A study of absorption characteristics in polyimide and polyimide fluorocarbon-2 polymer film

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Abstract. The absorption characteristics of polyimide (PM) and polyimide fluorocarbon (PMF-2) polymer film were studied at temperatures ranging from 20 to 230°C. The glass transition or critical temperature of PMF-2 was found at 160°C. Conduction of PMF-2 was observed due to the upper fluorocarbon layer below the transition temperature while the middle PM layer is important above this temperature. The time-dependent absorption/resorption current does not satisfy the traditional Curie-Von Schweidler law. The experimental results of the absorption characteristics are analysed using a simple R-C circuit.

Keywords. Absorption/resorption current; residual/discharge voltage; Curie-Von Schweidler low; conduction; R-C circuit.

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1. Introduction

Synthetic polymers are extensively used as electrical insulators because of their good electrical and mechanical properties. They have wide applications ranging from power apparatus and cables to microelectronics. Among the possible synthetic polymers, polyimide and polyimide fluorocarbon (abbreviated hereafter as PM and PMF-2 respectively) seems quite promising.

The present paper reports the comparative study of the absorption characteristics of both these films at different temperatures. Sample films have been used for measuring the absorption/resorption currents and the residual/discharge voltages.

The applications of step voltage to dielectric causes a flow of current which decays with time before reaching a steady-state value. The time-dependent part of the current (absorption current) is due to dielectric polarization under the applied electric field. The polarization of polymeric dielectrics may be due to dipolar orientation, accumulation of charge carriers near the electrodes or trapping in the bulk (Van der Schueren and Linkens 1976; Nakumara et al 1976). Under certain conditions, additional charge carriers may be provided by injection from the electrodes, which also contribute to space charge polarization (Wintle 1977). A systematic study of the absorption currents can reveal the carrier injection, trapping and polarization processes which may be present in a dielectric. An understanding of the absorption currents is therefore necessary to discover the true conductivity of the material.

The resorption current usually decays with time in the direction opposite to the absorption current. This has been explained as the result of dipolar depolarization
or redistribution of charge carriers due to interfacial polarization or space charge polarization (Das Gupta et al 1980).

Considerable high voltage sometimes appears on the inner-conductor of a power transmission cable and condenser after opening a circuit which was previously electrically stressed and short-circuited for a short time. This voltage gives an electric shock when touched and is termed the residual voltage. Recently, measurement of the residual voltage was proposed as a method for detecting degradation of the cable insulation (Kalsumi et al 1982).

In the present study the absorption/resorption currents and the residual/discharge voltages at different temperatures were measured in PM and PMF-2 and the results analysed using simple R-C circuits.

2. Experimental

Commercial-grade polyimide (Yslovia 1972) and polyimide fluorocarbon film [(10 μm fluorocarbon- 30 μm polyimide- 10 μm fluorocarbon sandwich film commercially known as PMF-2 (Yslovia 1983)] of thickness 40 μm and 50 μm respectively were used. After washing with alcohol, aluminium electrodes of 28 mm diameter were deposited on both surfaces of the films by vacuum evaporation. The sample was then mounted in a measuring cell and the absorption/resorption currents and the residual/discharge voltages at different temperatures were measured using a BK2-16 electrometer (USSR), an x-y recorder provided with a time base, and a stabilized d.c. power supply.

The absorption/resorption currents were measured according to standard procedures, of applying a step voltage, measuring the absorption current decay for some polarization time \( t_p \), short circuiting the sample and measuring the resorption current.

The measurement procedure of residual voltage was as follows. A voltage \( V_p \) was applied to a sample for a time \( t_p \) and the circuit shorted for a time \( t_s \). After the circuit was opened, a voltage \( V_R \) appeared on an electrode after \( t \). Also for measuring discharge voltage, \( V_p \) was applied to a sample for \( t_p \), the circuit opened and the discharge voltage \( V_d \) recorded.

3. Results and discussion

Variation of the absorption and resorption current with time for PM and PMF-2 is shown in figures 1 and 2 respectively at various temperatures. No time-dependent part of the currents was soon above 180°C for PM (figure 1) while the PMF-2 film showed time-dependent currents at higher temperatures (figure 2). Figure 2 shows that absorption and resorption current for PMF-2 above and below 160°C is sharply divided into two characters and so this temperature of 160°C may be the glass transition or critical temperature for PMF-2.

Atkinson and Fleming (1980) showed that absorption currents in non-polar materials were largely due to currents flowing on the surface of the polymer from the edges of the electrode. We may therefore conclude that the time-dependent parts of the currents for PMF-2 up to 120°C is due only to the outside fluorocarbon layers of the film.