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Flash sintering of ZnO, TiO2 and other oxides: The origin of onset flash and effects of atmosphere, doping and particle size

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FLASH SINTERING OF ZnO, TiO_2 AND OTHER OXIDES: THE ORIGIN OF ONSET FLASH AND EFFECTS OF ATMOSPHERE, DOPING AND PARTICLE SIZE

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Key Words: flash sintering; thermal runaway; sintering atmosphere; abnormal grain growth; electric field effects.

Flash sintering of ZnO, TiO_2 and a few other oxide systems has been investigated. A quantitative model has been developed to forecast the thermal runaway conditions (Fig. 1) [1]. The predicted thermal runaway temperatures from the measured conductivities are in excellent agreements with the observed onset flash temperatures for at least 15 cases with different base materials, doping and surface treatments, particle sizes, and sintering atmospheres, attesting that the "flash" starts as a thermal runaway.

Furthermore, a range of new phenomena of electric field/current effects on sintering and microstructural evolution have been observed and explained, which include: **1)** abnormal grain growth at the anode size in ZnO in air (but not in Ar + 5% H_2), **2)** flash of single-crystal ZnO (at a higher temperature than powder specimen) and 8YSZ (at a lower temperature than powder specimen), **3)** effects of grain/particle size and initial density on onset flash sintering temperature and final microstructures, **4)** a strong dependence of flash temperature on the sintering atmosphere, **5)** various doping and surface treatment effects on the flash sintering of ZnO and TiO_2; **6)** electric field induced migration of $Al_{Zn}^{\bullet}$ in Al_2O_3-doped ZnO (AZO), **7)** growth of aligned ZnO single-crystalline rods at high currents, and **8)** development of bimodal microstructures.

Specifically, using ZnO as a model system, a strong dependence of the onset flash sintering temperature on the atmosphere has been discovered. In a set of optimized conditions, ZnO specimens have been sintered to >97% relative densities in ~30 s at furnace temperatures of <120 °C in Ar + 5 mol. % H_2, with uniform microstructures and fine grain sizes of ~ 1 μm (Fig. 2) [2]. The enhanced conductivities of ZnO powder specimens in reduced atmospheres are responsible for the substantial decreases of the onset flash sintering temperatures.

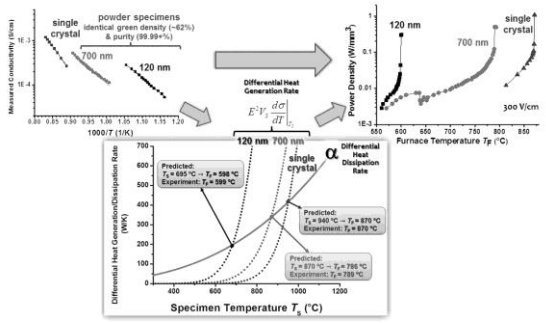

Figure 1 – A thermal runaway model using measured conductivity vs. temperature can predict the onset flash temperatures for 3 ZnO specimens (and at least 12 other cases) [1].

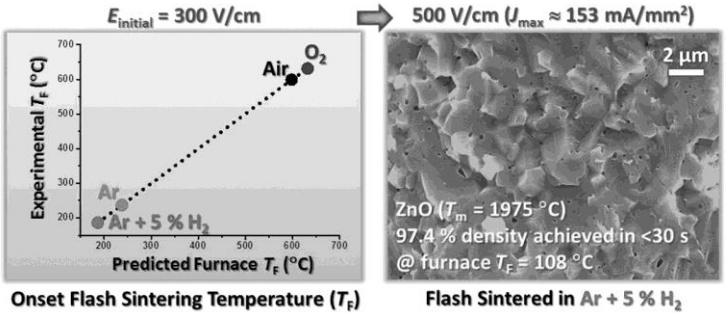

Figure 2 – A strong dependence of the onset flash sintering temperature of ZnO on the atmosphere has been discovered. ZnO specimens have been sintered to >97% densities at furnace temperatures of <120 °C in Ar + 5 mol. % H_2 [2].

References:

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[2] Y. Zhang, J. Luo, Promoting the flash sintering of ZnO in reduced atmospheres to achieve nearly full densities at furnace temperatures of < 120 °C, *Scripta Materialia* 106 (2015) 26-29.

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