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## **Thin-Film Temperature Sensor**

A thin-film capacitor sensor has been developed for measuring the rapid temperature changes in fluid streams. The sensor withstands contacts with various corrosive fluids, high fluid-flow rates, and the turbulences caused by rapid changes in flow rates.

The heart of the sensor is a temperature-dependent thin-film capacitor. Its temperature coefficient  $\alpha$  is defined by

$$\alpha = \frac{1}{C} \frac{dC}{dT}$$
(1)

where C is the capacitance and T is the temperature in degrees Kelvin. Thin dielectric films are generally known to have a large  $\alpha$ .

The capacitor is part of a resonant bridge circuit (Figure 1), which produces an ac voltage that is proportional to temperature. The output voltage V for a given temperature change  $\Delta T$  is described by

$$V = V_{\alpha} \alpha Q \Delta T$$
 (2)

where  $V_0$  is the initial amplitude of the harmonic voltage applied across the capacitive element. In Figure 1, the capacitive element is represented in the dashed box by its parallel equivalent capacitance C and resistance R.

If low-loss coils L are used, the circuit quality factor Q is determined by the capacitive elements, namely

$$Q = \omega RC \tag{3}$$



Figure 1, Resonant Bridge Circuit

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Figure 2, Temperature Sensor Structure

In this case, Q remains nearly constant for a wide range of frequencies  $\omega$ , because R is inversely proportional to  $\omega$ . The important parameters, therefore, that determine the temperature sensitivity of the sensor are  $\alpha$  and Q, as indicated in equation 2. The resonant bridge circuit produces an output voltage larger by the factor Q than the voltage from a simple capacitance bridge without coils.

The sensor consists of a tantalum foil supporting a thin-film capacitive element, as shown in Figure 2. The foil is 99.8-percent-pure tantalum approximately 0.025 mm (0.001 in.) thick. The capacitive element is formed by the vapor deposition of successive layers of aluminum, aluminum oxide  $(Al_2O_3)$ , zirconium oxide  $(ZrO_2)$ , silicon dioxide  $(SiO_2)$ , and aluminum. The aluminum strips form the capacitor electrodes, and the zirconium oxide with the aluminum oxide layers form the dielectric. In addition, a circular window approximately 0.38 mm (0.015 in.) in diameter is etched through the tantalum foil to the anodic film  $(Ta_2O_3)$ . The entire sensor is coated with a thermoplastic polymer, which provides chemical protection and electrical insulation.

## Note:

Requests for further information may be directed to: Technology Utilization Officer NASA Pasadena Office 4800 Oak Grove Drive Pasadena, California 91103 Reference: TSP74-10100

## Patent status:

This invention has been patented by NASA (U.S. Patent No. 3,676,754). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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