Sintering of Titania Nanoceramics: Densification and Grain Growth

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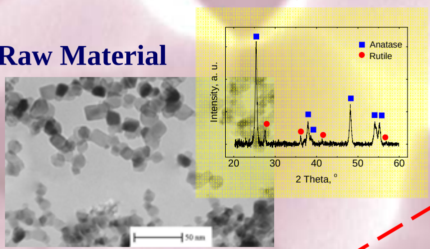
Introduction

To produce bulk nanoceramics from nanopowders, the accelerated grain growth at the final stage of sintering has to be abated. In doing so, one can added a second phase to pin grain boundaries while Chen and Wang [1] developed a novel technique using triple-point junctions to suppress grain growth during densification. This method modifies sintering regimes by high temperature (T_1) firing followed by rapid cooling down to a lower temperature (T_2) and prolonged soaking of the samples at T_2. A smaller grain size at the end of the first step, thus, consequences a higher density of unstable pores that pins-off the grain boundaries from further advancement [2]. Several researchers have successfully applied the two-step sintering procedure to exhaust grain growth of the nanoceramic specimens. A few others have used transformation assisted sintering [3] with the same purpose. No one has, however, designed any system of significant grain-growth suppression based on simultaneous two-step sintering and phase-transformation compaction [4]. In the present study, different regimes are envisaged to reveal the role of concomitant phase transformation/two-step sintering procedure on grain growth and microstructural evolution of the titania nanoceramics benefited from anatase to rutile phase transformation.

Experimental Procedure

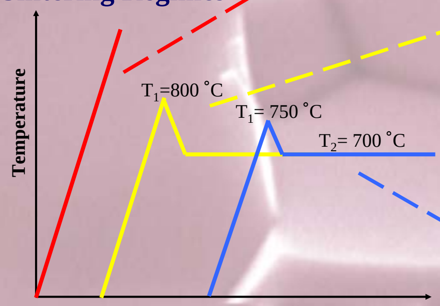
Raw Material



77% Anatase
23% Rutile

Average Particle Size ~ 19 nm

Sintering Regimes

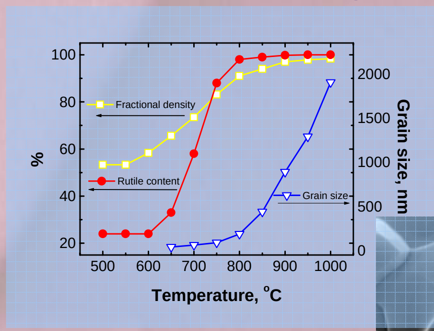


Conclusion

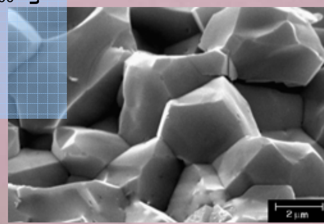
A remarkable suppression of grain growth was achieved by taking the benefit of two-step sintering. In doing so, the grain size was reduced from 2 µm down to ~ 250 nm. While simultaneous phase transformation and two-step sintering led to formation of a nanostructure with a grain size of 100 nm.

Results

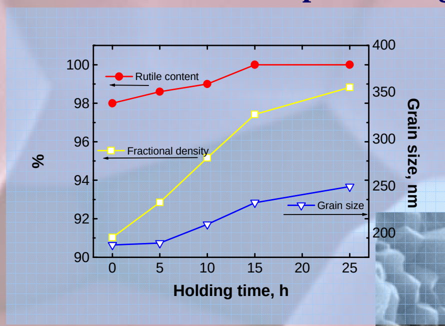
Normal Sintering



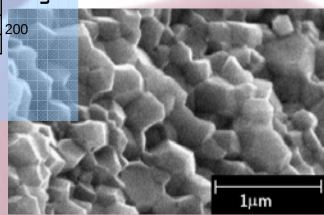
Structural evolution of normally sintered TiO_2 nanopowder.



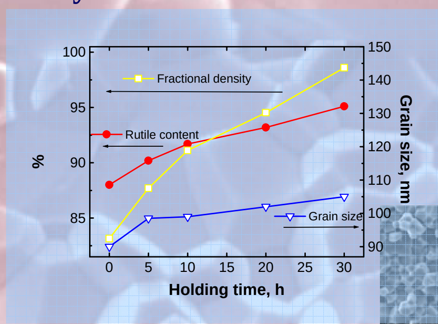
Conventional Two-Step Sintering



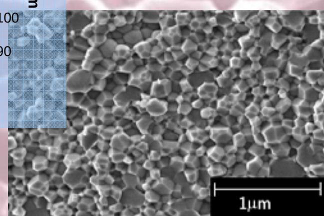
Fractional density, rutile content and grain size of sintered nanocrystalline TiO_2 powder versus holding time under conventional two-step sintering.

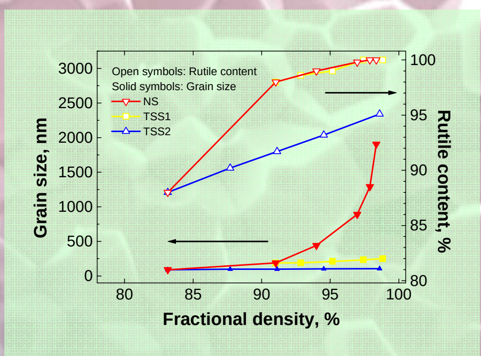


Two-Step Sintering Assisted by a Phase Transformation



Effect of phase transfprmation on fractional density and grain size of sintered nanocrystalline TiO_2 powder during densification in second step.





Effect of phase transformation on the “Sintering Path” of TiO_2 nanopowder sintered under normal sintering, conventional two-step sintering and transformation assisted two-step sintering.

[1] I. -W. Chen, X. -H. Wang, Nature 404 (2000) 168.

[2] M. Mazaheri, A.M. Zahedi, S.K. Sadrnezhaad, J. Am. Ceram. Soc. 91 (2008) 56.

[3] K. -N. P. Kumar, K. Keizer, A. J. Burggraaf, T. Okubo, H. Nagamoto, S. Morooka, Nature 358 (1992) 48.

[4] M. Mazaheri, Z. Razavi Hesabi, S. K. Sadrnezhaad, Scripta Materialia, 2008, in press.