

MEASUREMENTS OF INTERNAL TEMPERATURE PROFILES IN MICROWAVE-SINTERED CERAMICS USING LOCALIZED SPINEL-FORMATION REACTIONS

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Abstract

A small volume fraction of MgO crystallites is dispersed throughout an Al₂O₃ compact prior to sintering. The thickness of the MgAl₂O₄ spinel layers formed at the interface of the MgO crystallites and the surrounding Al₂O₃ is shown to be a reliable indicator of internal temperature.. Illustrative results reveal inverted temperature profiles expected of microwave-heated ceramics, although the elevated internal temperatures are insufficient to completely explain observations of enhanced sintering rates during microwave heating. The characteristics of a microwave field-induced “ponderomotive” driving force for ionic transport are entirely consistent with both the equivalent spinel reaction rates and the enhanced sintering rates for microwave versus conventionally heated specimens.

In a previous investigation, statistically-designed experiments comparing microwave (14 GHz) and conventional furnace sintering of alumina indicated faster sintering rates for the microwave-heated specimens when both cases were maintained at equal surface temperatures, as measured by a surface-contacting, shielded thermocouple [1]. However, it was considered possible that the enhanced sintering rates for the microwave-heated specimens might be the result of a hotter interior than inferred from the surface-contacting probe. A careful, quantitative analysis established that to explain the results of Ref. 1 as an artifact of the thermocouple underreporting the internal temperatures would require an internal specimen temperature $\geq \sim 150$ C hotter than the measured surface temperature [2].

A series of follow-up experiments were therefore conducted wherein a small volume fraction (< 5%) of MgO crystallites (~ 50 - 100 μm typical grain size) was mixed into the fine-grained alumina powder (~ 0.3 - 0.4 μm typical grain size) prior to pressing and subsequent sintering. To ascertain the local temperature within the powder compact during microwave or conventional heating it was then a matter of dicing, sectioning, and using optical microscopy to measure the thickness of the MgAl₂O₄ spinel reaction layers surrounding the MgO crystallites sampled from different locations within the specimen's interior. Calibration of spinel layer growth rate to reaction temperature was accomplished with a series of controlled, conventional-furnace experiments. Because of the initially large thermochemical driving force for solid state compound formation and chemical interdiffusion, it was expected that the growth rates of these spinel layers would be the same for both conventionally- and microwave-heated specimens, and therefore a reliable indicator of internal processing temperature in both environments. Figure 1 illustrates a typical optical micrograph showing spinel reaction layers around isolated grains of MgO, while Fig. 2 displays the final results in terms of internal temperature versus radius of the cylindrically-shaped specimens.