New Applications of FLC: Sensor Based on Ferroelectric Liquid Crystalline Freely Suspended Films

Serguei V. Yablonskii[1,2], Kazuyuki Nakano[1], Aleksey S. Mikhailov[2], Masanori Ozaki[1], Katsumi Yoshino[1].

[1]Department of Electronic Engineering, Graduate School of Engineering, Osaka University, 2-1 Yamada-Oka, Suita, Osaka 565-0871, Japan
[2]Institute of Crystallography, Russian Academy of Science, 117333 Leninskii pr.59, Moscow, Russia.

Here we report on a vibrating ferroelectric liquid crystal freely suspended film-based pressure gauge, which shows some promise of being sensitive to the pressures in the range from 50 to 10^5Pa. The gauge indicates changes in resonant frequency of the film caused by changes of air pressure. Pressure measurements using such sensor have been carried out.

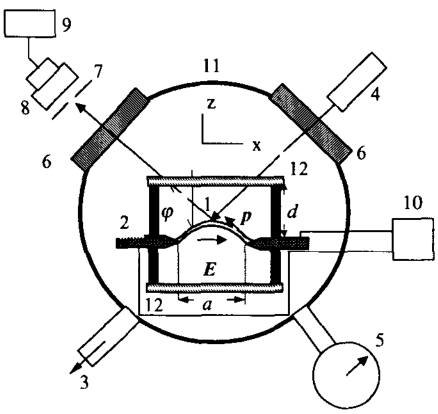

Fig. 1 Schematic diagram of the experiment. (1) ferroelectric freely suspended liquid crystal films (CS-1029), (2) two Al electrodes, (3) pump, (4) He-Ne laser (s-polarization), (5) manometer, (6) two quartz windows, (7) slit diaphragm, (8) photo-diode, (9) lock-in amplifier, (10) audio frequency generator, (11) vacuum chamber, (12) two glasses placed near the film surfaces at the variable distance d .

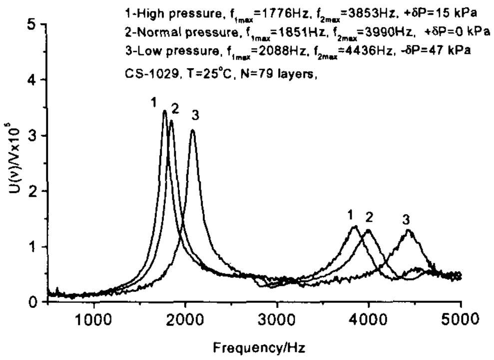

Fig. 2 The spectra of the linear electromechanical effect of a freely suspended liquid crystal film measured for three values of the differential air pressure: δP= +15 kPa (*1*), δP= 0 (*2*), δP= - 47 kPa (*3*). (Circular film –R = 0.15 mm, CS –1029, N = 79 layers, T = 25 °C).

The freely suspended ferroelectric liquid crystal films manifest very curious phenomenon, so called electromechanical effect, when alternating electric field is applied along the smectic layers [1-4]. In this case an interaction of the electric field with ferroelectric liquid crystal film, spanned on the rectangular frame, gives rise to the mechanical vibrations with a discrete spectrum of the pure tones [5]:

$$\nu = \frac{1}{2}\sqrt{\frac{2\sigma}{\rho_s}\left(\frac{n^2}{a^2}+\frac{m^2}{b^2}\right)}, \qquad (1)$$

where a and b are respectively the length and the width of the film, σ is the surface tension, $\rho_s = \rho Nl$ is the 2D surface mass density, N stands for the number of the smectic layers, ρ is the bulk density of the liquid crystal and l is interlayer distance. The integer n and m denote the normal modes.

The freely suspended films were drawn across a plane aperture made in a glass slide of 2-mm thickness. Process of the preparation of freely suspended films has been described elsewhere [6]. As the liquid crystal we used commercial ferroelectric liquid crystal mixture CS-1029, which has the advantage of being in the smectic C* at room temperature [7]. The film thickness was measured by means of reflection spectroscopy [6]. The reflection spectra were obtained with the aid of multichannel spectrum analyzer. The film holders mounted in the heating stage were contained in a vacuum chamber and the film can be stabilized at a given temperature to ±0.1°C.

In the experiment the alternating voltage applied across the electrodes excited the vibration modes. The laser beam was reflected from the surface of the film. The angular deviations of the beam were measured with the aid of a position-sensitive detector comprising a slit diaphragm and photo-diode, as shown in Fig. 1. The photo-diode response current was analyzed by a Fourier spectrometer and a lock-in-amplifier tuned to the first and second harmonics of the sinusoidal voltage applied to the film. The z-displacement of the film was sensitive to the polarity of applied electric field; therefore the linear electromechanical effect was basically detected.

Results of the crucial experiment are shown in Fig. 2. This figure presents the spectra of the linear electromechanical effect for some values of air pressure created by *human respiration*. When the pressure decreased, the spectra shifted dramatically to the high frequencies. Correspondingly, the spectrum shifted to the low frequencies, when pressure exceeded normal atmospheric pressure.

In conclusion, we have observed the high loading effect giving rise to the shift of the resonant frequencies of the freely suspended films. The freely suspended film-based pressure detector operating in the range from 100kPa to 50Pa has been realized. The absence of moving solid parts, simple design and miniature size are essential characteristics of such nanomechanical detector.

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[7] The bulk phase sequence for CS-1029 is Cr (-18°C) SmC* (73°C) SmA (85°C) N*(95°C) iso.