Journal of Alloys and Compounds, 194 (1993) L1–L3
JALCOM 603

Letter

Electrical conduction of potassium yttrium fluoride thin films

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(Received September 9, 1992)

The study of electrical conduction in thin dielectric films is of interest in various branches of electronics and has attracted much attention [1]. The rare earth oxides and fluorides seem to be promising materials for device applications because of their chemical and thermal stability [2]. This letter reports an investigation of current transport mechanism in potassium yttrium fluoride thin films as a function of applied voltage and temperature.

Potassium yttrium fluoride (KYF_4) was prepared in our laboratory by the solid state diffusion method [3]. KYF_4 powder was thermally evaporated from a tantalum boat on to precleaned Pyrex glass substrates under a vacuum of 2×10^{-5} Torr. Information on electrode structure, effective film area and other details is given elsewhere [4]. Prior to deposition, the powder was heated at a low temperature until it formed a lump from which the evaporation took place. Thick deposits of silver were used as top and bottom electrodes and thin film capacitors were fabricated in a metal–insulator–metal structure. The thickness of the film was measured by the multiple beam interferometry technique developed by Tolansky [5].

For studying the current–voltage characteristics the sandwich structure was placed in a circuit consisting of a d.c. source, a potential divider and a d.c. field effect transistor nanoammeter.

X-Ray diffraction analysis revealed the amorphous nature of the KYF_4 films. Several rare earth oxide and fluoride films [6, 7] exhibit amorphous structure.

The current–voltage characteristics of the KYF_4 films with a thickness of 360 nm are shown in Fig. 1 for different temperatures.

It is found that the current exhibited a voltage dependence of the form $I \alpha V^n$, where n depends on the field strength. The large thickness of the KYF_4 film (360 nm) used in the present investigation rules

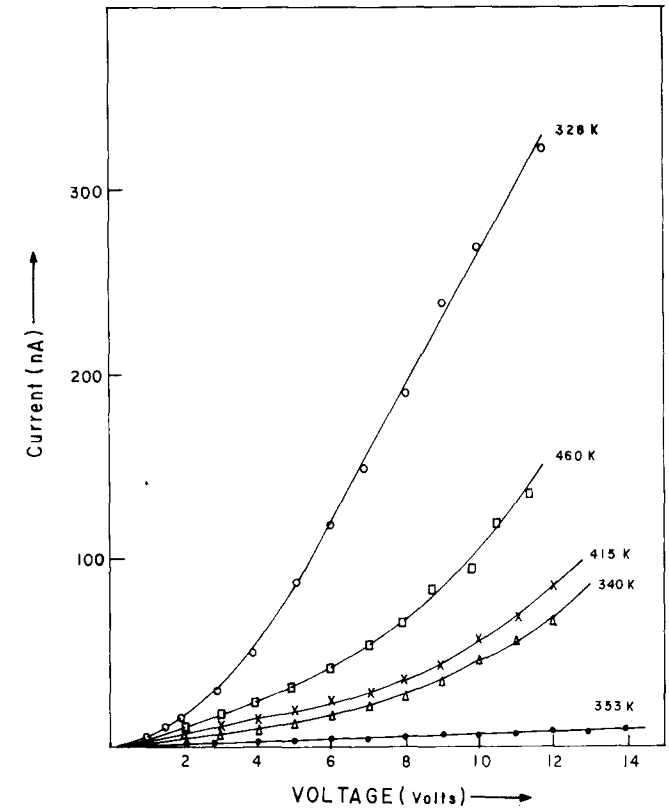

Fig. 1. Current–voltage characteristic of potassium yttrium fluoride film at different temperatures.

out a conduction mechanism by tunnelling. The current density in the space charge limited conduction (SCLC) [8–10] region is not followed; hence, the possibility of SCLC is also ruled out for the KYF_4 film.

The variation of log I with the square root of the electric field at different temperatures is shown in Fig. 2. The curves exhibit slight deviation from straight line characteristics at low fields, and this has been attributed to contact potential effects [11]. The straight line nature of the curves at higher fields may be understood in terms of either Schottky (S) or Poole–Frenkel (PF) mechanisms. In the Schottky emission process, electrons are emitted from the metal electrode into the conduction band of the insulating film over the image force interfacial barrier under attendant lowering of the applied electric field. In the Poole–Frenkel mechanism, the conduction is limited by the field-enhanced thermal emission of electrons from a discrete trap level into the conduction band. At high electric fields ($E > 10^6$ Vm^{-1}) several dielectric and semiconducting thin films [12–14] exhibit a current–voltage relationship charac-

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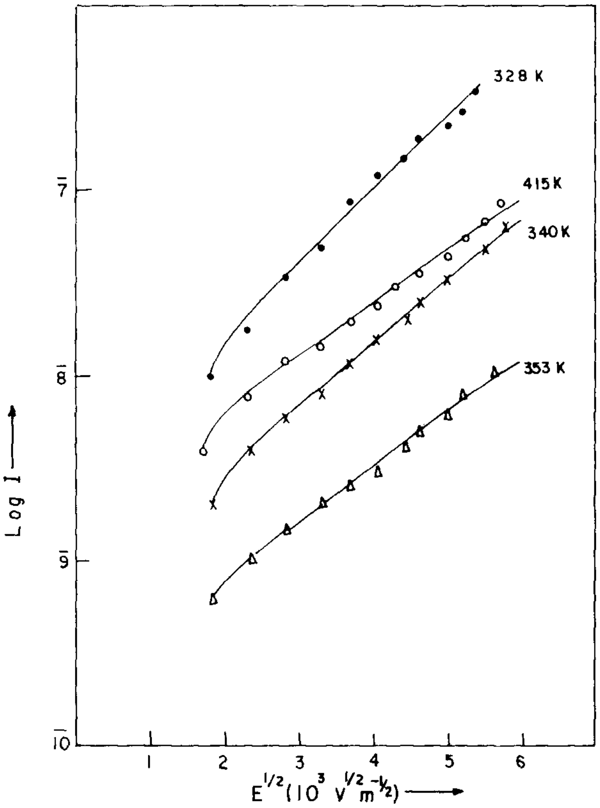

Fig. 2. Plot of log current *vs.* the square root of the applied field strength at different temperatures.

teristic of the form [15, 16]

$$I=I_0\exp(e\beta E^{1/2}/KT) \quad (1)$$

where $E=v/d$ and β is a constant given by

$$\beta=(e/\alpha\lambda\pi\epsilon_0\epsilon')^{1/2} \quad (2)$$

where e is the electronic charge, ϵ_0 the permittivity of free space and ϵ' the high frequency dielectric constant.

The value of α is 1 for Poole–Frenkel emission and 4 for Schottky emission. Since ϵ' appears to the power half in eqn. (2) it can be regarded as being of secondary importance as far as its effect on the theoretical magnitude of β is concerned [17]. In the present investigation the high frequency dielectric constant of 3.79 calculated from the usual parallel plate formula has been used for the evaluation of β in eqn. (2).

The slope of the straight lines obtained from log I *vs.* $E^{1/2}$ (Fig. 2) are plotted against e/KT, as shown in Fig. 3. From the slope of the straight line thus obtained, the experimental value of β can be calculated [15]. The theoretical values obtained from eqn. (2) are

$$\beta_S=1.71\times10^{-5}(mV)^{1/2}$$

$$\beta_{PF}=3.43\times10^{-5}(mV)^{1/2}$$

The experimental value of β derived from eqn. (1) is

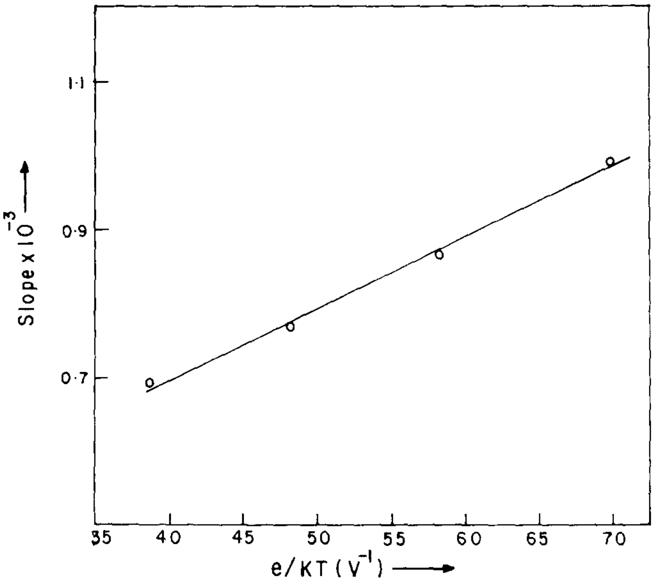

Fig. 3. Slope of the curve I *vs.* $E^{1/2}$ shown in Fig. 2 plotted against e/KT.

$$\beta_{exp}=3.90\times10^{-5}(mV)^{1/2}$$

Since the value of β_{exp} is closer to β_{PF} than to β_S, the conduction mechanism seem to be predominantly that of Poole–Frenkel emission for the temperature range studied.

Acknowledgments

The authors thank Prof. K. Rama Reddy, Head, Department of Physics, Osmania University, for providing laboratory facilities. M.N.C. thanks the Council of Scientific and Industrial Research for the financial assistance to carry out this work. M.D.S. is grateful to CSIR for the award of an SRF.

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