Digital Light Processing of Alumina Ceramics for Vacuum Electron Devices

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Abstract: *Alumina were fabricated by digital light processing (DLP) with alumina powders. Alumina surface morphology, microstructure and properties were studied by scanning electron microscopy and performance test system of electron gun assembly, respectively. The results indicate that DLP alumina has the characteristics of high density and conductivity. The heat transfer in electron gun assembly includes heat conduction and heat radiation. The heat transfer mode of DLP alumina was heat conduction and heat radiation, indicating high heating efficiency, compared to that of the alumina(heat conduction) by the existing technology.*

Keywords: alumina ceramics, digital light processing, vacuum electron devices

Introduction

Vacuum electron devices (VED) have been in development for many years due to its important applications in radar, communication, television broadcast, electronic countermeasure, particle accelerator, plasma heating device, International thermonuclear experimental reactor and other fields[1-2]. Electron gun assembly consists of alumina ceramic, cathode, support sleeve and heater assembly, which is the heart of VEDs and plays a decisive role in the mechanical and electrical property. However, it is difficult to control the alumina forming quality in the process of developing VEDs owing to different physical and chemical characteristics among alumina ceramics and tungsten metal material, used as heater. Therefore, the alumina ceramics manufactured by the existing high temperature technology show characteristics of poor quality, As a result, this is not be able to conform to requirements of long lifetime and high reliability for VEDs[3-4].

According to the philosophy of 3D Printing, the choice of a 3D computer graphic, 3D model, and material system are sufficient to build a part. Consequently, it is possible to generate parts with arbitrary geometries without the need of adapting the typical manufacture process itself[5]. DLP technique is based on the photopolymerization and stereolithography of a liquid resin. Due to the high green densities and the use of fine ceramic particles, stereolithography permits the production of almost dense ceramic parts after a sintering posttreatment[6-7].

Developments in DLP have made it possible to construct all-ceramic parts with arbitrarily complex geometries contributing to the improved performance for electron gun assembly and VEDs, such as long lifetime, high power, high frequencies and reliability. This study considers the effects of manufacturing a coiled periodic structure in alumina ceramic on the electron gun assembly.

To our knowledge, few studies have focused on the processing technology of the ceramics for VEDS. In this work, DLP alumina ceramics were comprehensively studied. The characteristic and regular of ceramic forming are researched from the process and method. The DLP ceramics reliability of electron gun assembly are also verified by the application in VED.

Materials and Methods

Digital light processing (DLP) was performed on a vat polymerization ceramic 3D printer-Ceramatrix. The peak wavelength of the ultraviolet light source is 405 nm in the prototype system. Figure 1 shows the schematic diagrams of alumina ceramic via digital light processing. To make a slow stepwise process for organic ingredients removal, intermediate temperature steps were set for warming to achieve a temperature of 600°C and 1650°C, respectively. The raw material in this study is pure alumina powders with particle size of 500 nm, as shown in Figure 2.

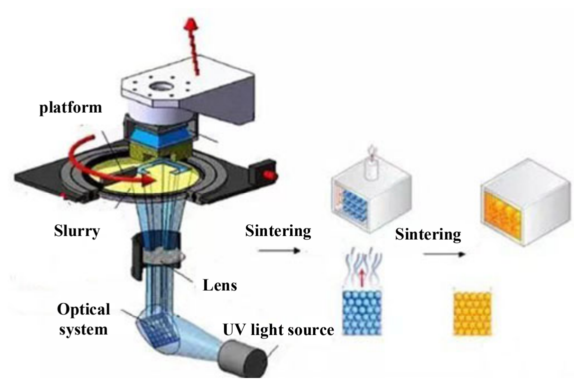

Figure.1 Schematic diagrams of alumina ceramic via digital light processing

Results and Discussion

Figure 3 presents the microstructure of alumina ceramic. DLP alumina ceramic displays relatively homogeneous and continuous grain distribution with many boundaries.

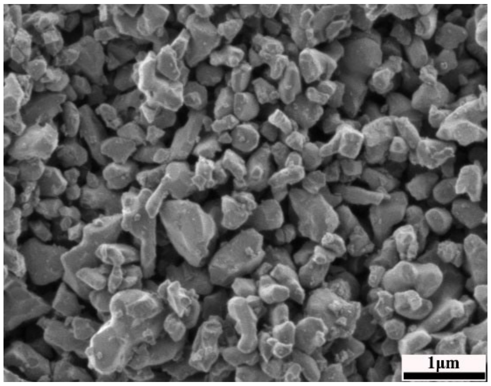

Figure. 2 Morphology of the alumina powder

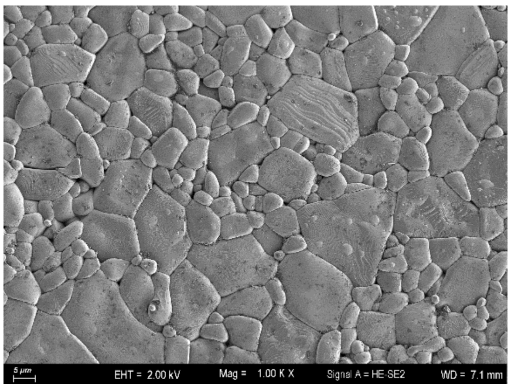

Figure. 3 Microstructure of DLP ceramic

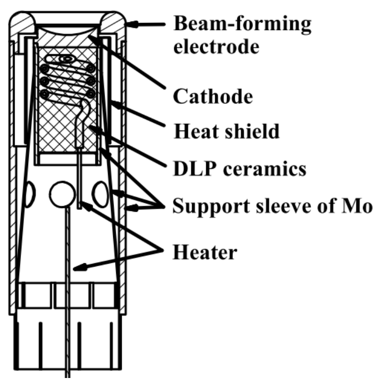

Figure. 4 Structure chart of electron gun assembly

Figure. 4 presents the structure chart of the electron gun assembly, which is made up of electron gun assemblies, beam-forming electrode and support sleeve of Mo. Performance test of the electron gun assembly shows high heat transfer efficiency, in accordance with the requirements of the design index. The heating efficiencies from the heater assembly to the cathode is equivalent to that of the assembly with the alumina (heat conduction) by the existing technology.

Conclusions

Digital light processing technology is applied to the conduction of 3D alumina ceramic structures. The electron gun assembly with DLP ceramics shows high heat transfer efficiency, in accordance with the functional requirement of VEDs.

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