A Microwave Applicator for Uniform Irradiation by Circularly Polarized Traveling Waves in an Anechoic Chamber


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Abstract—Microwave applicators are widely employed for materials heating in scientific research and industrial applications. For the majority of microwave applicators, materials are heated in the standing waves of a resonant cavity, which can be highly efficient in energy consumption, while often lacks the field uniformity and controllability required for a scientific study. Here, we report a microwave applicator for rapid heating of small samples by highly uniform irradiation. It features an anechoic chamber, a 24-GHz microwave source, and a linear-to-circular polarization converter. With a rather low energy efficiency, such an applicator functions mainly as a research tool. This paper discusses the significance of its special features and describes the structure, in situ diagnostic tools, calculated and measured field patterns, and preliminary heating tests of the overall system.

I. INTRODUCTION

The main body of the microwave applicator under study is a radio-frequency anechoic chamber, which is commonly used for the measurement of antenna radiation patterns, radar cross-sections, and the electromagnetic compatibility of various equipment. Much less frequently, simple anechoic chambers have also been built for sample irradiation at relatively high power levels. For such experiments, irradiation uniformity is highly desirable.

Emitted from a conical horn antenna into an anechoic chamber (Fig. 1), the radiation intensity on a horizontal plane can be spatially nonuniform in both the radial and azimuthal directions. The radial nonuniformity can be minimized with a small sample size or at a distance far away from the antenna, while the azimuthal nonuniformity can be completely eliminated with a circularly polarized wave. In addition, at a given point on the sample, the heating rate depends not only on the radiation intensity, but also on the orientation of the sample with respect to the electric field. This is due to the shielding effects by the induced polarization charges on the sample. A linearly polarized wave, even if spatially uniform in intensity, is intrinsically nonuniform in polarization; however, this can be fully remedied in the rapidly rotating electric field of a circularly polarized wave. For these reasons, we have employed a circularly polarized wave as the radiation source.

Both the 2.45 GHz and 24 GHz frequencies belong to the industrial, scientific, and medical (ISM) bands. The 2.45 GHz radiation is widely used for dielectric heating, whereas the 24 GHz radiation has been rarely exploited. However, given the same (complex) dielectric constant and electric field strength, materials absorb microwave energy at a rate proportional to the frequency. On the other hand, the penetration depth decreases with an increased heating rate. Thus, the 24 GHz radiation results in nonuniform heating of large samples. However, for small samples, it affords the advantage of both uniform and rapid heating. This has motivated us to specialize in small sample irradiation experiments in the 24-24.25 GHz ISM band.

II. RESULTS

The applicator system under study (Fig. 1) features a lab-made, 1-KW, 24-GHz extended interaction oscillator (EIO) [1] as the radiation source and a polarization converter [2, 3] to convert its linearly polarized output wave into the circularly polarized state.

Fig. 1. Schematics of the microwave applicator. (a) The radiation source, diagnostic circuit, and polarization converter. (b) The anechoic chamber.

In this talk, we will describe the structural details of the anechoic chamber, the radiation source, the polarization converter, in situ diagnostic tools, calculated and measured radiation patterns, and a preliminary heating test.

REFERENCES