TA007
SYSTEMS ARCHITECTURE AND DESIGN

TUBULAR MICROWAVE SINTERING FURNACE WITH INERT GAS FLUSHING FOR SINTERING METALLIC SAMPLES

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ABSTRACT

Microwave sintering is now emerging as an energy efficient process with short processing time and yielding improved product properties. Most microwave sintering systems in the past have been designed for ceramic processing.

Recently, Roy *et al.* [1] have shown that metal too can be heated to high temperatures in a microwave field, provided they are in powder form. Consequently, the as-pressed metal powder compact can be consolidated to full density using microwave furnace. Unlike ceramic powder compact sintering- which can be sintered in air- metal powders require either an inert or a reducing atmosphere. This poses a challenge in designing such microwave sintering furnaces with controlled atmosphere capability. One of the common design hypothesized is a tubular configuration furnace. Till date, the tubular arrangement for small sample sintering in inert gas environment has been limited to the laboratory demonstration and have comprised of the placement of a microwave transparent high density alumina or mullite tube in a commercial oven [2,3].

This paper describes a microwave sintering system with tubular arrangement for sintering in inert gas atmosphere so that sintering of metallic samples have been realized. This system has been successfully developed and being regularly used at P/M Lab, IIT Kanpur for sintering several metallic systems, such as bronze, stainless steels and tungsten based heavy alloys (WHAs). The obvious benefits of our design include the decreasing the total sintering time by 70% which directly results in lower processing costs. The present microwave sintering furnace ‘SINTERWAVE’ has relatively simple and flexible arrangement to locate the sample in a multi-mode microwave field and thereby precisely control the process. In the present configuration up to 1 inch diameter samples are reliably sintered in inert atmosphere up to 1300°C using a 1 kW microwave source.

The microwave sintering cavity is a rectangular aluminium box of size 300 mm depth x 425 mm width x 600 mm length and with wave-launcher interfaced to one side of the vertical face for directing the microwaves into the cavity. The side flanges with end fittings has provision for locating a microwave transparent ceramic tube of size 71 mm ID with 5 mm thickness and 660 mm length. The ceramic tubes are insulated by low density alumina fiber blanket to prevent heat convection inside the cavity. In addition the cavities are provided with holes for hot air convection to outside the cavity. In order to prevent microwaves leaking from the microwave cavity, The small amount of leakage that has been detected with this design was less than 10% of the current permitted maximum and out of range of

normal operation. The horizontal tubular arrangement with appropriate end fittings allows for easy location of the sample, monitor the temperature of the sample and control the process using a PID controller.

The control system is a PID controller which can take thermocouple inputs or 4-20 mA output from IR monitor for temperature control. The process timer and magnetron switching is done using a touch pad with microprocessor-based control with a timer and has a provision to vary average power in discrete steps. This can be used in preheating stage. Using this arrangement the furnace has been shown to be capable of achieving temperatures in excess of 1300°C using 1 kW of microwave power without damaging either of the sample holder, the tube or the lining of the furnace. In particular, no arcing has been observed either between thee walls of the microwave cavity.

In use the instantaneous sample temperature within the sample holder is measured by a Mikron 680 pyrometer or inconel sheathed K-type thermocouple. The advantage of using a sheathed thermocouple however is that it permits the ambient temperature within the sample holder to be read throughout the range from room temperature. The IR temperature measuring devices have a more restricted range and are typically only used at temperatures in excess of 500°C. Signals from sensors are then directed to a suitable control unit with PID controller such as a Eurotherm 2116 programmer which then adjusts the heat generated by microwaves and radiant heating elements in accordance with the set program thereby ensuring a desired thermal profile.

During preliminary trials the temperature of a series of test pieces can be measured with both thermocouple and infrared sensor and at soaking temperature the emissivity can be generated for the specific material. Subsequently only IR measurement and control system can be used.

In current system microwave power is adjusted manually by input voltage to magnetron. We have also tested a thyristor drive control and with Eurotherm 2404 controller, where the ramp rates can be precisely controlled. Finally, the maximum temperature is determined by the heat source (sample to be sintered) and the materials of construction of the furnace (insulation). Temperatures in excess of 1300°C have been achieved with out much heat loss or cracking of the alumina tube. Furthermore, although the furnace has been described as comprising a single microwave generator, by employing two or more magnetrons or one 2 kW magnetron a maximum temperature in excess of 1500°C can be realized.

REFERENCES

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3. A. Upadhyaya and G. Swaminathan, <u>Patent: Tubular Microwave Sintering Furnace with Inert Gas Flushing for Sintering Metallic Samples</u>, 2003 (under processing)