EFFECT OF HEAT SHIELD ON THE SHAPE OF THE SOLID/LIQUID INTERFACE AND TEMPERATURE FIELD IN THE BGO-EULITHINE LTG CZ GROWTH

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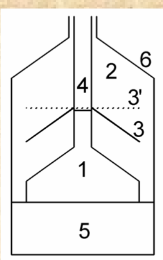
1. Introduction

Most applications of $Bi_4Ge_3O_{12}$ crystal (ranging from high-energy and nuclear physics to medical equipment) require high quality boules, free from voids and coloration. The low-thermal-gradient Czochralski technique (LTG Cz) allows the obtaining of nearly perfect BGO crystals [1]. Nevertheless, the upper part of the boules contain a lot of gas inclusions and quality of the crystals near the cone of shouldering is noticeably worse than in its middle and lower parts. **There is a good reason to believe that this phenomenon is closely related to variations of the shape of the solid/liquid interface (SLI) during the pulling.** At the beginning of the growth the SLI is deeply convex to the melt and its convexity decreases with crystal pulling. **The reason for such behavior of SLI is specular (Fresnel) reflection of heat radiation at the conical part of crystal surface [2].** Thus, it is necessary to search for ways to decrease the negative effect of it. Arrangement of a special shield directly above the crystal shoulder is one of such ways. Previously similar approach was considered in Ref.[3].

The aims of the presented paper is to study the influence of shields on the shape of SLI and crystal quality.

2. Statement of the problem.



1 – crystal,
2 – gas gap,
3 (3`) – shield,
4 – seedholder,
5 – melt
6 – crucible.

Fig.1. Scheme of experimental set-up used in simulations.

Geometrical dimensions:

Crystal radius: $R_{crystal}$ = 2.5 cm
Crucible radius: $R_{crucible}$ = 3.5 cm
Shield radius: R_{shield} = 2.5 cm
Thickness of the shield is 0.3 mm

The shield and crucible are made of platinum (emissivity) ε=0.1
Growth velocity is 2 mm/h.

References

1. Yu.A. Borovlev, N.V.Ivannikova, V.N.Shlegel et al., J. Crystal Growth 229 (2001) 305.
2. V.S. Yuferev, O.N. Budenkova, M.G. Vasiliev, et al., J. Crystal Growth 253 (2003) 383.
3. J. C. Rojo, E. Diéguez, J. J. Derby, J. Crystal Growth 200 (1999) 329.

3. Experimental results

Changes in the shape of solid/liquid interface at the same (approximately) stages of the growth process:

Without a shield

With a shield

Although using of the shield results in rather moderate changes in *convexity* of the crystallization front,…

... the size of facets increases distinctly!

Without a shield

With a shield

As a result, density of gas inclusions in the upper part of the boule also significantly decreases with introducing the shield.

Without a shield

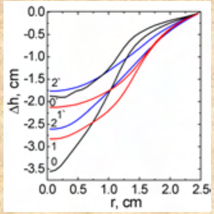
With a shield

2. Results of modeling

The growth process was modeled in the calculation domain shown in Fig.1.

2.1 Variations of solid/liquid interface (conical shield)

The modeling is not (totally) adequate to a real process, since crystals of $Bi_{12}Ge_3O_4$ demonstrate the strong tendency to the faceting. This implies the significant supercooling of some part of the interface. For this reason the convexity of the facetted front (in an actual process) could be noticeably less then that of the round one in simulations.



Simulation results of the solid/liquid interface: 0,1,2 – indicate the length of the cylindrical part of the crystal (in centimeters) Strokes (`) correspond to the case with the shield.

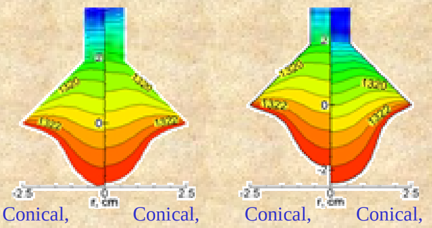
Summary

1. Calculation results correlate well with experimental ones.
2. The shield is the most effective at the initial stages of the growth.
3. Presence of the shield leads to decreasing of variations in the shape of the SLI with increasing the crystal length.
4. Use of the shield forces to decrease the furnace power and temperature of the crucible (see Table 1) to obtain the same growth velocity.

Table 1. Temperature shift obtained in modeling with applying the shield

Length of the cylindrical part of the crystal, cm	0	1	2
$T-T_s$, ^{O}	3	4	0.7

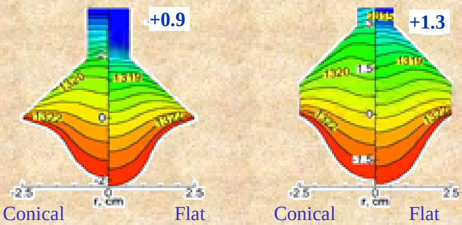
2.2 Effect of radiative properties of the shield.



Conical, diffuse, ε=0.1 | Conical, specular, ε=0.002 | Conical, diffuse, ε=0.1 | Conical, diffuse, ε=1.0

Specular, totally reflective shield is a little more effective than diffuse or black one!

2.2 Effect of a shape of the shield.



Conical shield | Flat shield | Conical shield | Flat shield

Conical shield is a little more effective than a horizontal one!

Summary: radiative properties of the shield and its geometrical form influences on the shape of the SLI insignificantly

Conclusion

The results presented here demonstrate that a shield with the shape of umbrella decreases the deflection of the solid/liquid interface to the melt, increases the size of the facets and diminishes the density of gas inclusions at the initial stage of growth.

Nevertheless, arrangement of this shield cannot cardinally eliminate strong non-uniformity of the radiative heat flux near the SLI because the shield diminishes the radiative heat flux as a whole, rather than directs the reflected radiation toward the center of the SLI.

Distortion of isotherms near the cone shoulder in the presence of a shield is also kept because of the weak dependence of temperature field in the crystal on the environment temperature due to the large transparency of BGO.