

Fabrication of Microcomponents Using Fe Based Nanopowder

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ABSTRACT

The metallic microcomponents were fabricated by pressureless sintering of nano-sized pure Fe nanopowders. The nanopowders were synthesized by plasma arc discharge process using raw materials sources in hydrogen and Ar atmosphere. The compacting and sintering behaviors of nanosized Fe powders have been evaluated and compared with those of conventional micron powders. Their compactibility was poor, but those could be enhanced by milling, due to the agglomeration to a micron size. The Fe nanopowders represented that the shrinkage finished at low sintering temperature of 600°C. They also showed 6 times higher densification rate and more isotropic shrinkage behavior than those of micron sized Fe powders. The microstructure evolution and dimensional change during sintering were evaluated in detail.

Keywords: microcomponent, Fe nanopowder, dimensional change

1 INTRODUCTION

The nanoscale powders have been known that they may be consolidated more readily or more completely than conventional powder, because the high surface area of nanopowder provides a significant driving force for the densification [1]. However, the high driving force also leads the tremendous grain growth during the densification process, so there are some limitations to obtain the fine crystallite size with full densification in the sintered bodies. The pressureless sintering of unagglomerated nanopowder has a great potential for powder injection molding (PIM) process which is suitable for fabrication the near net shaped micro components with complex shapes.

In this study, we have adopted the Plasma Arc Discharge (PAD) process for the fabrication of Fe nanopowders. So the feasibility of pressureless sintering for PADed nanopowder has been investigated with the powder characteristics in this study. Also, the shrinkage behavior of Fe nanopowder was systematically analyzed and compared with that of micron sized Fe powders.

2 EXPERIMENT

Fe nanopowders were fabricated by plasma arc discharge process as described in our previous work [1]. The Fe metal vapors evaporated by plasma arc heat in the reaction chamber collided each other and condensed to form Fe clusters or nanopowders. The prepared Fe nanopowders were passivated in the collection chamber filled with Ar + 1 vol. % O₂ mixture gas for 24 hours, in order to prevent the explosive oxidation of the Fe metal nanopowders. The Fe nanopowders were uniaxially pressed with 175-2,100 MPa in a cylindrical compaction die, to form disk shape specimens. The shrinkage behaviors of compacted bodies were measured by using laser opto-dilatometry system developed by Lee and his coworkers [2]. The compacted bodies were heated up to 1000°C in hydrogen atmosphere with various heating rates of 5, 10, 20 and 30°C/min. The dimensional changes of diameter and height of each sample were measured and plotted against elevating temperatures. For comparison, micron sized Fe powders (5-10µm, 99.9%) were compacted with 350 MPa (47%T.D. of green density) and sintered at 1200°C for 2 hours in H₂ atmosphere.

3 RESULTS AND DISCUSSION

Fig. 1 shows the change of green densities of Fe nanopowder and micron powder with compaction pressures. The micron size Fe powder represented the much higher compactability than nanopowders. Their green density increased with compaction pressure and reached to 85%T.D. at 2,100 MPa compaction pressure. In the case of nanopowder, however, the green densities were lower than the micron size powder samples and the highest green density was less than 60%T.D. at 2,100 MPa. The low green density for nanopowder is quite well known that as the nanopowders have the low dislocation density and the dislocation sources, their plastic deformation may be low not to enhance the green density. In addition, as the PADed Fe nanopowder has oxide layer on the powder, the hard oxide layer inhibits the compactability even at high compaction pressure.

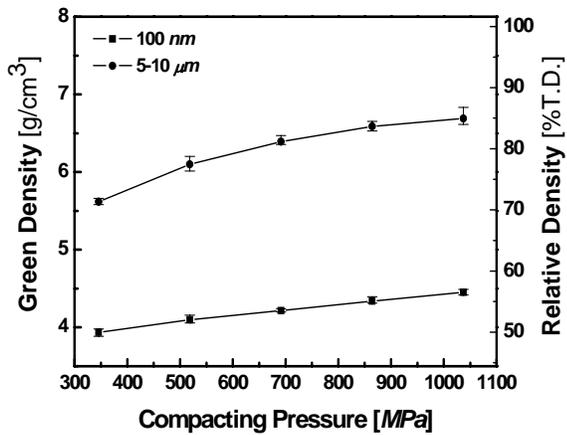


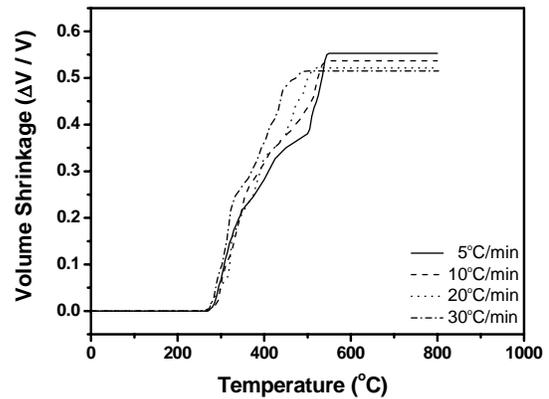
Fig. 1. Variations of green densities of PADed nanopowder and micron powder as a function of compaction pressures.

The densification behaviors of PADed Fe nanopowders with the different heating rates are depicted in Fig. 2. In the sample of low pressure compacted specimens of Fig. 2 (a), the sintering behavior started at 280°C and finished at 560°C for 5°C/min. heating rate condition. And the shrinkage divided into two steps, namely, the rapid densification at low temperature region and the densification retardation at higher temperature range. The transition temperature of densification rate is 380°C and the green density is around 70%T.D. at this point. This tendency could be observed in the high pressure compacted specimens in Fig. 2 (b). But in high (b) 2,100 MPa, the densification finished at a little higher temperature of 610°C for 5°C/min. heating rate condition.

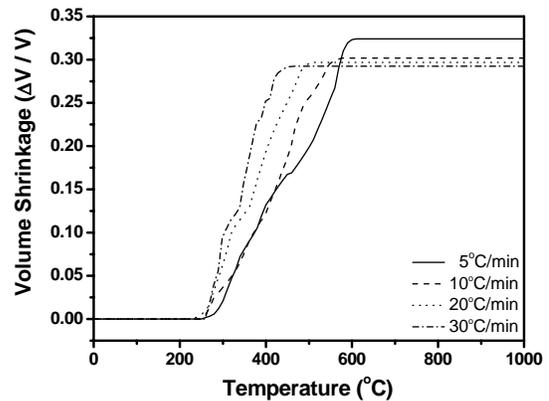
With increasing of the heating rates, the finishing temperature of densification and the volume shrinkage decreased at the same time. The sintering density for low pressure compacted samples are in the range from 83 %T.D. to 91 %T.D. after heating up. The highest sintering density is 90.5 %T.D. at lowest heating rate of 5°C/min condition. This kind of densification behavior could be shown in high pressure compacted sample of 2,100MPa. But in high pressure condition, the highest sintering density reached to at least 84 %T.D. maximum. With concerning to the relatively high green density (62%T.D.) for high pressure condition, it is hardly accepted that their sintering densities are much lower than those of low pressure condition having around 43%T.D. green density

So the sintering density of high pressure condition is much lower than low pressure condition. The PADed nanopowder has higher sintering density than micron size powder (95 %T.D.) at even low temperature as a half of sintering temperature for micron powder. In micron size powder sample, the grains remarkably grew up to 50μm due to relatively high sintering temperature. But the grain growth for nanopowder was not significant with considering of 100 nm of initial powder size and nearly full densification of 98.5 %T.D. sintering density. And the Vickers hardness of

PADed nanopowder was around 250 Hv, which is 3 times higher than that of micron size powder.



(A) 175 MPa



(b) 2,100 MPa.

Fig. 2. Volume shrinkages of PADed nanopowders with different heating rates, compacted with (a) 175 MPa and (b) 2,100 MPa.

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