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Micro Fabrication Process of Powder Compact with Semi-solid Mold

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Abstract

New powder compaction process, in which a Bingham semi-solid/fluid mold is utilized, is developed to fabricate micro parts. In the present process, a powder material is filled as slurry in a solid wax mold, dried and compressed.The wax is heated during compaction and becomes semi-solid state, which can acts as a pressurized medium for isostatic compaction. Since the compacted micro parts are very fragile, the mold's temperature is controlled to higher than its melting point during unloading, to avoid breakage of the compacts. To demonstrate effectiveness of this process, some micro compacts of alumina are shown as examples.

Keywords : powder compaction, isostatic pressing, micro fabrication, semi-solid material

1. Introduction

There are many processes for fabricating green compacts. Among them, isostatic pressing process is one of good solution to make powder compacts with homogeneous density distribution. Cold Isostatic Pressing (CIP) is the most popular isostatic process, and Rubber Isostatic Pressing (RIP) is newly developed and employed for compacting magnetic materials [1, 2]. These isostatic processes use rubber molds, however, which causes breakage of powder compacts because of spring back during unloading process. Author proposed and developed a new process to overcome the problem [3, 4]. It is an isostatic pressing process in which a semi-solid mold material is employed. There are some advantages in the new process over the conventional powder compaction processes. However, it is difficult to make very small mold cavity with semi-solid material. In the present paper, temperature control is employed with solid wax mold, which will be changed into a semi-solid state by heating before loading process. During unloading, the temperature is set to higher than the melting point of the wax to avoid the breakage by the spring back of the mold.

2. New Process with Semi-solid Mold Material

A key material of the present method is a semi-solid material. Two essential features for the present process are found as following; 1) The semi-solid material reveals a yield stress which is much smaller than the pressure commonly used for a powder compaction process, 2) The mold flows like a liquid when the load exceeds the yield point. In other words, the mold behaves like a solid below the yield point and like liquid above the yield point. These characteristics are useful for the isostatic pressing process. The mold can form a cavity, in which the powder is filled, as a solid material before pressing, while it transmits pressure isostaticaly to the powder as a liquid material during pressing. In the present work, solid oil-wax material is employed as a mold material. It becomes semi-solid state by application of heat during process.

The present process consists of three steps; mold forming, powder filling and pressing process. At first, a master pattern is made with a soft-MEMS process. Spin-coated photo resist (SU-8) is exposed through masked pattern. The obtained SU-8 pattern is transcribed to silicone polymer (PDMS). This PDMS pattern is used as a master pattern to make a wax mold; melted wax is casted into this PDMS pattern. Next process is filling. Since it is difficult to fill dry powder into this narrow groove-like cavity, slurry is prepared. The flow of filling process is shown in Fig. 1. At first step, the wax mold is dipped into ethanol to remain ethanol only in the cavity, which helps leading the slurry into the cavity. Next, the slurry is poured onto the mold and then extra slurry on the cavity is removed. Finally, the slurry is dried out and remains powder material in the cavity. The behavior of the slurry will change with its components. Especially, contact angle with wax is one of the most important factors. In the present paper, alumina slurry is prepared, which is composed of Al_2O_3 powder, water, dispersion (polysodium acrylate; PAS) and binder (polyethylene glycol; PEG). The contact angle changes with proportions of slurry. It is found that the slurry with the contact angle from 60 to 90 degree is preferred by preliminary experiment. If the angle was lower than 60 degree, slurry would flood out the cavity, and if higher than 90 degree, the slurry could not be filled into the cavity.

After fill of the powder, the wax mold is set in a metallic container, and heated by band heater and compressed. Schematic apparatus of the compaction process is shown in Fig. 2.

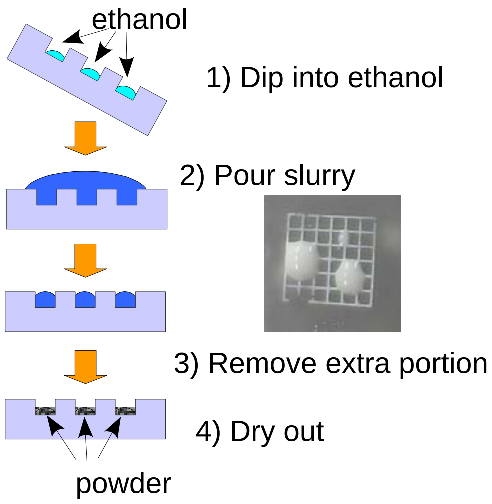

Fig. 1. Filling process with slurry.

The mold becomes semi-solid state before applying p ressure by heating. The semi-solid material works as a fluid medium which would realize the isostatic state.Fol lowing this heating, the mold is pressurized to 100MPa, and heated to 80 degrees C during unloading which is higher than the melting point of the mold, where the wax becomes liquid.

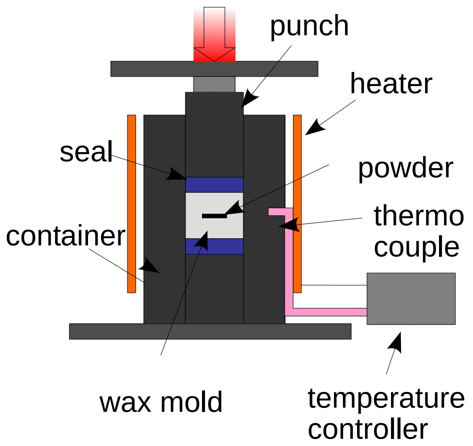

Fig. 2. Schematic view of experimental apparatus

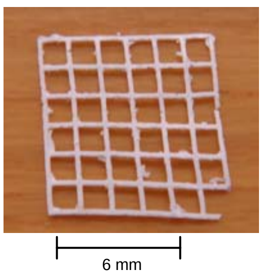

Fig. 3. Sintered sample (alumina:water:PAS:PEG =6:4:3:1).

3. Results

If the proportion of powder in the slurry is not sufficient, sintered body was distorted. While the binder is not enough, the sample was broken. Fig. 3 shows the sample successfully sintered after compaction with the present method. It is needed to optimize proportions of the slurry for both compact and sintering process.

4. Summary

New process is employed to fabricate micro parts of ceramics, in which slurry is utilized for easy filling. Small complicated sintered samples are obtained with this process. It is noted that the components of slurry is changed and it is noted that there is proper proportion for compaction and sintering.

5. Acknowledgement

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