Nitrogen Solid Solution Strengthening in AM Titanium Materials

Katsuyoshi Kondoh, Ammarueda Issariyapat and Junko Umeda
Joining and Welding Research Institute
Osaka University
E-mail: kondoh@jwri.osaka-u.ac.jp

In the previous studies, rare-metals free titanium (Ti) sintered materials with high strength and ductility were successfully developed by solid solution strengthening behavior using nitrogen and oxygen elements [1~3]. The pre-mixed Ti+TiN and Ti+TiO_2 powders were employed as the starting raw materials to fabricate PM Ti-N and Ti-O materials, respectively. The additional particles of TiN and TiO_2 were completely dissolved during solid-state sintering, and then nitrogen and oxygen atoms existing in α -Ti as interstitial solution elements resulted in the significant improvement of tensile strength of PM Ti materials. When the solid solution strengthening by nitrogen atoms is applied to the additive manufactured (AMed) Ti materials, instead of the above pre-mixed Ti+TiN powder, the spherical Ti powder containing nitrogen elements (0.1~1.2 wt%), which was prepared by heat treatment at 800C (1073 K) in nitrogen gas atmosphere, was consolidated by selective lase melting (SLM) process. The surface of this Ti powder was coated by Ti_2N thin layer (thickness; ~ 1 μm), and nitrogen atoms were also soluted in Ti matrix. In the matrix of AMed Ti-N materials, the nitrogen elements also existed as solid solution atoms and no titanium nitride (Ti_2N and TiN) was observed because rapid solidification behavior in SLM was effective for the complete solution of nitrogen into α -Ti matrix. With increase in the nitrogen content of Ti materials, the tensile strength drastically increased, but they showed poor elongation. The increment of tensile strength was theoretically estimated by using Labusch model, and the calculation results corresponded well to the experimental data after removing the α -Ti grain refinement effect. It was concluded that nitrogen solution strengthening mechanism was also useful to improve the mechanical properties of AMed Ti-N materials as well as the conventional PM Ti-N ones.

[1] J. Shen et al., Materials Science and Engineering A, 716 (2018) 1-10.
[2] K. Kondoh et al., Int. J Powder Metallurgy, 50 3 (2014) 35-40.
[3] B. Sun et al., Materials Science and Engineering A, 563 (2013) 95-100.

Biography

Dr. Katsuyoshi Kondoh is a Vice Executive Director in charge of Global Engagement of Osaka University, a Director of Overseas Office in the Center of Global Initiative, and a Professor of Joining and Welding Research Institute. He graduated from the Graduate School of Engineering, Osaka University in 1988, and got PhD on Welding Engineering from Osaka U in 1998. He worked in Sumitomo Electric Industries Co. for 12 years, and worked in the University of Tokyo as an Associate Professor for 6 years before the present position. His main research areas are Powder Metallurgy (PM), Nanocomposites Metal Materials and Severe Plastic Deformation. He has published

more than 300 papers in journals, and holds more than 40 patents regarding PM non-ferrous materials (Ti, Mg, Al, Cu etc.) and their processing. In addition, he had 46 keynotes and plenary talks at the international and domestic conferences. In 2015, Prizes for Science and Technology, The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology (MEXT) in Japan were given to his excellent fruits of research regarding PM high strengthened titanium alloys with no use of rare metals.