APPLICATION OF NONTHERMAL EFFECTS IN HIGH DIELECTRIC MATERIALS TO MICROWAVE DOSIMETRY

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Abstract

Thermoluminescent properties of high dielectric materials were examined before and after exposure to 2450 MHz microwave radiation. Fading of low temperature peaks was significantly greater in phosphors exposed to microwaves than in oven heated controls.

Introduction

Critical reviews of the literature on the hazards and biological effects of microwave radiation reveal the limitations and inadequacy of much of the work performed to date.[1,2] At the present time microwave hazard evaluation is hindered by the lack of adequate equipment for measuring power density or absorbed energy in or around a biological specimen or tissue equivalent medium. The uncertainty of microwave hazards and the potential for exposure make dosimetry one of the most important research needs in the area of microwave effects.

It has been reported that liquid crystal techniques,[3] mathematical techniques coupled with impedance calculations,[4] and a cavity irradiation technique utilizing a biological absorption measurement[5] could be used to determine dose due to microwave exposure. However, these techniques cannot be used in the near field, do not interact with the field the same as biological tissue, and cannot be placed in the field with the biological specimen.

Two devices were produced to be used as personnel dosimeters but suffered from significant deficiencies. A multiturn coil was used as an antenna in a pocket dosimeter made by Scientific Protection Devices, Inc.[6] The Richardson Microwave Dosimeter used a small self-contained thermometer to indicate the temperature of a small mass of gelatin. The gelatin was to simulate any avascular body structure heated by an electromagnetic field.[7]

Conover studied a sensitive thermoluminescent material which is widely used as a personnel dosimeter for ionizing radiation.[8] He attempted to induce a reduction in the thermoluminescent response (fading) by exposing the material to high levels of microwaves hoping to correlate the reduction in response to microwave dose. He reported no effect, however.

With these problems in mind, a study was designed with the objective of examining the thermoluminescent response of high dielectric inorganic materials before and after microwave exposure. The thermoluminescent properties of these materials were unknown, therefore activation and thermoluminescent characterization studies were also designed. Some of these and other materials were also examined for a change in thermal stimulated exo-electron emission (TSEE) after exposure to microwaves.

Materials and Methods

The inorganic materials studied were phosphors of the perovskite structural class including $BaTiO_3$ activated with various concentrations of the rare earth dysprosium and $(BaSr)TiO_3$ with various ratios of Ba to Sr. These phosphors were studied in the powdered and ceramic states. Powdered samples were contained in paper envelopes but ceramic phosphors were handled directly.

Samples of each phosphor were predosed with 10^5 R Co-60 gamma radiation which caused electrons in the phosphor material to be raised to excited states. Thermoluminescent response was determined by heating the phosphor samples, gradually increasing their temperature, and measuring the light output of the luminescent phosphors with a photomultiplier tube and associated electronics.[9] The phosphors showing the greatest response were examined for peak stability and linearity of response. Predosed samples of the most sensitive and stable phosphors were exposed to 2450 MHz microwave radiation in an anechoic chamber, 305 X 244 X 213 cm high, with a -40 dB quiet zone. The power level was determined with a directional coupler and Hewlett-Packard 432A Power Meter, and power density was monitored with a Narda 8110 Electromagnetic Radiation Monitor. Samples of powdered phosphors were exposed in the near field and far field of the anechoic chamber. The far field exposures were performed at a power density of approximately 200 mW/cm^2. Because the number of samples was limited, ceramic phosphors were exposed only in the near field. The power density of the near field could not be validly determined but was admittedly high with respect to personnel safety considerations.

For a thermal control, a sample of $(Ba_{.8}Sr_{.2})TiO_3$ powdered phosphor was heated in an oven to the maximum temperature reached during microwave exposure (28°C) and was kept at this temperature for a time equal to the corresponding microwave exposure.

Phosphors examined for a change in TSSE included CaF_2, $BaSO_4$, and $BaTiO_3$. Samples of each phosphor were predosed with Co-60 gamma radiation, exposed to 2450 MHz microwaves, and analyzed with a proportional counter which counted the electrons emitted by the sample when it was heated.

Results and Conclusions

The reduction in thermoluminescent response of the $(Ba_{.8}Sr_{.2})TiO_3$ phosphor was significantly ($P < .05$) greater than that of the thermal control. This was true for samples placed in the near field or far field of the anechoic chamber. Fig. 1 shows that thermoluminescent response decreased with time of microwave exposure. Fading was thus dependent on energy fluence at the surface of the phosphor.

Ceramics produced from the activated phosphors of $BaTiO_3$ containing 0, 0.1, and 0.5 mole percent Dy and from the combination powder $(Ba_{.8}Sr_{.2})TiO_3$ showed a marked reduction in thermoluminescent response when compared to a control stored at room temperature. Fig. 1 shows that the reduction in response of ceramics was also energy fluence dependent.

There was a significant ($P < .05$) reduction in TSEE in phosphors exposed to microwaves only when graphite was combined with the powdered phosphor and only when the phosphors were exposed to the high power densities in a microwave oven.

We suggest that the reduction in thermoluminescent response seen in the phosphors used in this study is nonthermal since it was greater than an oven heated control. This fading phenomenon may provide a method for determining microwave absorbed energy.

The reduction in TSEE occurred only when graphite was mixed with the phosphor. We conclude that this reduction was due to thermal build-up resulting from conductive loss in the crystals and would have little or no use in microwave dosimetry.

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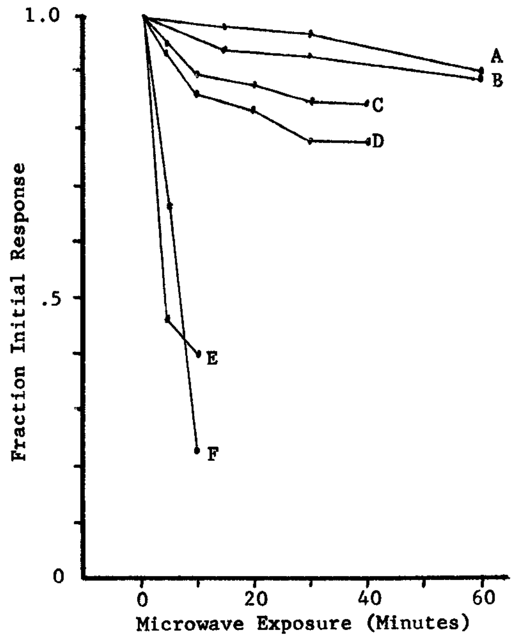

FIG. 1. Effect of microwaves on thermoluminescent response of powder and ceramic phosphors. (A), Room temperature; (B), elevated temperature; (C), $(Ba_{.8}Sr_{.2})TiO_3$ powder exposed in far field; (D), $(Ba_{.8}Sr_{.2})TiO_3$ powder exposed in near field; (E), $(Ba_{.8}Sr_{.2})TiO_3$ ceramic; (F), $BaTiO_3$ ceramic. Results of the microwave exposures were normalized to the control to obtain fraction of initial response (no microwave exposure). Results of the elevated (28°C) exposure were not normalized in order to compare them directly with a control (22°C). In the latter comparison the zero time is a phosphor sample stored on dry ice and receiving no exposure to room temperature or to elevated temperature.