A PASSIVE METHOD FOR MONITORING NON-IONIZING RADIATION

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Abstract

The temperature-dependent light scattering properties of cholesteric liquid crystals are used as both the sensing and indicating mechanism in a calorimetric radiation monitor. The liquid crystals are arranged on two dielectric disks; one is a plain dielectric and the other is metal coated. While both disks will respond to general changes in ambient conditions, the metallized disk will also have a temperature change due to absorbed radiation. Thus, the difference between the temperatures of the two disks, as indicated by the liquid crystals, is a measure of radiation. Experimental models are described and the results of tests at 2.45 GHz for power densities of from 1 to 15 mW/cm^2 are presented.

Introduction

It has been said that our society is bathed in electromagnetic radiation from commercial broadcasting, radar, portable transmitters and a host of on-the-job industrial sources.* When this condition is coupled with increased concern about the possibilities that some of these radiations may be hazardous, it is easy to see the need for effective radiation monitoring. Presently most of the equipment available for this purpose uses antenna-detector configurations, electronics and associated metering. As a consequence these instruments are relatively expensive and their availability is limited. The result is that cost and convenience reduce the monitoring of areas where there is potential for hazardous radiation and the possibility of human exposure to these radiations is increased. The purpose of this paper is to describe a passive method for monitoring non-ionizing radiation that should be so inexpensive it could be made available wherever there is a need.

Liquid Crystals

The property utilized in this approach to radiation monitoring is the temperature-dependent ability of cholesteric liquid crystals to scatter light selectively. A change in the temperature of a material coated with liquid crystals causes a change in color. In general the color will pass from red to green to blue as the temperature increases and it will be limited to a temperature range; the range is determined by the compounds or mixtures of compounds used. The surface of a material whose temperature is to be measured must first be coated with a black paint to absorb all light not scattered by the liquid crystals. Then the liquid crystals are applied. In operation the liquid crystals that are responsive at the temperature of the coated surface will be producing color play and the remainder of the surface will be black. These temperature measuring and indicating properties are used in forming a liquid crystal calorimeter that can be used to monitor non-ionizing radiation.

The Liquid Crystal Calorimeter

The radiation monitor consists of two plastic temperature sensing disks. One of the disks has a metal coating and the other does not. After the disks are coated with a black paint, liquid crystals having color play centered at different temperatures are painted on in concentric circles. The temperature required for color play is highest in the outermost circle and decreases monotonically, in 1.11 °C (2 °F) increments, with each circle toward the center of the disk. When there is no radiation present the circles having color play will have the same radius. When radiation is present the metallized disk will absorb radiation, its temperature will rise and the radius of the circle having color play on this disk will be larger than that on the nonmetal disk. Thus, with the nonmetal disk serving as an ambient temperature indicator, the difference between temperature indications of the two disks can be used as a measure of the radiation. Operation of the monitor is illustrated in Figure 1.

Experimental

Experimental models of the sensors were fabricated from 3 cm diameter plastic disks. The metallized plastic disks had surface resistivities of 150, 250, 377, 450, 650 and 850 ohms per square. Additional sensors were made from 377 ohm per square material that had diameters of 6.1 and 12.2 cm. The response of a sensor is in terms of its temperature rise above ambient. This is determined by noting the circle number and the color of the circle that is showing color play. For the experimental models there were 10 circles and the outermost circle had color play centered at 31.11 °C (88 °F).

Thus, a center color play of green on circle number 8 would be 28.89 °C (84 °F). Since color play passes from red to blue as the temperature increases, it is possible to estimate temperatures that fall on either side of the center temperature.

Experiments were conducted in an anechoic chamber with radiation from a standard rectangular pyramidal horn antenna. Radiation at the sensor position was determined using a Narda Model 8100 radiation meter. These measurements (see Figure 2) show a generally decreasing response to radiation as surface resistivity is increased. The reason for this characteristic is that the thickness of the metal film is much smaller than the skin depth at this frequency and it can be shown that less energy will be absorbed by the metal film as the surface resistivity is increased.

The thermal response characteristics of the sensors were found to have more influence on the radiation response than was originally expected. This was observed when sensors having a surface resistivity of 377 ohms/square and diameters of 3, 6.1, and 12.2 cm were subjected to radiation. At an ambient temperature of 26.11 °C (79 °F) and a radiation intensity of 5 mW/cm^2, the temperatures reached were 28.89, 27.78, and 27.22 °C

*Mennie, D. "Microwave Ovens: What's Cooking?" IEEE Spectrum, 12(3):34-39 (1975).

for the 12.2, 6.1, and 3 cm diameter disks, respectively. It was concluded that although there may be differences in electromagnetic absorption by disks having different diameters, these effects are overshadowed by the dependence of the sensor thermal response on disk diameter. Additional thermal response effects were noted when the disks were covered with a transparent plastic material as a shield against drafts: higher temperatures were reached for the same radiation intensity, and the time required for the sensors to cool to normal, after radiation removal, was increased.

Discussion

The liquid crystal calorimeter is a unique method for monitoring non-ionizing radiation. Because the liquid crystals function as both the sensing and indicating mechanism, the device does not need a power source, electronics or a meter. Since it only requires a small amount of material and its manufacture could probably be automated, it has promise for being inexpensive. Thus, the liquid crystal calorimeter could provide radiation monitoring that every owner of a radiation source could afford. Homes, industries, laboratories and other places that presently are seldom, if ever, checked for hazardous radiation could now undergo regular monitoring.

Acknowledgment

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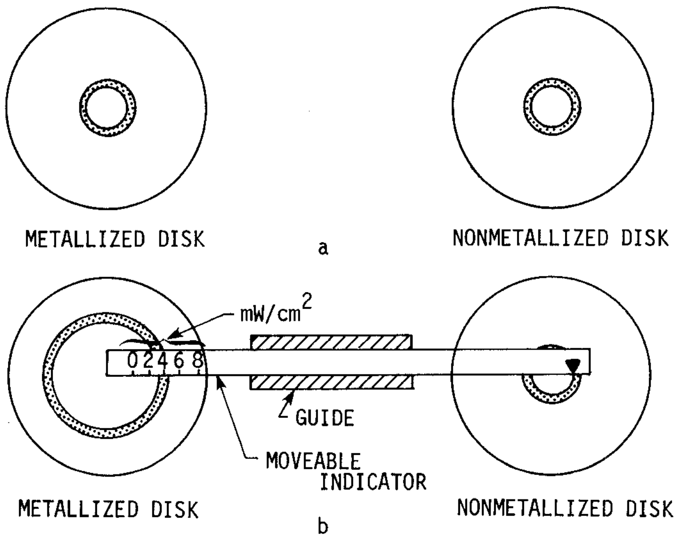

Figure 1. 1a. Illustration of the color play on the calorimeter with no radiation present.

1b. Illustration of the color play on the same calorimeter with radiation present.

This figure also illustrates an approach for using the difference in temperature indications to determine the radiation level.

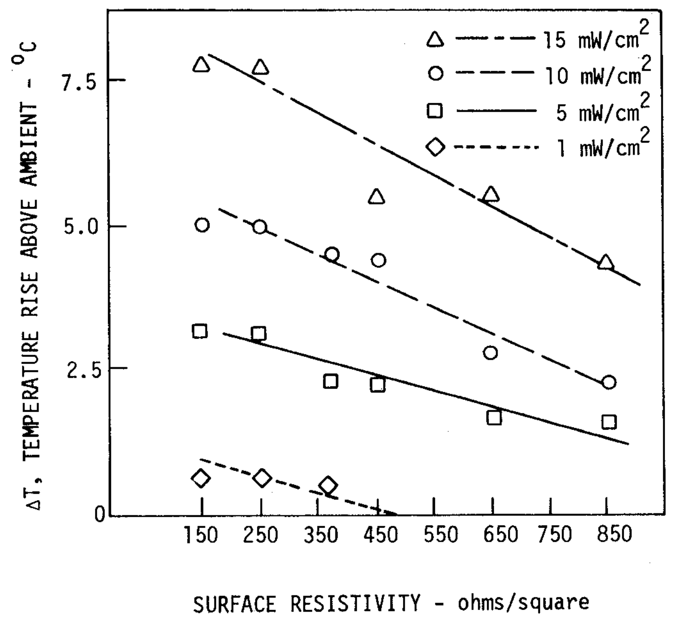

Figure 2. Radiation response of the calorimeter sensors, in the form of temperature rise for a given value of radiation, as a function of surface resistivity.