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C. BECKER
E. ZSOLDOS
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DISLOCATION CONFIGURATIONS AT INCLUSIONS IN GGG /$Gd_3Ga_5O_{12}$/

C. Becker*, E. Zsoldos and A. Weber*

Solid State Physics Division

Central Research Institute for Physics of the
Hungarian Academy of Sciences, Budapest, Hungary

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*Central Institute for Solid State Physics and Material Research
Academy of Sciences of the GDR, Dresden

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ABSTRACT

Single crystal substrates of gadolinium gallium garnet were investigated by X-ray topography and optical microscopy.
The observed dislocation configurations at inclusions were 100-200 µm in diameter. Three types can be distinguished:
A - perfect loop configuration, B - imperfect loop configuration and C - spiral dislocation. Possibilities of detecting the different configurations by applied methods and the mechanism of their formation are discussed.

АННОТАЦИЯ

Исследованы субстраты из граната /ГГГ/ оптическими и рентгено-топографическими методами. Диаметр конфигураций дислокаций возникающиеся около вкраплений - 100-200 µм. Мы наблюдали три типа конфигураций
A: совершенная конфигурация лупов
B: несовершенная конфигурация лупов
C: спиральная дислокация.
Рассматривается возможности наблюдания разных конфигураций выше-упоминаемыми методами и механизмы их возникновения.

KIVONAT

Gadolinium-gallium gránát szubsztrátokat vizsgáltunk röntgentopográfiával és optikai módszerekkel. A zárványok körül kialakult diszlokáció-konfigurációk átmérője 100-200 µm.
Három tipusu konfigurációt észleltünk: A - teljes loop konfiguráció, B - hiányos loop konfiguráció és C - spirál diszlokáció A különböző konfigurációk fenti módszerekkel történő lehetőségeit és keletkézési mechanizmusukat tárgyaljuk.

1. INTRODUCTION

In order to test the surface quality of gadolinium gallium garnet /$Gd_3Ga_5O_{12}$, GGG/ substrates a series of wafers were examined by X-ray surface topography [1]. In some cases we observed contrast by reason of large crystal defects the presence of which, in GGG substrates for epitaxial magnetic garnet layers, is expected to be detrimental to magnetic bubble device applications. The defects to be described are dislocation loops and spirals at inclusions. They were investigated by X-ray topography and optical microscopy using birefringence they induced and the chemical etching technique. The aim of this paper is to describe these defects in accordance with the investigations of Matthews et al [2] completed by topography.

2. EXPERIMENTAL

The platelets examined were selected from a series of wafers cut from a single crystal bule grown by the Czochralski technique. The surface normal was parallel to the growth direction /[111]/. The wafer surfaces were lapped to a thickness of about 2oo µm. This was followed by Syton polishing to remove 5 - 2o µm from the surfaces. Some of the polished platelets were etched for 3 min. in a hot /165 C^o/ solvent prepared by mixing 3 : 1 volumes of concentrated sulphuric and phosphoric acid. The wafers were examined by X-ray topography, by polarizing microscopy with polarizer and analyser set at right angle and by optical microscopy after etching. All X-ray topograms were made by the Lang method in back-reflection or transmission arrangement using Cu K_{α_1} or Mo K_{α_1} radiation, respectively. The topograms illustrated here show the original contrast of the photographic plate. The back-reflection topograms were taken with /880/ - type reflections /it follows from this geometry that the diffracted beam is nearly perpendicular to the photographic plate/, the transmission topograms with /42o/ reflections. All straight lines visible in the figures are scratches due to the incomplete polishing process of the substrates.

3. RESULTS

On the topograms we observed a large number of defects with diameters from loo to 2oo μm. The transmission topogram showed that they have spherical or ellipsoidal shape. The observed configurations can be divided into three types:

A: perfect loop configuration

B: imperfect loop configuration

C: spiral dislocation

Figures 1,2 and 3 are images of the same perfect loop configuration /A/ taken by optical-, polarizing microscopy and X-ray topography. Based on the observations of Matthews et al [2], we assumed that these configuration consist of systems of inner and outer loops. In the case of a perfect configuration a loop system will exist on each {111} plane. The model in Fig. 4 shows the four {111} -type planes with loop systems. Looking parallel to the [111] direction only the three intersection lines of the {111}-type planes with the /111/ plane /each parallel to one of the <llo>-type directions/ and one loop system lying in the /111/ plane can be observed. Therefore on the topogram /Fig. 3/ at "A" we can see three line contrast in the <llo> directions and ringcontrasts /loop/ in the picture level. On the micrograph /Fig. l/ we can find only three rows of etch pits in the <llo> directions, the loops lying exactly in the /111/ plane are not visible. However if they incline to the /111/ plane, etch pits at their emergence points /marked with "l" in Figs l and 3/ can be observed. The inclination of the loop-system to the /111/ plane can be explained by climb-mechanism which takes place during the formation of the loops /[2],[3]/. As can be seen in Fig.2, around a perfect loop configuration /A/ no stresses are observable in the polarizing microscope.

However, the defects taking place at inclusions in the GGG substrate wafers are usually imperfect loop configurations, which means either that not all possible loop systems are excited or that in one or two of the {111}-type planes more than one /for example a pair of/ loop systems are present. Their formation depends on the shape of the inclusion /[2],[3]/. Figures 5,6 and 7 are pictures similar to Figs 1,2 and 3 but with imperfect loop configurations and spiral dislocation. Imperfect loop configurations are marked with B_1 and B_2. Figures 5 and 7 show rows of etch pits and contrast lines of loop-system pairs parallel to the [011] at B_2 and to the [101] direction at B_1 respectively. According to the asymmetrical stresses around the imperfect loop configurations /in Fig. 6. B_1 and B_2/in the polarizing microscope a contrast effect /Fig. 6. "3"/ is visible. The existence of the inner and outer loops can be demonstrated by the arrangements of the etch pits /2 in Fig. 5/.

In a few cases we observed spiral dislocations lying in the /111/ plane, such as for example that marked with "C" in Figs 5,6 and 7. Its spiral character is obvious only from the topogram /Fig. 7 "C"/. On the optical micrograph the distribution of the etch pits /Fig. 5 "C"/ is irregular and depends on the emergence points of the spiral disloca - tion. We found no effect in the polarizing microscope either /see Fig. 6 "C"/.

4. DISCUSSION

On comparing the three methods of investigations, it is evident that all three methods are necessary for an adequate interpretation of the different types of disloca- tion configurations at inclusions in [111] orientated GGG substrates. The transmission topogram of the wafer provides information of the defect shape only, but the resolution is insufficient to be able to recognize the details. The reflec- tion topography completed by optical microscopy of the etched surface gives good proof of the nature and shape of various configurations.

The investigations in the polarizing microscope with crossed polarizer and analyser showed that there are asymmetrical stress fields with components parallel to the wafer surface only in the case of the imperfect loop configu- rations - by reason of the different number of loop systems on the possible climb planes of /111/-type. In the case of the perfect configurations the long stresses into the matrix are low; as these configurations are symmetrical it is im- possible or very difficult to observe these stresses. If the perfect configuration cuts the specimen surface or a spiral dislocation lies in the /111/ plane parallel to the surface, only stresses perpendicular to the surface appear. These are parallel to the optical axis of the microscope and are therefore not visible. Our investigations confirm the forma- tion mechanism described by Matthews et al [2]-[5]. We were unable to find any proof for the statements for the colony formation as described by Nes [6],[7].

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CAPTIONS

Fig. 1. Optical micrograph of a GGG platelet /111/ orientation with perfect loop configuration /A/ after etching of 3 min. Thickness of platelet 200 μm.

Fig. 2. Optical micrograph of area as in Fig. 1. taken in a polarizing microscope with polarizer and analyser set at right angles; A-perfect loop configuration.

Fig. 3. X-ray topogram of same area as in Figs. 1.and 2. /Cu K_{α_1} radiation, $\overline{G} = \overline{8}0\overline{8}$/. A-perfect loop configuration.

Fig. 4. Model of perfect loop configuration.

Fig. 5. Optical micrograph of a GGG platelet /111/ orientation with imperfect loop configurations /B_1 an B_2/ and spiral dislocation /C/ after etching of 3 min. Thickness of platelet 200 μm.

Fig. 6. Optical micrograph of area as in Fig. 5. taken in a polarizing microscope with polariser and analyser set at right angles. B_1 and B_2- imperfect loop configurations, C-spiral dislocation, D-growth striae.

Fig. 7. X-ray topogram of same area as in Figs 5 and 6. /Cu K_{α_1} radiation, $\overline{G} = \overline{8}0\overline{8}$/. B_1 and B_2 - imperfect loop configurations, C- spiral dislocation, D-growth striae.

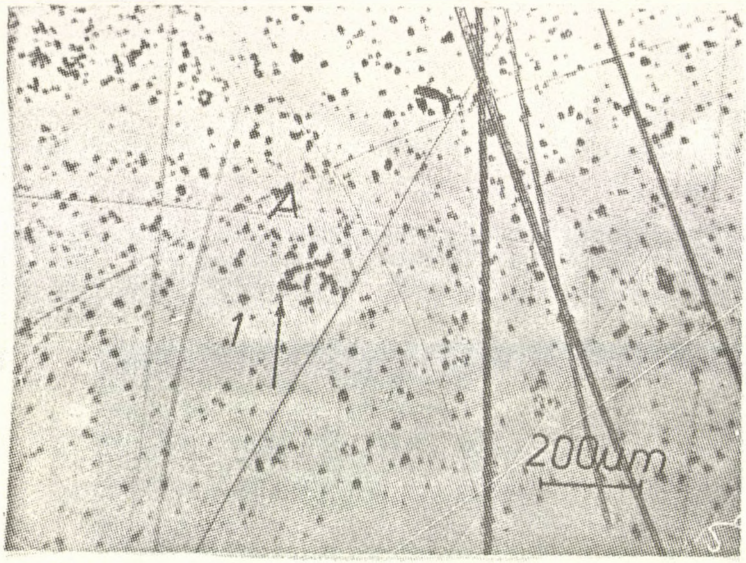


Fig. 1.

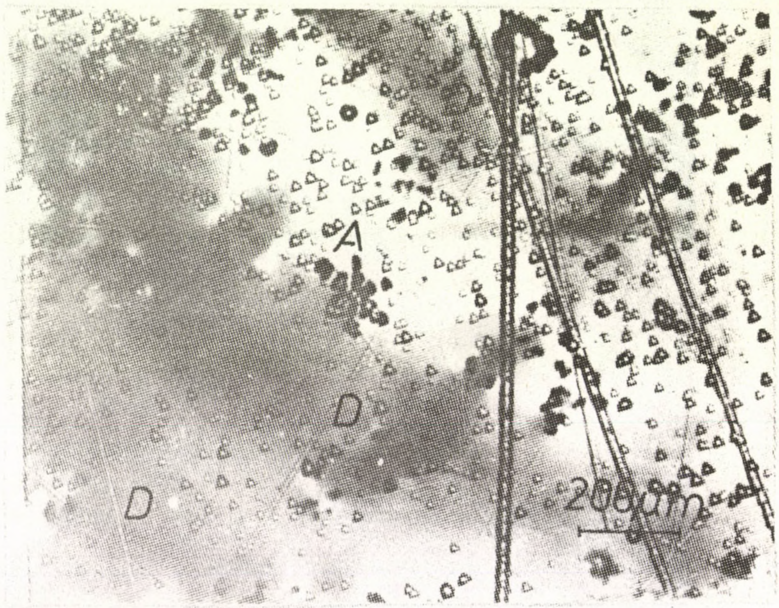
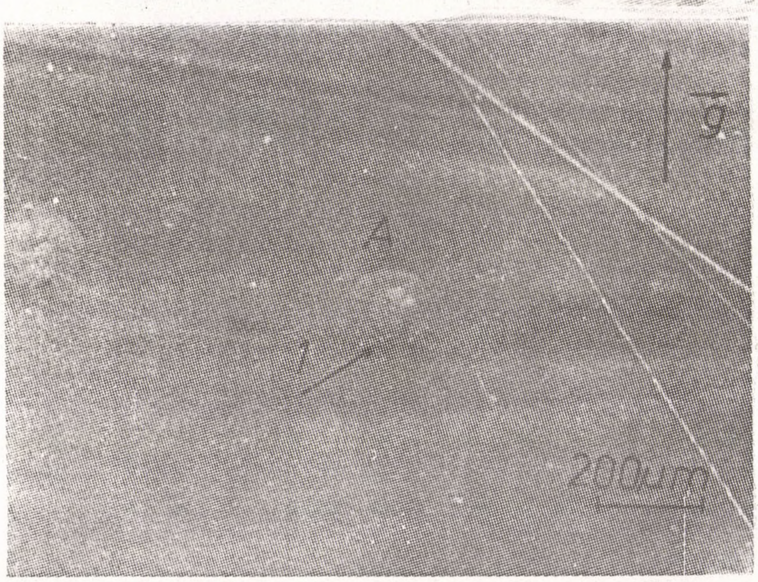


Fig. 2.



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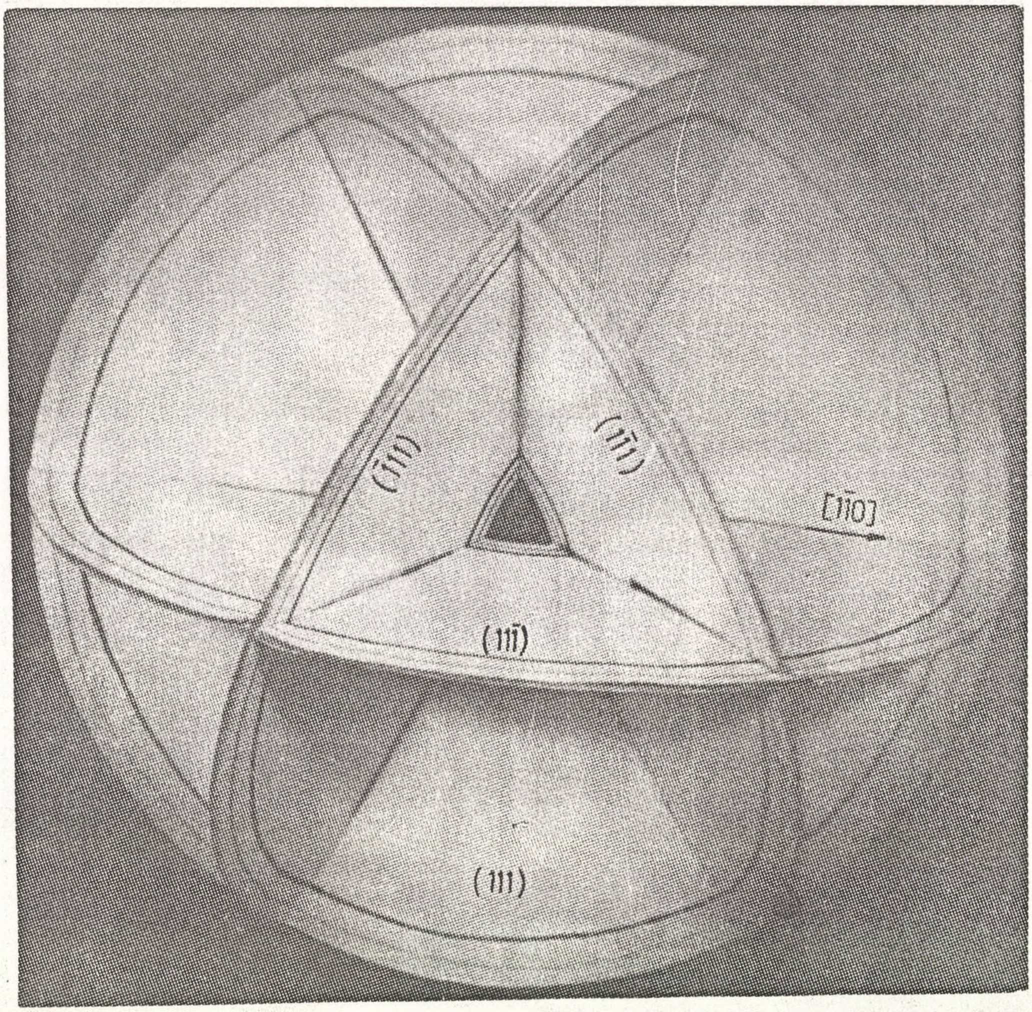

Fig. 4.

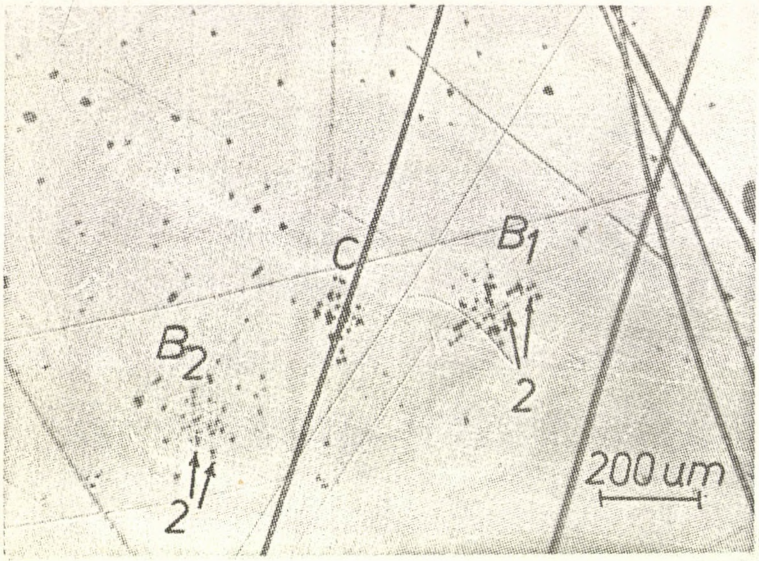

Fig. 5.

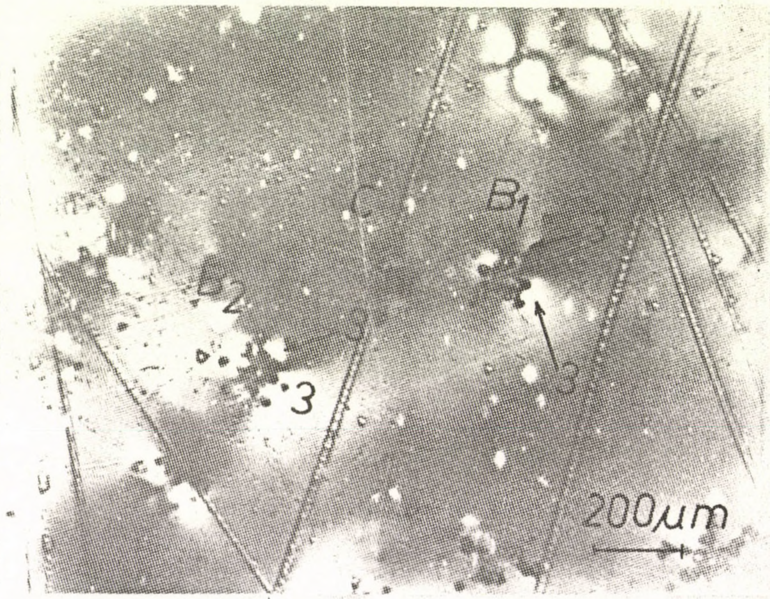

Fig. 6.

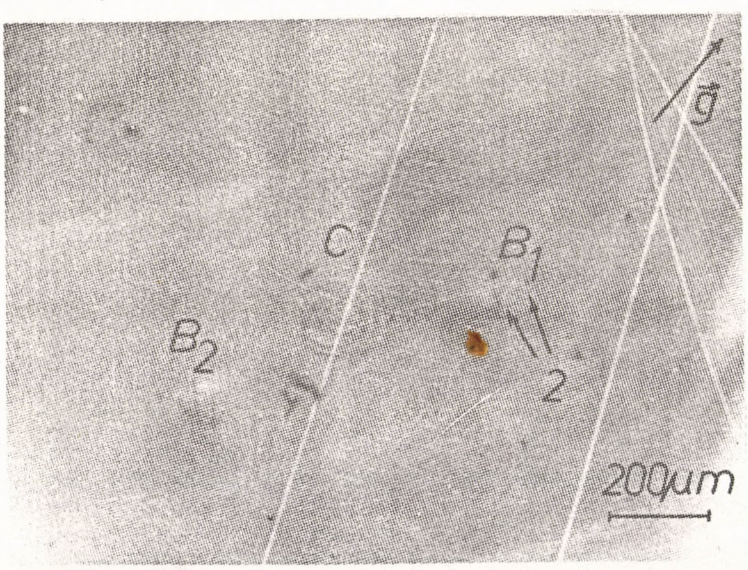

Fig. 7.

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Felelős kiadó: Krén Emil, a KFKI Szilárd-
testkutatási Tudományos Tanácsának
szekcióelnöke
Szakmai lektor: Zimmer György
Nyelvi lektor: H. Shenker
Példányszám: 220 Törzsszám: 76-21
Készült a KFKI sokszorosító üzemében
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