Zinc Oxide Modeling to Create Semiconductor Dendrites by Using Micro Stereolithography

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Abstract

Zinc oxide ceramics exhibit various semiconductor properties through optimized elements or materials doping. The elements doping of aluminum or gallium can control the electric conductivity, and composites doping of indium and rare earth such as yttrium can increase the thermoelectric conversion efficiency. In this investigation, dendritic lattice structures of the zinc oxide semiconductors with periodically ordered arrangements or self similar patterns were fabricated successfully to increase the surfaces area and porosity values by using micro patterning stereolithography of a computer aided design and manufacturing. These semiconductor dendrites with penetrable paths and extensive interfaces will be used for fluid and heat flow receptors and applied to the novel sensor devices and energy generators. The dendritic lattice models sliced into a series of cross sectional patterns with uniform thickness by using a stereolithographic file format convertor. These numerical data were transferred into the micro processing equipment. High viscosity slurry material was prepared through the mixing of photo sensitive acrylic resin and the zinc oxide particle at 30 % in volume fraction. The slurry was supplied on a flat substrate with 8 μm in layer thickness by using a mechanical knife edge. The cross sectional image was exposed on the slurry surface by using digital micro mirror devices. Through the layer by layer processes, the solid component was obtained with micrometer order part accuracies. The dense ceramic sample was purchase after de-waxing and sintering process.

Key wards: Zinc oxide, Dendrite, Micro stereolithography

Introduction

Zinc oxide ceramics is excellent electrical property which has been used to fabricate varistors [1,2], sensors [3], thermoelectric transducers [4], etc. The elements doping can control zinc oxide electrical properties. For example, Cr_2O_3, CoO, MnO, Bi_2O_3 and Pr_6O_{11} additives exhibit a nonlinearity

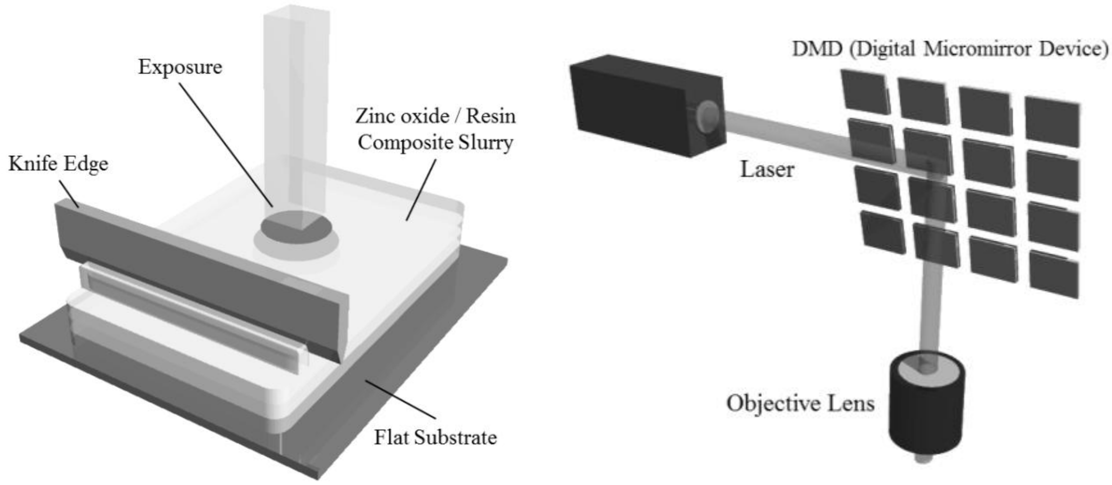

Fig.1 A schematically illustrated micro stereolithography system.

of electrical conductivity [5] was reported. And, Al_2O_3 doping improves electrical conductivity [6-8]. Al_2O_3 dissolves in ZnO, the carrier concentration can be controlled for controlled valency. Furthermore, photonic crystal of artificially aligned structure leads to expression of unique character [9,10]. In our group, the micrometer order photonic crystals with the diamond structure composed of ceramics lattices were fabricated by using micro stereolithography of a computer aided design and manufacturing (CAD/CAM) syatems [11-12]. In this investigation, dendritic lattice structures of the zinc oxide semiconductors with periodically ordered arrangements or self similar patterns were fabricated successfully to increase the surfaces area and porosity values by using micro patterning stereolithography of a computer aided design and manufacturing. These semiconductor dendrites with penetrable paths and extensive interfaces will be used for fluid and heat flow receptors and applied to the novel sensor devices and energy generators.

Experiment and procedure

The dendric zinc oxide model was fabricated by using computer aided design and manufacturing process. The model was converted into stereolithography (STL) files of a rapid prototyping format and sliced into a series of two dimensional cross sectional data of 8μm layer thickness. These data were transferred into

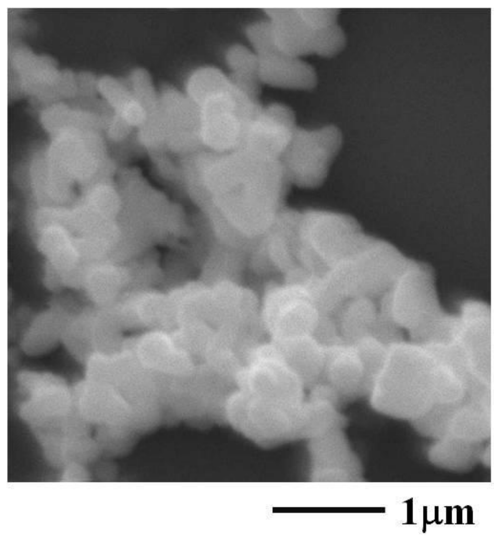

Fig.2 SEM image of zinc oxide powder. (Grain size: 0.2-0.6μm, Wako Pure Chemical Industries, Ltd., Japan, Standard grade)

micro stereolithographic equipment (D-Mec Co. Ltd., Japan, ST-C 1000). Figure.1 shows a schematic illustration of the micro stereolithography system. The photosensitive acrylic resin including zinc oxide sub-micron particle (Grain size: 0.2-0.6μm, Wako Pure Chemical Industries, Ltd., Japan, Standard grade) (Figure.2) at 30 volume % content were supplied on a flat substrate from a dispenser nozzle by the air pressure. This paste was uniform spread by using automatically moving knife edge the thickness of each layer was set at 8μm. Two dimensional patterns were exposed on the liquid resin surface by using a visible laser of 405nm in wavelength. The high resolution image has been achieved by using a digital micro mirror device (DMD) and objective lens. The DMD is optical element assembled by mirrors of 14 μm in edge length. Each mirror can be tilted autonomously by piezoelectric actuators. Through the layer by layer stacking process is controlled by computer, the resin component with the zinc oxide powder dispersion was obtained. This precursor was dewaxed at 600 ^{o}C for 2hs and sintered at 1200 ^{o}C for 2hs in the air atmosphere. The sintered temperature in the same way as reference 13 and 14. The ceramics sample was observed by using digital optical microscope and scanning electron microscope. The grain size of zinc oxide sintering body measured by using intercepts method.

Results and Discussion

Figure. 3 show the fabricated dendric zinc oxide model (a) and sintered sample (b). The sample shape is diamond lattice (100) structure. We were successfully fabricated zinc oxide ceramics by using micro stereolithography. After sintered zinc oxide sample are exceedingly-small, it is impossible to measure density by using Archimedes method. Because of it is hard to operate and the weight of the

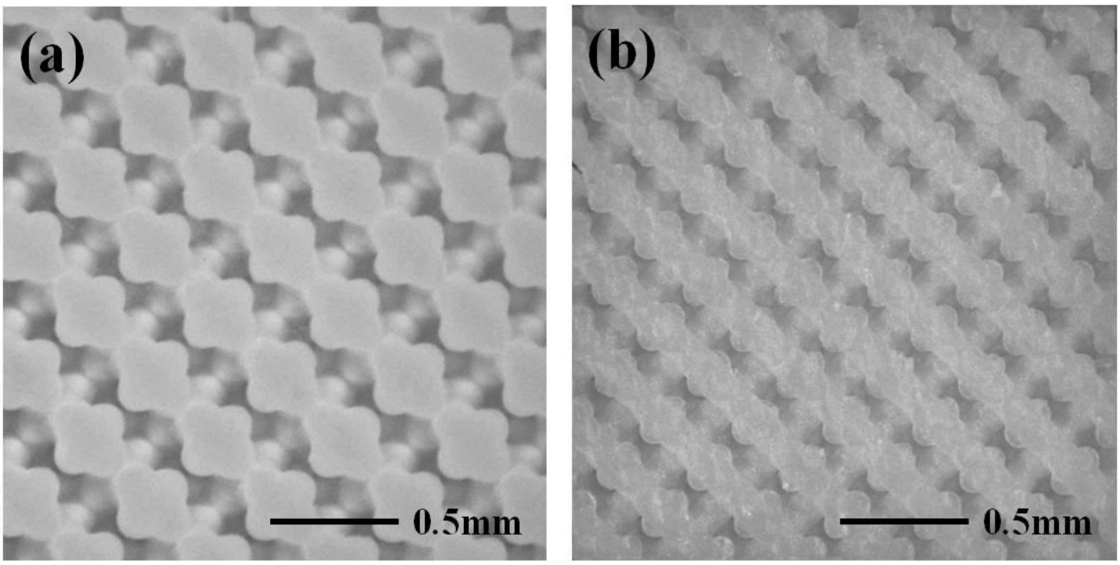

Fig.3 A dendrite structure of diamond lattice structure (110) with zinc oxide particles dispersions formed by the micro stereolithography (a), the sintering body after dewaxed at 600 ^{o}C and sintered at 1200 ^{o}C (b).

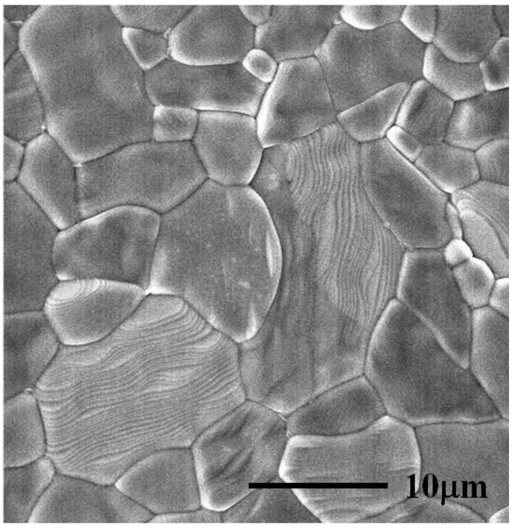

Fig.4 SEM image of microstructure zinc oxide sintering body.

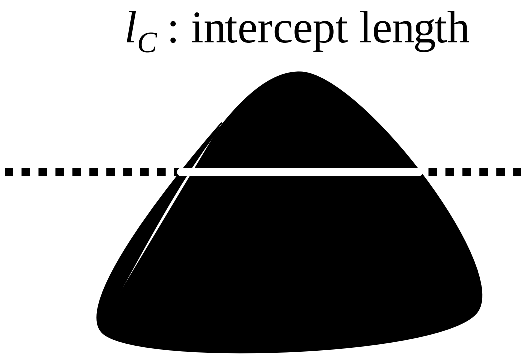

Fig.5 The intercept length of the intercept method.

sample close to within the measurement error. The liner shrinkage on the horizontal axis was 29.3 % and that on the vertical axis was 30.6 %. The SEM image in figure.4 shows the microstructure of the zinc oxide sintering body. This sample do not occur large pore and defect. Zinc oxide is dense for microstructural observation. The de-waxed temperature at 600 ^oC is slightly high for zinc oxide. Because of, the zinc oxide sintering shrinkage starts at a temperature of approximately 600 ^oC [14]. However, that did not effect for density. Finally, we measured the grain size of the sintering body by the intercept method [15]. The average grain size, *D*, was calculated according to the following equation;

$$D = k \cdot l_C \tag{1}$$

K is 1.5 when the grain shape is assumed to be spherical and l_C is the average intercept length (Figure. 5). The grain size of the zinc oxide sintering body was about 4.4 μm. In other researcher, the grain size of zinc oxide reaches 5 to 10 μm and more. These researches of green body relative density start 65 to 68 %. In this study, the surly of photosensitive resin and 30 vol % zinc oxide powder contents were use. The grain size is smaller but these experimental conditions were thought to be best for fabricate dendric zinc oxide.

Conclusion

We were fabricated dendric zinc oxide model perfect successfully by using micro stereolithography. The dendric sample is uniform shrink for vertical and horizontal axis. From in this investigation lead to the suggestion that the different structure dendric zinc oxide can be manufactured.

Acknowledgments

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