Journal of Engineering Physics and Thermophysics, Vol. 66, No. 3, 1994

CAPACITIVE STRUCTURES BASED ON "MUSCOVITE" MICA

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UDC 621.319.4:621.315.613.1

The influence of pressure, irradiation with β-particles, and the intercalation process on the "capacitive" properties of "muscovite" mica has been investigated, and optimal regimes of silverless facing formation have been found.

It is well known that capacitors made from mica have good characteristics in the high-frequency wave range and low dielectric losses and are effective at high temperatures [1]. Due to these properties mica capacitors are widely used in the electronics industry. Despite the great advantages they still have some drawbacks [2, 3]. Among these are low specific capacitance and use of expensive silver in the deposition of the capacitor facings.

The aim of the present work is an experimental search for possible ways to overcome the aforementioned drawbacks.

Indium (III) oxide was selected from a number of different conducting materials. A film of In_2O_3 was deposited on mica plates by spraying in a cassette with a rectangular hole of the required dimensions. The specified temperature was maintained automatically. For the deposition a 0.5-mole solution of $InCl_3 \cdot 3H_2O$ + 3 wt.% $SnCl \cdot 5H_2O$ in ethanol was used. The thickness of the In_2O_3 film was controlled by the deposition duration. Investigating the deposition process in the temperature range 350-600°C, we found that the most appropriate temperature for formation of the In_2O_3 film on the mica surface ranges from 450 to 460°C. From the measurements performed it follows that the capacitance of devices with an In_2O_3 film is not reduced relative to that of capacitors with silver facings, and in some cases the capacitance of the former is increased by 8–10%.

We studied the influence of pressure on the mica capacitor parameters. In these experiments mica plates with previously deposited silver facings were used for compressing uniaxially a sample along the crystallographic axis *C*. It have been found that with a pressure increase the sample capacitance increases and this increase attains 10–12% at $P = 39.2 \cdot 10^6$ Pa, while the dielectric loss tangent is constant within the error range of the instrument. It is noteworthy that this increase is not covered completely by the decrease in sample thickness.

We have likewise performed experiments on the effect of high-energy irradiation on the "capacitor" properties of mica. A sample was irradiated with β-particles on an LUCh-4 electron accelerator. The energy of the particles was $6.888 \cdot 10^{-13}$ J at the current density $j = 0.25$, 1, 3 A/m^2. The radiation dose of mica plates with deposited silver facings was 10^{16}, 10^{18}, 10^{20} e/m^2. A comparison of "capacitor" properties of irradiated samples with those of a reference lot indicated that irradiation leads to a decrease in the dielectric loss tangent. Among the aforementioned ranges of radiation dose and current density the best result was obtained at radiation dose 10^{18} e/m^2 and the current density $j = 0.25$ A/m^2. In this mode the dielectric loss tangent decreased by a factor of 4.

For solving the fundamental problem - synthesis of materials with specified properties in the field of laminar crystals - intercalation is of great interest. Intercalation means that foreign ions, atoms, or molecules are introduced into interpacket sites of substances having a laminar crystal structure. This method of target-oriented modification of the initial crystal properties, as a certain kind of crystal engineering, can play a decisive part in substantial increasing substantially the dielectric permeability of mica. An analysis of the literature data indicates that attempts to produce intercalated mica are given much attention. However, information in accessible publications is very

Chernovtsy Branch of the Institute of Material Science Problems, Academy of Sciences of Ukraine, Chernovtsy, Ukraine. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 66, No. 3, pp. 345-347, March, 1994. Original article submitted August 11, 1992.

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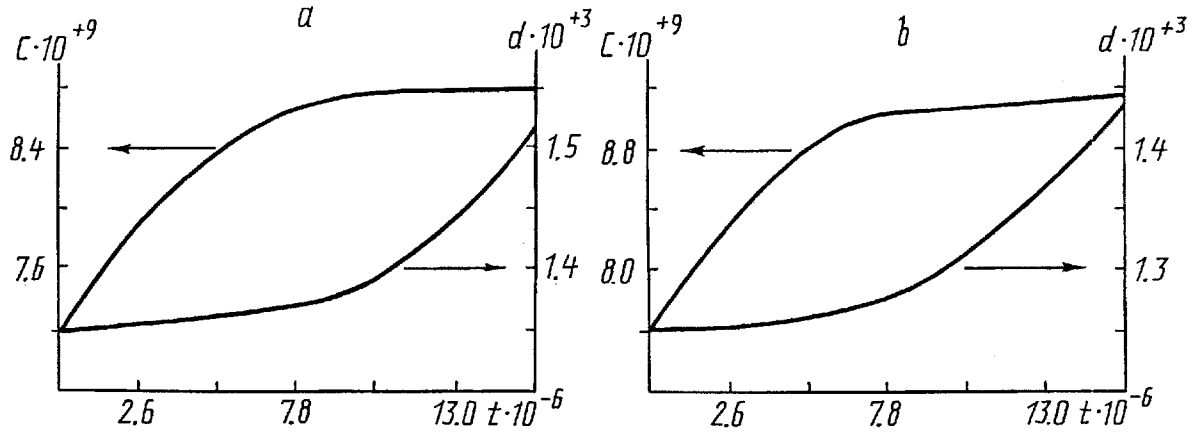

Fig. 1. Dependence of thethickness and capacitance of mica plates on the exposure time in piperedine (a) and aniline (b). C, Φ; d, m; t, sec.

sparse. Generally speaking, production of intercalated mica, and "muscovite" especially, is a difficult problem mainly because of the presence of potassium ions, which are "driving force" of water adsorption, in the interplane regions. In principle, intercalation can replace or neutralize the effect of the ions. In doing so it may introduce simultaneously the required useful "capacitor" properties.

Mica may not be intercalated by the most common electrochemical method since it is a good insulator. That is why we have chosen another method, namely, exposing the "host" crystal in the "guest" substance being introduced. Moreover, it is desirable to choose a guest substance that is energetically driven into the interlayer regions and can improve the "capacitor" properties of the mica as well.

Experiments on intercalating mica with piperedine $CH_2(CH_2)_4H$ and aniline $C_6H_5NH_2$ were performed at room temperature. The exposure lasted six months. It was noted that intercalation results in an increase in the sample thickness and an increase in the capacitance. Results of the investigation on intercalation with piperedine are presented in Fig. 1a, and with aniline in Fig. 1b. Fig. 1a indicates that the rate of increase in capacitance is greatest in the first two months and then a considerable decrease occurs. The thickness of the samples increases at the maximum rate in the last three months. The dielectric loss tangent experiences an increase from 0.001 to 0.018. Just as in intercalation with piperedine, the raye of change of the mica device capacitance is greatest in the first two months, and then a considerable decrease occurs, in intercalation with aniline. The dielectric loss tangent remains a problem, since it increases from 0.001 to 0.013. The use of β-irradiation, as described above, is of interest for solving this problem.

We studied the possibility of intercalating mica by the ion-exchange mechanism by exposing it in the following melted salts: $LiClO_4$, LiCl, Cu_2Cl_2, which have singly-charged ions. The melt was heated to 15° above the melting point T_m and maintained constant within ±5° automatically. The mica was exposed in the melted salts for 12 h. After exposure in the melted salts a film of In_2O_3 was deposited on both sides of the samples, and then the capacitor parameters were measured. It was noted that the samples exposed in melted $LiClO_4$ with T_m = 236°C and Cu_2Cl_2 with T_m = 430°C did not change their device capacitance. On the other hand, the mica plates exposed in LiCl with T_m = 614°C increased their dielectric permeability, and the capacitance of the corresponding device increased by a factor of 3. The ion-exchange melting point of the salt is probably of importance, since, despite the fact that the same lithium cations take part in ion-exchange processes in the case of $LiClO_4$ and LiCl, in the former the capacitance does not change, but in the latter it increases severalfold.

NOTATION

P, pressure, Pa; j, current density, A/m^2; C, capacitance of the capacitor, Φ; d, thickness of the mica plates, m; t, exposure time, sec; T_m, melting point of the substance, °C.

REFERENCES

1. V. T. Renne, Electrical Capacitors [in Russian], Moscow-Leningrad (1959), pp. 280-289.
2. M. S. Metsik and L. A. Shcherbachenko, Electrical Properties of Micas [in Russian], Irkutsk (1990).
3. A. Tripathi, A. K. Tripathi, and P. K. C. Pillai, J. Mater. Sci. Lett., 9, No. 4, 443-445 (1990).