Development of a carbon coating process for a detector-grade CZT growth

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1. Introduction

Cadmium Zinc Telluride (CZT) can be used in radiation safety in a nuclear power plant and a nuclear waste storage site, as one of its various radiation applications. High quality crystal is a crucial factor to make a CZT radiation detector. Fused synthetic silica (quartz tube) is generally used in the construction of the cruciable or ampoule for a crystal growth or materials purification applications for a number of reasons. Quartz is readily available in a very pure form while possessing the ability to withstand high temperatures and high thermal gradients. The material also maintains a good mechanical strength at elevated temperatures. However, for all of the beneficial properties of quartz, devitrification and other deleterious effects occur in the presence of some materials.

The adhesion not only induces cracks in the ingots and limits the size of the crystals but also creates defects such as dislocations inside the ingots. Several methods have been suggested to minimize this problem. These methods include a degassing of the ampoule at a high temperature in a vacuum [1]. In the case of a Bridgman growth of cadmium telluride (CdTe) [2] or CdZnTe [3], the ingot tends to adhere to the sidewalls of the quartz vessel in which it is grown. Presumably, cadmium oxide (CdO) reacts with the silicon in the sidewall to form cadmium metasilicate ($CdSiO_3$) [1]. However, at elevated temperatures, carbon reacts easily with O_2 and H_2O to form carbon dioxide (CO_2) and carbon monoxide (CO), thus tying up otherwise free O_2 molecules. Without the presence of free oxygen, the reaction between CdO and quartz is much less severe since CdO does not form initially. Therefore, the inclusion of carbon within the ampoule serves two purposes. The first purpose is to gather any O_2 or H_2O. Second, the carbon layer physically prevents CdO from contacting the inner ampoule walls. Similar benefits are reported for the growth of copper indium selenide ($CuInSe_2$) [1].

The carbon coating process and its effects on a crystal growth are mentioned several times in the literature. However, a definitive procedure for obtaining uniform, adherent coatings of carbon is not present. This work describes a reliable, reproducible carbon coating technique and presents data regarding the thickness of coatings at various locations along the ampoule.

2. Experimental procedure

The process described here has four basic steps: ampoule cleaning, ampoule annealing, carbon deposition, and film annealing. The cleaning and annealing procedures were found to greatly impact the carbon film quality and are therefore included. Carbon deposition is the process of cracking hydrocarbon molecules to produce an amorphous carbon layer. The deposited carbon film must then be heated to sufficiently high temperatures to densify the layer into a glass-like form of a lower porosity. Each of these four steps for obtaining a uniform, well-adhered carbon film on the inner walls of a quartz ampoule is explained in detail in the following sections.

Each ampoule was, in turn, cleaned in a cleanroom using an etchant to minimize impurities within the ampoule. Upon completion of the cleaning step, the inlet tube was sealed using Parafilm. Next, each ampoule was inserted into a rapid thermal annealing apparatus (RTA) for a processing, immediately after being cleaned. To ensure a uniform heating, the ampoule was centered.

Once mounted, the ampoule was ready to be annealed. To begin, ultra-high-purity (UHP) argon was used to purge the ampoule of any impurities or water. During the purging, the RTA was ramped to 700℃ at a rate of 20℃/min. Once the RTA reached 700℃, the temperature was held constant for 4h to anneal the quartz. Upon a completion of the annealing step, quartz tube was filled with a carbon solution. And then the furnace temperature was raised to the carbon deposition temperature to avoid introducing stress back into the ampoule as it cooled. Once the annealing was completed, the furnace was ramped down to room temperature.

3. Results

The carbon-coated quartz tube appeared as shown in Fig. 1. when removed from the furnace. It was observed that a sample was partially burnt out of the carbon film. It may be thought that the carbon solution was not sufficiently fabricated as a dry carbon-coated quartz tube in the furnace.

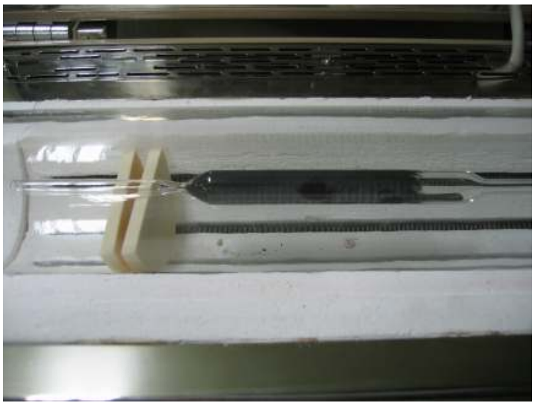

Fig. 1. Carbon-coated quartz tube in furnace

4. Conclusion

Carbon coating of fused silica ampoule was implemented in four basic steps. It was observed that a sample was partially burnt out of the carbon film. A carbon coating solution into the ampoule makes a sufficiently dry carbon film.

Acknowledgements

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Reference

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