ABSTRACT

Title of Dissertation: UNIQUE HIGH TEMPERATURE MICROWAVE SINTERING OF ALUMINUM NITRIDE BASED CERAMICS WITH HIGH THERMAL CONDUCTIVITY

Gengfu Xu, Doctor of Philosophy, 2002

Dissertation directed by: Associate Professor Isabel K. Lloyd

High temperature microwave sintering is one of the most challenging areas in microwave processing of ceramics. In this dissertation, for the first time, stable, controlled "ultra" high temperature (up to 2100 °C) microwave sintering was achieved by development of a unique insulation system based on BN/ZrO_2 fiber composite powder synthesized by a unique processing route. It uses a system approach to mitigate the tendency of all insulation materials to interfere with specimen coupling. This insulation system allows stable, controlled ultra high microwave sintering and could be modified to microwave process materials with different thermal, dielectric properties with improved properties. In addition, unlike other high temperature microwave insulation schemes that must be replaced after each run, the insulation system is robust enough for repeated use.

Using the insulation design, high density and very high thermal conductivity (~ 225 W/m•K) AlN ceramics were fabricated much more efficiently (≤ 6 hours

versus 10's to 100's of hours at high temperature) by microwave sintering than by comparable conventional sintering. A detailed data study of densification, grain growth and thermal conductivity in microwave sintered AlN indicated that there were two time regimes in the development of high thermal conductivity AlN and that oxygen removal was more important to the development of high thermal conductivity than removal of the liquid phase sintering phase. While there have been many previous studies examining processing of high thermal conductivity AlN, this was the first study of microwave processing of high thermal conductivity AlN.

AlN- TiB_2 composites, which had previously only been successfully densified with pressure-assisted techniques such as HIPing or hot pressing, were successfully microwave sintered in this dissertation. The effect of TiB_2 on the densification behavior and thermal, mechanical, and dielectric properties of microwave sintered AlN based composites was investigated. Microwave sintered AlN-TiB_2 shows a combination of thermal, mechanical and dielectric properties that are far better than those reported in the literature. A thermal conductivity as high as 149 W/m·k was achieved. In addition, the dielectric losses of the AlN- TiB_2 composites could be tailored to allow it to serve as a replacement for BeO-SiC in power electronics.

Finally, microwave sintering was found to be very promising for the densification of AlN and AlN based composites. It consistently produced dense, high thermal conductivity materials with controlled microstructures.