Pressure-Assisted Microwave Sintering for Production of Transparent Polycrystalline Spinel: Experimental Study on Non-Thermal Ponderomotive Effect and Uniaxial Pressure

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Microwave sintering is known to provide rapid volumetric heating that reduces processing time compared with conventional furnace sintering methods. With the application of uniaxial pressure, sintering rates can be further enhanced. This novel hybrid technology of microwave sintering and external pressure called Pressure-Assisted Microwave Sintering (PAMS) has been investigated using an 83 GHz Gyrotron. Magnesium Aluminate Spinel samples were sintered at 1550°C following a temperature-optimized sintering procedure with external pressures up to 10 MPa. Spinel samples were sintered to higher optical quality with 99.6% of theoretical density and typical grain size ranging from 3 – 35 μm. Density analyses revealed that 5 MPa of uniaxial pressure was sufficient for virtually complete removal of open pores and reduction of closed porosity to ~0.5%, suggesting that agglomerates were the primary cause for coarsening. Scanning Electron Microscope (SEM) images were also obtained to measure grain size and porosity distributions in the spinel matrix along the longitudinal axis of the microwave beam. These distributions indicate that a non-thermal effect of microwaves (i.e. Ponderomotive Effect) was responsible for removing most of the remaining pores after thermal and pressure treatment. In addition, using a modified model equation relating temperature, grain size, and processing time, it was found that the combined benefits from external pressure and the Ponderomotive Effect improved the sintering rate of spinel by ~300 times that of pressureless furnace sintering.