Gas Nitriding Mechanism in Titanium Powder Injection Molded Products

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Abstract

Gas surface treatment is considered to be effective for titanium because of its high reactivity. In this study, we investigated the gas nitriding mechanism in titanium sintered parts produced by metal powder injection molding (MIM) process. The microstructure and nitrogen content of sintered MIM parts were greatly affected by nitriding conditions. Nitriding process strongly depended on the specimen size, for example, the size of micro metal injection molding (μ-MIM) product is so small and the specific surface is so large that the mechanical and functional properties can be modified by nitriding.

Keywords : metal injection molding, titanium, gas nitriding, micro vickers hardness, EPMA

1. Introduction

Metal injection molding (MIM) is an effective manufacturing technology, which provide the fabrication of tiny and complicated metal parts for mass production. The term of “μ-MIM” can be defined as very small-sized and fine structured metal injection molded products, whose dimensions is less than one millimeter. The μ-MIM approach has been focused recently on the application of microsystem technology [1]. The μ-MIM products are so small that the specific surface is quite larger than conventionally sized MIM products.

Titanium and its alloys are one of the materials used in the MIM process, but titanium has low hardness compared to stainless steels and copper. However, titanium easily reacts with nitrogen during the sintering in a nitrogen gas atmosphere and TiN is formed on the surface of sintered compacts. TiN is stable in all environments and shows high hardness. However, it is characterized as a very hard-machinable material due to the high hardness.

In general, the surface treatment of metal products such as nitriding, carburizing and coating is an effective fabrication technique to obtain high hardness and wear resistance on the surface. Such surface treatments can be applied industrially to almost all kinds of metals.

The aim of this study is to investigate the gas nitriding mechanism in titanium sintered parts produced by the MIM process. In the MIM process, gas nitriding can surface-treated subsequently debinding and sintering process. Moreover, a μ-MIM specimen is so small, and the specific surface area is so large, that the mechanical and functional properties may be easily changed by surface treatment. Therefore, the effects of nitriding on the properties of μ-MIM products were also investigated.

2. Experimental procedure

Materials used in this study were a gas atomized Ti powder (20μm in mean diameter) and a wax based binder. Two types of the specimens were used; the larger one was a block specimen of rectangle shape with 9mm on a side and 40mm in length, and the smaller one is a micro dumbbell specimen with pallarel portion of 0.2mm in width and 0.15mm in thickness as shown in Fig.1. The specimens were sintered in the vacuum furnace, and followed by nitriding. Sintering was carried out at 1200 °C for 1.5 hrs. Then, nitriding was processed for 0, 1, 3 and 5 hrs, and the effects of nitriding time on the nitrogen content and microstructure of the specimens were investigated.

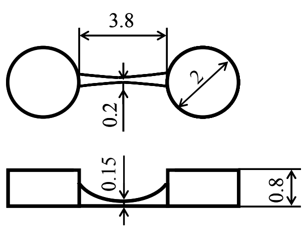

Fig. 1. Geometry of micro dumbbell specimen (mm).

3. Results and discussion

Fig. 2 shows the microstructure for the cross-section of block specimens. TiN layer was observed in the surface of specimen and also α-phase and acicular-α phase could be seen inside of the specimen. As can be seen in Fig.2, there are voids at the boundary between α-phase and acicular-α phase.

Fig. 3 shows the relationship between the nitrogen content and the nitriding time of both block and micro dumbbell specimens. Nitrogen content increased with increasing nitriding time in both specimens. Nitrogen content of micro dumbbell specimen is five times higher than that of block specimen, because the specific surface area of the micro dumbbell specimen is larger than that of block specimen.

Fig. 4 shows micro Vickers hardness (μHv) from the surface to the interior of the specimen. The TiN layer is so thin and brittle that the micro Vickers hardness test was conducted in the α-phase area. Block specimens without nitriding treatment show a constant value in μHv. For the nitrided specimens, on the other hand, quite higher μHv values were obtained in the vicinity of surface. However, the μHv value decreased with increasing distance from the surface to around 0.4mm in depth. For the micro dumbbell specimens, a dissimilar tendency was shown compared with the hardness profile of block specimen. The thickness of specimen is around 0.2mm and the center of the specimen is 0.1mm from the surface. Micro dumbbell specimens show higher μHv in the center than the block specimen. Therefore, the microstructure and nitrogen content of μ-MIM compacts are believed to be strongly and easily affected by the nitriding treatment, which may lead to the higher performance of μ-MIM compacts.

Fig. 5 shows the nitrogen distribution from the surface to the interior of the specimen obtained through EPMA analysis. For both specimens a similar tendency was observed: the nitrogen content on the surface is higher than that in the interior. However, the nitrogen content of micro dumbbell specimens is much higher than that of the block specimens, resulting in higher micro Vickers hardness even in the interior of the specimen.

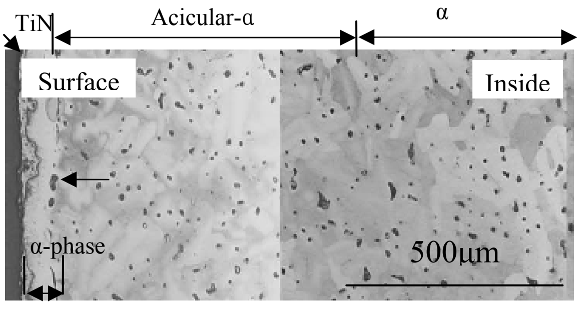

Fig. 2 Cross-section of block specimen nitrided for 3hrs.

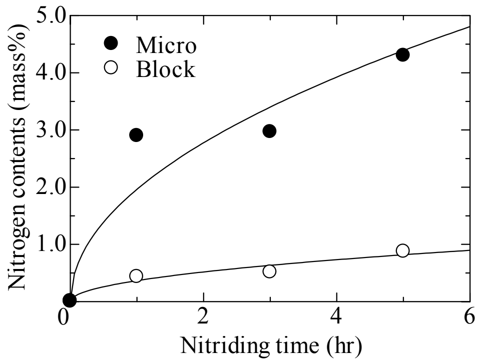

Fig. 3. Nitrogen content versus nitriding time.

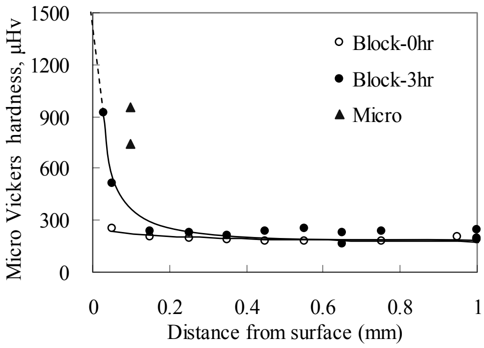

Fig. 4. Micro Vickers hardness profiles.

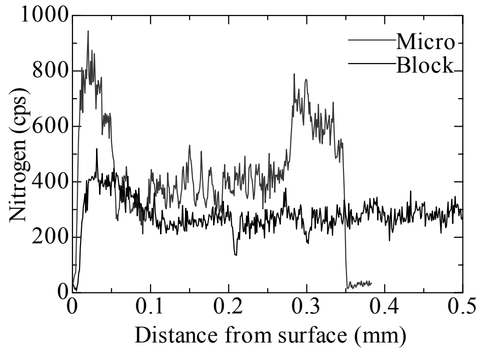

Fig. 5. Line analysis of Nitrogen by EPMA.

4. Summary

In this study, the application of MIM process to Ti powder was investigated and the nitriding treatment was conducted after the sintering in the same process. Nitrogen content increased with increasing nitriding time. TiN and α-phase could be observed within the nitrided specimens. Due to the easy nitriding on μ-MIM specimens, micro Vickers hardness of micro dumbbell specimens is higher than that of conventional MIM block specimen, and nitrogen contents of micro dumbbell specimen is also higher than that of block specimen.

5. References

1. S.Rath, L.Merz, V.Piotter, R.Ruprecht and J.Hausselt, Proceedings of PM^{2}TEC2003, 8-45-51, 2003.