ULTRA HIGH TEMPERATURE MICROWAVE SINTERING – FURNACE AND PROCESS DESIGN

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ABSTRACT

Scale up of microwave sintering for high temperature stable non-oxide ceramics, such as SiC, Si_3N_4, and dispersion ceramics, like SiC-$MoSi_2$ is still difficult, mainly because of lack of an affordable equipment. For air atmosphere sintering different furnaces were developed, like e.g., gas-microwave hybrid heated tunnel kilns [1] or microwave sintering using an adiabatic casket in tunnel kilns [2].

For inert and controlled sintering atmosphere batch furnaces, so called "hot wall" multi mode microwave furnaces, developed in 1996-2000 for microwave sintering of cemented carbides and Si_3N_4 [3,4] have shown, that homogeneity of microwave field not necessarily yields also homogeneity of the thermal field, unless the cavity walls can be heated to compensate for thermal gradients caused by radiation heat loss to the colder environment. A successful scale up of such furnaces to industrial scale requires measures to further improve the homogeneity of the thermal field, thus avoiding any heat sinks inside the sintering chamber or within the sintering material, particularly when temperatures exceeding 1700°C have to be reached.

Unfortunately, for the high microwave power levels required in large sintering furnaces state of the art microwave technology offers wave guide systems only. In most microwave sintering furnaces wave guides – rectangular, slotted, cylindrical protected against the sintering atmosphere by microwave transparent windows, are directly attached to the processing chamber, in order to introduce the microwave radiation into the furnace. The wave guides have to be kept at ambient temperature for save operation. Therefore, each microwave coupling window represents a heat sink inside the sintering furnace. On principle, the enormous radiation heat loss through such structures at temperatures > 1700°C can be reduced by using a thermally insulating casket inside the microwave furnace, but at such high temperatures each insulating material becomes partly transparent to Infrared Radiation, causing "cold spots" within the process chamber. Particularly for industrial scale sintering furnaces, with volumes of 1 m^3 and more, microwave power levels of 50-100 kW would require numerous coupling ports, each of them representing a heat sink.

Therefore, a new concept for microwave application into high temperature sintering furnaces was developed, enabling high power microwave coupling by means of a high temperature resistant antenna [5].

The paper will present microwave sintering results for SiC and other carbide ceramics as well as for AlN-TiN sintered at temperatures of 1900 – 2200°C at ambient inert gas pressure. Some details of the antenna system and the processing technology will be also presented.

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