DESIGNING A RIDGE WAVEGUIDE CAVITY USING SIMULATION SOFTWARE FOR GENERATING MICRO-PLASMA FOR WOOL FIBER COATING OPERATION

Nguyen Tran*, Wing K. Tam and Michael Malcmann
Industrial Research Institute of Swinburne, Swinburne University of Technology

ABSTRACT

This project sets out to design a microwave cavity, which is capable of producing a micro-plasma for applications in wool fiber processing. It is not generally practical to use a large plasma source for our study because the diameter of a wool fiber is very small and the temperature of the plasma gas must be restricted to a low value to prevent burning. In the literature there are many publications on the microwave plasma cavity designs. A single mode cavity type using a rectangular or circular waveguide is often used. The principle of such a cavity is described in most textbooks on microwave engineering including "Industrial Microwave Processing" by A.C. Metaxas and R.J. Meredith [1]. Bae et al [2] describe a plasma torch using a rectangular waveguide with a reduced height. The microwave required to operate the plasma is of the order of 600 Watts. Spontaneous plasma ignition is not achieved and a wire probe is used. Woskov and Hididi[3] describe a similar applicator and a high power up to 1 kW is used.

In our application, we need a cavity which must spontaneously ignite the plasma without having to resort to a wire probe, a spark plug, a laser source or reducing the pressure. We further require that the plasma torch is small and benign in temperature at the space where a wool fiber passes through for processing. The latter condition is equivalent to a low power microwave generator.

We are looking for a cavity with a high Q (quality factor) and our choice is a ridge waveguide cavity. We begin our design by carrying out eigenmode simulation on the cavity using a FDTD software and a FEM software. The former solves the Maxwell equations governing the cavity in the time domain while the latter uses the frequency domain. It turns out that both software are capable of producing accurate results in a comparatively a short period of time using a PC with 800 MHz and 512Mb of RAM. We are able to include the plasma tube as well as the cooling tube in our simulation to account for the change in resonance frequency of several MHz. The dielectric properties of the gas can also be included in our transient simulation. From the eigenmode simulation, we then deduce the maximum achievable Q under the practical situation of wall and dielectric losses.

The cavity was constructed as close as possible to the simulated geometry and was tested using a stable microwave generator using a 2M137 magnetron. The generator generates continuously variable CW waves in a WR340 waveguide. A circulator was used between the cavity and the generator. The gas used was argon and its flow rate was monitored by a flow meter.

The most interesting result was that a micro-plasma can be established spontaneously with a very low level of microwave power. It was found a power level of 40 W is sufficient to generate a micro-plasma under the atmospheric conditions.

The micro-plasma was provided with an UV shielded chamber through which a wool fiber is passed at a controlled speed. A provision is made for other chemicals to be introduced to affect the processing and coating of the fiber.

When operated downstream, the temperature at the wool fiber space was found to be acceptable.

The paper discusses the cavity design process in detail including its performance.

REFERENCES

[1] Metaxas, A.C. and Meredith, R.J. "Industrial Microwave heating" Peter Peregrinus , London 1983.

[2] Bae, Y.S., Choi, E.M., Chung, W.S., Lee, Y.H. and Namkung, M.H. “Development of a 2.45 GHz Microwave Torch System” apcpst.org
[3] Woskov, P.P and Hadidi, K. “Large electrodeless plasmas at atmospheric pressure sustained by a microwave waveguide”, IEEE transactions on plasma Science.