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Development of Ceramic Arc-tube by the PIM Process

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Abstract

A ball-shape alumina arc-tube for low-wattage lamp was developed by the PIM process. An ultra high purity translucent-grade alumina powder was used. In injection molding process, a hot-runner type mold was developed. The translucent-grade alumina powder was extremely sensitive to contamination so that the injection molding condition and atmosphere control in the furnace should be taken care of with extreme caution. Contamination sources were pinpointed with EPMA. The arc-tube was molded in half and two halves were bonded in the middle by a new bonding technique at room temperature developed in this study.

Keywords : pim, ceramic arc-tube, translucent alumina, room temperature bonding

1. Introduction

Ceramic arc-tubes have been developed by several lighting companies in order to replace quartz glass tubes of metal halide lamp. With a higher mechanical property, durability and optical performance of ceramic arc-tubes surpass quartz glass tubes. However, mass production technology of ceramic arc-tubes has been an obstacle to a fast market growth. The powder injection molding (PIM) process is one of the available technologies for mass production of ceramic arc-tubes.

Currently two types of ceramic arc-tubes are produced. Cylindrical shaped arc-tubes are mainly used for Sodium lamp. It has a thick wall and a simple shape. It is produced by extrusion process. The other type of ceramic arc-tubes is ball or oval shape. This type of ceramic arc-tubes is largely used for metal halide lamps. It has a thinner wall than the cylindrical shaped tubes. It is produced by injection molding process due to its shape complexity [1]. Only a few companies have the production technology of the ceramic arc-tubes all over the world.

In this study, a ball-shape ceramic arc-tube for low-wattage lamp was developed by the PIM process. A translucent-grade alumina powder with ultra high purity was applied to manufacture the arc-tube. In order to reduce scrap material and increase molding efficiency, a hot-runner type mold was developed. For the sintering of the arc-tube, a high-temperature furnace was developed with wet hydrogen supplying equipment. Contamination sources were pinpointed by analyzing the contaminated samples with EPMA. The ball-shape arc-tube for low-wattage lamp has a small internal volume with narrow and long electrode holes at both ends. It was almost impossible to mold the tube at once. Therefore, it was molded in half and two halves were bonded in the middle. A new bonding technique at room temperature was developed for precise and rapid manufacturing [2].

2. Experiment and Results

The first requirement of the translucent alumina was ultra high purity. Only a few alumina powder manufacturers in the world can supply the proper grade powder. Depending upon the powder the sintering condition should be adjusted. A translucent grade alumina powder, UA5055 from Showadenko Co., Japan was tested for the study. The specific particle size of the powder was 3 micrometer. The powder has an alpha-phase and 99.99% of purity.

The ball-shape arc-tube has 15 mm of diameter with 1.0 mm of wall thickness. At both ends, electrode tubes with 2.8 mm of outer diameter are attached. Total length of the arc-tube is 54.0 mm. Fig. 1 shows the shape of the arc-tube. Due to the geometry of the arc-tube, it was extremely difficult to mold as one piece so that the half of the arc-tube was injection molded and bonded at the center. An injection mold with hot runner technology was developed to mold the two halves of the arc-tube in a single mold. No weldline caused in the molding was permitted in the arc-tube due to its structural strength. The mold should be designed not to produce any weldline in the product. The hot runner mold was essential not to produce any scraps due to the high price of the powder

and extremely high sensitivity of the powder to contamination.

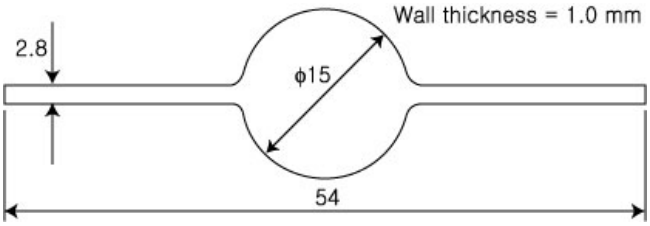

Fig. 1. Dimensions of the arc-tube

The two molded halves were bonded at the center before debinding process in a solvent. A proprietary bonding technique at room temperature was developed in the study. The bonded green body of the arc-tube was debinded in a solvent and in a furnace in order to burn out the binder completely. The brown body was completely sintered at 1800℃ in a high temperature furnace. Fig. 2 shows the sintered arc-tube.

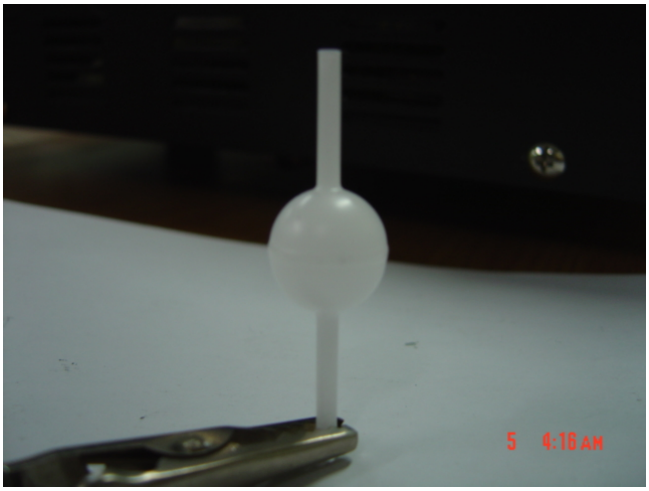

Fig. 2. The final product of the arc-tube after sintering

The powder was extremely sensitive to contamination. Contamination sources existed in the molding, debinding and sintering. In the molding, highly abrasive hard particles of the alumina could scratch the surface of the tooling to contain metallic contaminants in the product. In the debinding process, carbon residue in the brown body might leave carbon contaminants in the product. In the sintering process, any contaminants from the tube of the wet hydrogen supplying device or the wall of the furnace might degrade the translucence of the arc-tube. Fig. 3 shows a photo of the contaminated arc-tube. Contamination sources were investigated by EPMA. The debinding and sintering condition should be delicately chosen for the minimum contamination level and geometrical stability of the product. The optical transmittance of the final product was tested and showed satisfactory result as shown in Fig. 4.

Fig. 3. A photo of a contaminated arc-tube

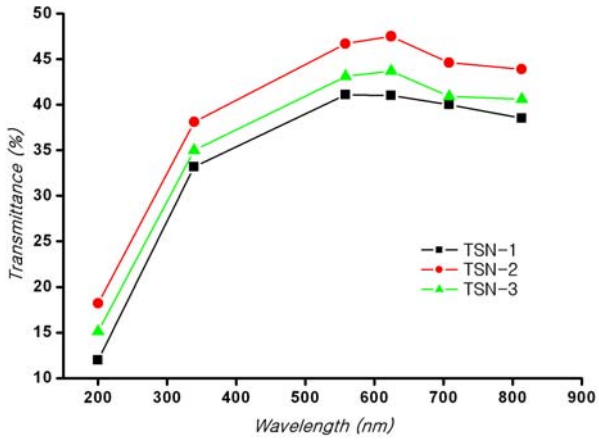

Fig. 4. Transmittance test result of the arc-tube

3. Summary

Ceramic arc-tube for a low wattage metal halide lamp was successfully developed by the PIM process. A translucent grade alumina powder with ultra high purity was used to produce the arc-tube. In order to save powder and reduce contamination in the molding, an injection mold with hot runner technology was developed. The molded two halves were bonded at the center by a proprietary bonding technique. The final product showed a satisfactory optical transmittance.

4. References

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