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# Comparison between bottom-seeded Bridgman and accelerated crucible rotation Bridgman method for detector-grade CdZnTe growth

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## 1. Introduction

Wide band gap compound semiconductor cadmium zinc telluride ($Cd_{1-x}Zn_xTe$, or CZT) has been widely used for lots of applications because of its excellent photoelectric properties [1]. When x=0.04, it is used as epitaxial substrates of $Hg_{1-y}Cd_yTe$. When x=0.05~0.2, it can be used for the fabrication of high performance x-ray and γ-ray detectors. However, large-size low defect CZT single crystals are difficult to produce because of its unique thermal physical properties [2, 3].

In this work, we report our new progress on the growth of large diameter CZT crystal with bottom-seed Bridgman method as well as Bridgman Accelerated Crucible Rotation Technique (ACRT-B) method. A comparison between CZT crystals grown with these two methods is developed to evaluate the effects of the introduction of seed and ACRT.

## 2. Experimental

The growth procedure is as follows: First, the raw materials of Cd (7N), Zn (7N) and Te (7N) were loaded into the carbon-coated quartz crucible. The crucible was sealed under vacuum up to $2\times10^{-4}$ Pa and synthesized in a rocking furnace. The polycrystalline materials were taken out and fit to another crucible, which were arranged a seed ingot previously. The crystal growth with ACRT method was carried out in the same crucible in a five-zone furnace after synthesis. The temperature gradient at the growth interface was 10 k/cm, and the withdrawing rate was 1mm/h.

Fig. 1 shows the ACRT sequence used in crystal growth process, suggested by Capper [4].

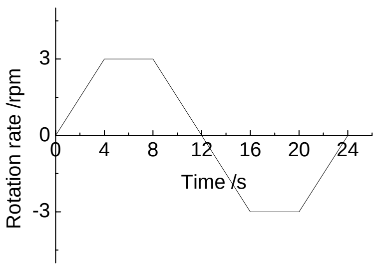


Fig. 1 ACRT rotation sequence

Several ingots with the diameter of 60mm and the length of 160mm were successfully prepared with bottom-seeded Bridgman method, as well as ACRT-B method. Here, we define CZT1 as ingot grown with bottom-seeded method and CZT2 as ingot grown with ACRT-B method.

## 3. Results and Discussions

3.1 Macroscopic features

Fig. 2(a) shows a photo of CZT1, fig. 2(b) shows a section cut from the ingot. Fig. 3 shows a photo of CZT2.

(a)

(b)

Fig. 2 (a) Photo of CZT1 (b) Section cut from the CZT1 ingot

Fig. 3 Photo of CZT2

Single crystal volumes exceeding 200 $cm^3$ were produced by CZT1. Yields up to 50% and 30% were achieved by CZT1 and CZT2, respectively.

3.1 Structural quality

X-ray rocking curves of CZT1 and CZT2 are shown in Fig. 4. FWHM are determined to be 30 and 56 arcs for CZT1 and CZT2, respectively, which indicates a better structural quality of CZT1.

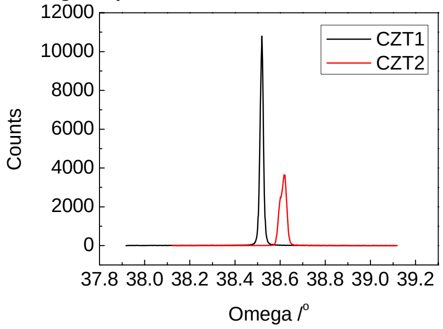


Fig. 4 X-ray rocking curves of CZT1 and CZT2

3.2 Zn distribution

The Zn axial segregations were determined by measuring the Zn concentration in the center of the wafers along the CZT ingot. Fig. 5 shows the distribution of Zn along CZT1 and CZT2. As the withdraw rate of crucible is low enough, and thus the growth process of CZT could be regarded as a steady state unidirectional crystallization process, Zn segregation in CZT can be evaluated by using Pfann equation, given by,

$$C_S / C_0 = k(1-g)^{(k-1)} \quad (1)$$

where $C_0$ is the initial Zn concentration in CZT, g is the solidified fraction of the ingot and Cs is the impurity concentration at the interface on the solid side. $k_{Zn}$ in CZT1 and CZT2 were determined to be 1.28 and 1.16, respectively. The results indicate that the introduction of ACRT has homogenized the melt composition and thus reduced the segregation.

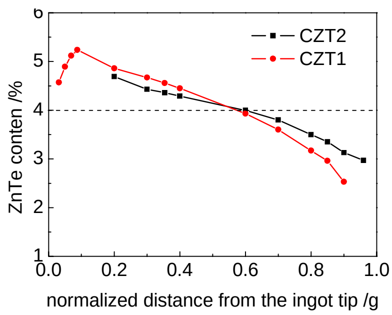


Fig. 5 Zn distribution along the ingots of CZT1 and CZT2

3.3 In distribution

The effective In segregation coefficient in CZT was evaluated by using the pfann equation given by Eq. (1).

In distribution along CZT ingots is shown in Fig. 6. By fitting the concentration according to Eq. (1), the effective In segregation coefficients in CZT $k_{In}$ and the error of the $k_{In}$ values δ were obtained, see also Fig. 6. Different In behaviors in CZT can be concluded. First, the $k_{In}$ values vary from 0.19 in CZT1 to 0.50 in CZT3. Secondly, the error of $k_{In}$ in CZT2 is large, indicating an inappropriate fitting of Eq. (1). To understand the results, it is suggested that a Te excess in the melt enhances the impurity solubility in the solid by associating formation and/or precipitation of Te related inclusions [5], which introduced by ACRT.

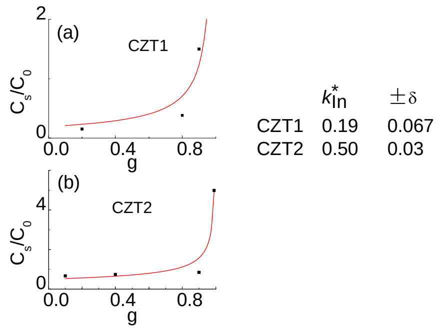


Fig. 6 In distribution along CZT1 and CZT2

## 4. Conclusions

In this work, detector-grade CdZnTe crystals with diameter up to 60 mm were grown by using bottom-seeded Bridgman method as well as Bridgman accelerated crucible rotation technique (ACRT). Both ingots exhibit high yields, where single crystal volumes exceeding 200 $cm^3$ were produced from bottom-seeded Bridgman crystal. For CdZnTe ingot grown by bottom-seeded Bridgman method, the full width at half-maximum (FWHM) of X-ray rocking curve was determined to be 38 arcs, indicating a better crystalline quality than ingot grown by ACRT-B method, which gave the FWHM 56 arcs. The effective segregation coefficients of Zn $k_{Zn}$ for bottom-seed Bridgman crystal, is 1.28, and for ACRT crystal, $k_{Zn}$ is 1.16. However, The effective segregation coefficients of In dopant $k_{In}$ was determined to be 0.19 and 0.5, for bottom-seeded Bridgman crystal and for ACRT crystal, respectively.

According to the above results, methods combined the two techniques are recommended to improve the yield of CdZnTe ingots and produce high quality detector-grade CdZnTe crystals.

## Acknowledgment

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