CERTAIN FEATURES OF A THIN-FILM CAPACITIVE TRANSDUCER WITH A GASEOUS DIELECTRIC

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This article discusses the development and testing of a thin-film capacitive transducer for the measurement of pressure pulsations.

Thin-film capacitive transducers are designed to measure pressure pulsations on the surface of a specimen without preliminary machining. The flexibility of such transducers allows them to be mounted on models and products with a large curvature, in hard-to-reach places, on thin sections, etc. [1, 2]. The base of the transducer is a polyimide film possessing good mechanical strength and constant characteristics within a broad range of temperatures.

The transducer, with a gaseous dielectric and one sensitive element (SE) (Fig. 1), contains a base consisting of an initial polyimide film 1 with a solid shield 2 (section C-C). A side shield 4 and a capacitor plate 5 are placed on top of the second polyimide film 3 (sections A-A, C-C). The third polyimide film 6 is perforated (sections B-B, C-C) to enhance the sensitivity of the transducer. Another side shield 7 and the answering plate 8 are located on the bottom surface of the fourth dielectric film 9 — the diaphragm (section C-C).

To study the stability of the output signal of the transducer, we isolate a section containing a single cell of the perforation between the capacitor plates (Fig. 2). The diaphragm 9 of the transducer is bent relative to its base about periphery of the cell (see Fig. 1). The fact that the SE of the transducer is made of a solid piece of the thin film allows us to ignore the support reactions of the perforation and hysteresis in the transducer, since they are observed only in the case of large strains of the SE or static loading. To ensure that the calibration curve is linear, we choose the thickness of the diaphragm 9 to be much less than the radius of the cell \( \delta << a \) and less than or equal to the thickness of the perforated film \( \delta \leq t \). The load (pressure) on the surface of the film of the SE is distributed uniformly and is the only bending force. Tensile stresses over the radius of the diaphragm can be ignored due to the smallness of its deflections. The deflections of the diaphragm inside each cell are the same.

In accordance with Fig. 2, the change in the capacitance of one cell relative to the base due to the pressure exerted on the transducer can be determined as

\[
dC = 2\pi e_0 \epsilon_0 d\epsilon / (t - y),
\]

where \( \epsilon_0 \) is the absolute dielectric constant of the gaseous dielectric (air) in the cells of the perforation; \( r \) is the running radius of the cell; \( t \) is the thickness of the perforated film; \( y \) is the deflection of the diaphragm.

Proceeding on the basis of the above assumptions and hypotheses, we can determine the deflection of the diaphragm (see Fig. 2) under pressure by means of the equation [3]

\[
y = 3p(1 - \mu^2)(a^2 - r^2)/(18E\delta^3),
\]

where \( p \) is the pressure; \( E \) is the elastic modulus of the material of the diaphragm; \( \mu \) is the Poisson’s ratio.

With allowance for Eqs. (1) and (2) and in accordance with Fig. 2, the effective increment of the capacitance of one cell under pressure can be determined as follows with the condition \( y/t << 1 \) [4]:

Simultaneously solving Eqs. (1-3), we obtain
\[ C + \Delta C = \int_0^a \frac{2\pi \varepsilon_0 \partial \psi}{t-y} \, \mathrm{d}r. \]  

(3)

We find from (4) that
\[ C = \frac{\pi \varepsilon_0 a^3}{t}; \]  

(5)
\[ \Delta C = \frac{\pi \varepsilon_0 a^2 (1 - \mu^2)}{16 \delta^3 r^2}. \]  

(6)

The total initial capacitance \( C_0 \) of an SE without a perforation is
\[ C_0 = \varepsilon_0 S / t, \]  

(7)
where \( \varepsilon \) is the permittivity of polyimide film 6; \( S \) is the area of plate 5.

The capacitance of the \( n \)-th cell with the gaseous dielectric
\[ C_n = \varepsilon_0 \pi a^3 n / t. \]  

(8)

We can use (7) and (8) to find the capacitance of the wall of the cell.