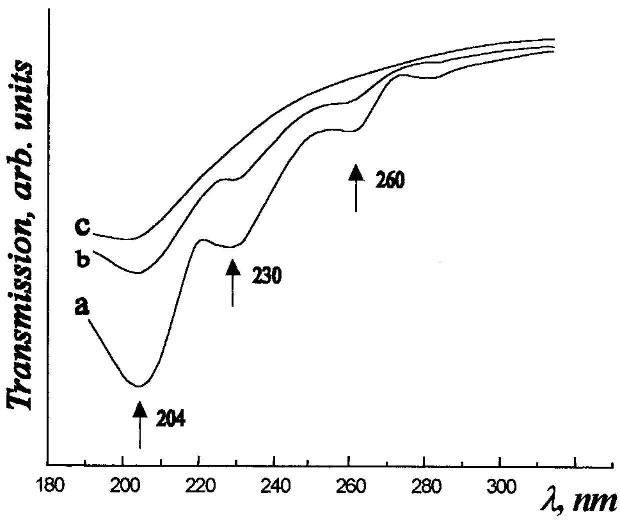

Fig. 2: Optical transmission spectra of as-grown sapphire ribbons: (a) - grown with normal grade graphite succeptor; (b,c) - grown with the succeptor covered by pyrocarbon

The life time of graphite susceptors covered by pyrocarbon exceeds by large that of the susceptor made of normal grade graphite. Fig. 1 shows the surface of susceptors after 500 hours of work: (a) susceptor made of normal grade graphite, (b) susceptor made of pyrocarbon covered graphite (the thickness of pyrocarbon layer is 10-12 μm). The figures make it apparent that the normal grade graphite surface is subjected to erosion much more severely than the surface of pyrocarbon. That is, the surface of normal grade graphite is subjected to thermal and chemical destruction during the sapphire crystal growth.

Optical transmission spectra were obtained with the Specord spectrophotometer. It was found that optical transmission of sapphire ribbons grown with the pyrocarbon covered susceptor was better than that of the ribbons grown when the normal grade graphite susceptor was applied (Fig. 2).

3. Discussion

The normal practice of the shaped sapphire crystal growth means that graphite is used as the susceptor material, molybdenum - as the crucible and die material, and argon - as a protective atmosphere. It was shown (BORODIN et al.) that the physico-chemical processes occuring in the “normal” growth chamber at high temperatures usually form the reducing chemical potential, which results in the disturbance of the crystal stoichiometry (increased concentration of the anion vacancies). Such anion-defected sapphire demonstrates some changes in the transmission and luminescence spectra due to the F and F^+ centers which are oxygen vacancies having trapped 2 or 1 electron, correspondingly. The structure and properties of elecronic colour centers in sapphire is in detail investigated in (EVANS, STAPELBROEK; LEE, CRAWFORD). Optical and thermal energy level positions determined by studies of optical absorption and/or luminescence for Al_2O_3 with native defects are summarized in (KROGER).

Optical transmission spectra of the two types of as-grown sapphire (Fig. 2) bring out clearly that the sapphire ribbons grown in “normal” conditions demonstrate additional absorption in UV region. Fig. 2b shows transmission spectra of sapphire ribbons grown with the succeptor covered by layer of pyrocarbon 1-2 μm thick, Fig. 2c - grown with the succeptor covered by layer of pyrocarbon 10-12 μm thick.

4. Conclusion

Replacement of RF succeptor made of normal grade graphite by that made of pyrocarbon covered graphite allows to improve optical transmission in the UV region of the as-grown sapphire ribbons obtained with the Stepanov/EFG technique.

Besides, the life time of graphite susceptor covered by pyrocarbon exceeds by large that of the susceptor made of normal grade graphite.

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