

Dynamics of heat removal at largesize alkali halide crystals growth

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Dynamics of heat removal from the growth furnace to the inner surface of the water cooled walls has been experimentally detected for the first time by an example of a "ROST" type setup when growing CsI(Na) single crystals of 320 mm in dia. Evolution of temperature field on different growth stages, as well as role of the precipitated melt condensate in heat transfer has been discussed. Possible origins of structure defects in crystals caused by anomalous intensification of heat transfer between the growing crystal and environment (growth furnace walls) have been founded.

Впервые экспериментально выявлена динамика отвода тепла от растущего кристалла к внутренней поверхности водоохлаждаемой стенки ростовой печи на примере вакуумной установки серии "РОСТ" при выращивании монокристаллов CsI(Na) диаметром 320 мм. Обсуждается эволюция температурного поля на различных стадиях роста кристалла, а также роль осаждающегося конденсата расплава на стенках ростовой печи. Установлены возможные источники и геометрическое положение структурных дефектов в кристаллах, обусловленных активизацией теплообмена между растущим кристаллом и окружающей средой, а, точнее, стенками ростовой печи.

Structure defects formation during the large-size alkali halide single crystals growth leads to the substantial decrease of the single crystalline material applicable for the further machining. Obviously, in many cases this fact is connected with possible presence of uncontrolled temperature field changes inside the furnace [1].

A procedure of non-contact temperature measurements on the growing crystal surface, as well as on crucible elements and growth furnace inner walls using a Raytek Marathon MA2SC infrared thermometer was developed in [2]. Temperature distribution on the crucible and crystal surface was studied in [2, 3]. It was shown that temperature profiles on the side and upper surfaces of the single crystal abruptly change in the moment when crystal starts to leave the crucible limits.

The great majority of radiant heat transfer energy during the crystal formation is directed from the bottom and side heaters, through the melt and crystal, to the water cooled furnace walls [1]. Two mechanisms act here: wall heating due to direct radiation from the heated crucible through the "free" melt surface, and radiant heating from the growing crystal surface.

Thus, temperature of the furnace walls covered with non-uniform condensate layer from within (Fig. 1) is an important origin of information allowing one to describe the heat transfer peculiarities on the different stages of crystal growth process leading to changes in the crystallization front shape. The experiment was carried out at growth of CsI(Na) crystals of 320 mm in dia. The reference point at scanning by the height corresponds to the upper crucible edge level.

One can see (Fig. 2) that all the curves, at the first glance, have the similar character. Let us consider in more detail the seeding stage (curve *1*), radial growth till the preset diameter value (curve *2*), and stage when the crystal upper butt leaves the crucible limits. The curve 1 has the highest temperature level despite of the fact that crystal itself does not exist yet. We suggest

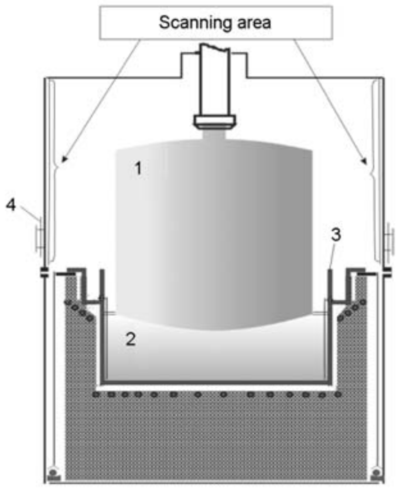

Fig. 1. Scheme of the experiment: *1* — crystal, *2* — melt, *3* — crucible, *4* — removable quartz window.

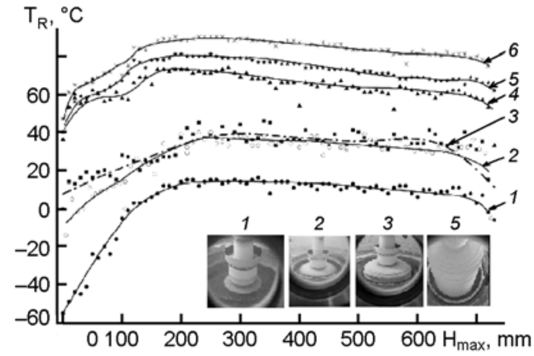

Fig. 2. Plots of relative temperature change on the inner surface of the growth furnace upper case vs. case height at different growth stages: *1* — seeding, *2* — start of the cylindrical part growth, *3* — cylindrical part height 50 mm (the crystal leaves the crucible limits), *4* — 205 mm, *5* — 370 mm, *6* — 540 mm. Below — photos of the corresponding growth stages.

that this effect is the evidence of heat transfer to the water cooled furnace walls from the crucible surface and relatively large "free" melt surface. The small temperature gradient on the 0–200 mm height has the same reasons. Then, furnace walls temperature decreases and temperature gradient increases due to overlap of the melt surface square by the growing crystal (curves *2*, *3*). It was shown in [2] that the upper crystal butt is covered by a thick heat-insulating condensate layer blocking a part of radiant heat flux from the inside of the crystal.

During the crystal body growth the free melt surface square is significantly smaller than one at radial (cone) growth, and side crystal surface is less covered with melt condensate and is capable to transmit more radiant energy. Just the same effect is observed on curves *4–6*. The sharp temperature increase on the curve 4 in compare to the curve *3* is an evidence of heat transfer increase from the side crystal surface in the moment when the crystal leaves the crucible limits; herein, relative temperature increases at 50–100°C.

We suggest that sharp changes in heat removal from the crystal requires the adequate action from the automated growth control system, i.e., active compensation of heat removal using the bottom heater which is responsible for this process. It was shown in [4] that structure defects caused by melt overcooling are located just at this height of the crystal cylindrical part. Moreover, the results obtained are very important material for numerical simulations of global heat transfer inside the furnace at continuous feed growth of alkali halide single crystals.

References

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Динаміка тепловідведення при вирощуванні великогабаритних лужногалоїдних кристалів

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Вперше експериментально виявлено динаміку відводу тепла від кристала, що вирощується, до внутрішньої поверхні водоохолоджуваної стінки ростової печі на прикладі вакуумної установки серії "РОСТ" при вирощуванні монокристалів CsI(Na) діаметром 320 мм. Обговорюється еволюція температурного поля на різних стадіях вирощування, а також роль конденсату розплаву, що осаджується на стінках ростової печі. Встановлено можливі джерела та геометричне розташування структурних дефектів у кристалах, що обумовлені активізацією теплообміну між кристалом, що вирощується, та навколишнім середовищем, а саме стінками ростової печі.