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Aging And Dielectric Response Of $NaYF_4$ Thin Films

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ABSTRACT

Sodium Yttrium Fluoride thin films were prepared by vacuum thermal evaporation under vacuum (10^{-5} torr). Thickness of the films were measured by Tolansky's interferometric technique. Variation of the effect of aging, AC voltage with capacitance and loss tangent were studied. The time dependent decay behaviour of the thin film capacitor at a given AC voltage and also the percentage variation of capacitance with frequency were studied and the results were discussed.

KEYWORDS

Loss tangent;
Capacitance;
Thin films;
Vacuum.

INTRODUCTION

Thin insulating films find a large number of applications in micro electronics and in optical devices. Rare earth compounds have attracted particular attention for device applications owing to their mechanical and chemical stability[1,2]. Dielectric materials are employed in the preparation of thin film capacitors and attempts have been made to explore new materials and study their characteristics. To a large extent this has been associated with the more stringent requirements on the parameters and the reliability of micro integrated circuits. The required degree of perfection varies according to the specific application. In all these applications its is mandatory that the insulating film retains its insulating properties with time and stress. DC conductivity[3], electrical behaviour[4] in $NaYF_4$ thin films were studied earlier. In the present paper, the effect of aging on the capacitor, percentage variation of capacitance with frequency, effect of AC voltage and time dependent decay behaviour of vacuum evaporated $NaYF_4$ thin films were investigated.

EXPERIMENTAL

Sodium yttrium fluoride compound was prepared in our laboratory by solid state diffusion method[5]. $NaYF_4$ powder was thermally evaporated from a tantalum boat on to glass substrates under a vacuum of 2 x 10^{-5} Torr. Information of electrode structure, effective film area and other details were given elsewhere[6]. Prior to deposition, the powder was heated at a low temperature until it is formed a lump from which the evaporation took place. Thick deposits of alluminium were used as top and bottom electrodes and thin film capacitors were prepared in a metal-insulator-metal structure. The thickness of the film was measured by the multiple beam intereferometry technique developed by Tolansky[7]. The capacitance and loss tangent were measured using systronics LCR Bridge type 921 with Philips external frequency generator.

RESULTS AND DISCUSSION

The variation of capacitance with aging time at different frequencies for $NaYF_4$ film (thickness of 3050 Å) is shown in figure 1. Capacitance of the capacitor decreases as the aging time increases. Ini-

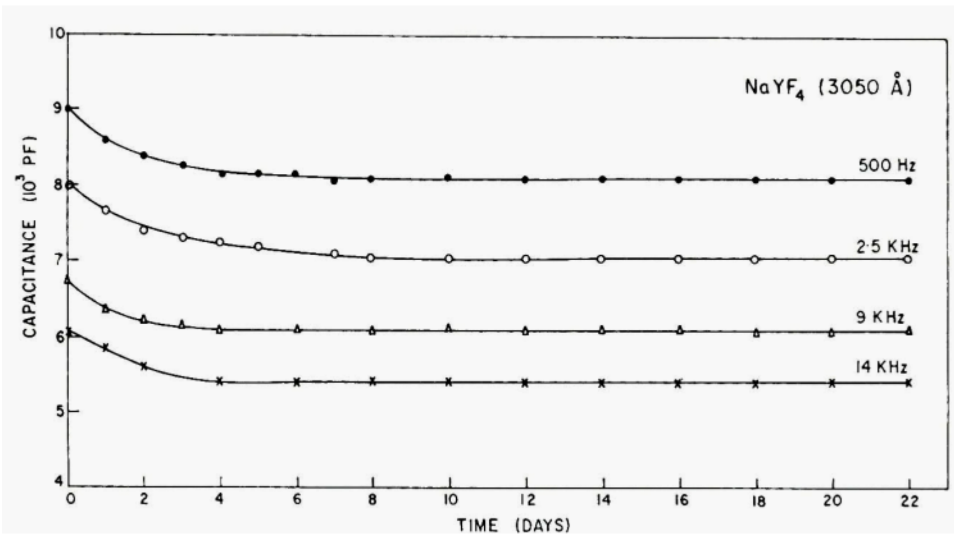

Figure 1: Capacitance with aging time

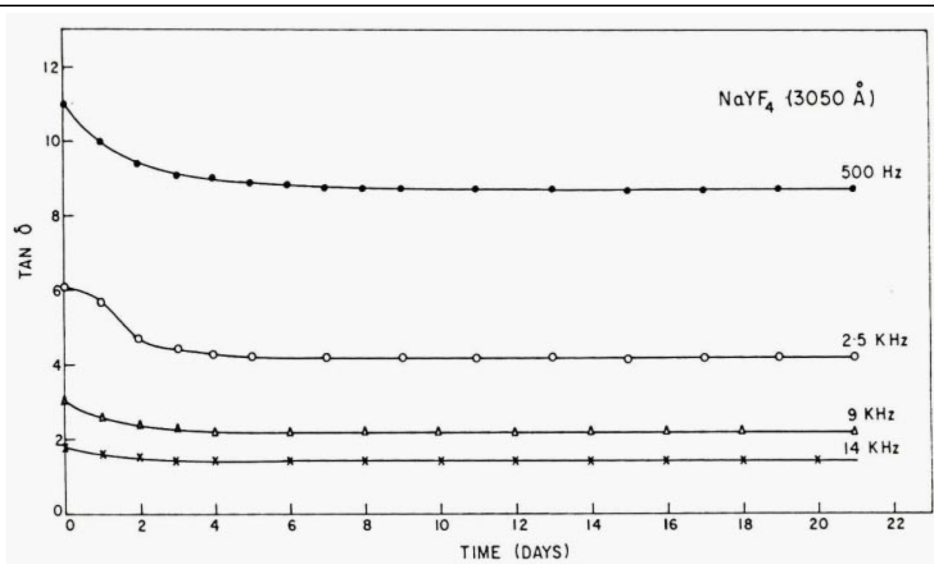

Figure 2: Tan δ with aging time

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tially the capacitance of the dielectric film falls off rapidly and thereafter it attains a constant value even after aging the capacitor for about 20 days. The variation in capacitance is more with aging time for lower frequencies whereas the effect is not much for higher frequencies. The variation of tan δ with aging time for different frequencies of $NaYF_4$ thin film (thickness of 3050 Å) is shown in figure 2. The change in tan δ with aging time is found to be a function of frequency. The change is more at low frequencies. The tan δ decreases rapidly after the capacitor ages for 2-3 days and the decrease is gradual thereafter. The percentage variation of capacitance (Δ C/C)% with frequency for four dielectric film thickness of $NaYF_4$ films normalized at 1 kHz is shown in figure 3. The results clearly indicate that the percentage variation in capacitance is more at frequencies less than 1 kHz. The percentage variation of capacitance normalized at 1kHz changed from a positive value to a negative value with increase of frequency. From this figure, it is clear that at low frequencies, the capacitance strongly depends upon the frequency. The variation of capacitance and tan δ with applied AC voltage at different frequencies 1,5 and 10 kHz for a $NaYF_4$ film of thickness 2070 Å is shown in figure 4. Capacitance in general increases with increase of AC voltage. Initially upto 2.0 volts, the change in the capacitance is not much, but thereafter, the increase in capacitance is considerable upto 13 VAC for the film at 1kHz. The capacitance increases slowly with increase of AC voltage at the frequencies of 5 and 10 kHz. But after 9 volts of AC the capacitance and tan δ increases rapidly even for a small increase of AC voltage. Further increase of voltage beyond 9 volts, it is found that the capacitor becomes unstable and the values of capacitance and tan δ are found to be time-dependent. The decay characteristic of the capacitor maintained at 9.0 V AC and at a frequency of 5 kHz of $NaYF_4$ film (thickness 2070 Å) is shown in fig.5. Initially the capacitance and tan δ falls off rapidly and the variation is small afterwards. The capacitance and tan δ attains a constant value after 160 minutes. The aging behaviour of $NaYF_4$ film shown in figure 1 and 2 has been observed by many researchers in the dielectric films[8-11]. In freshly prepared dielectric films, many defects such as vacancies, voids, dislocations, grain boundaries and stacking faults may be present and during the aging process, some of them may be annealed out. It is well known that each defect is associated with some strain energy and the decrease in the density of defects with aging results in the decrease of strain energy. Planar and Philips[12] thought the fall in capacitance may be due to the relief in strain energy, associated with these defects as suggested by Anderson[13] and Neugebauer[14]. The

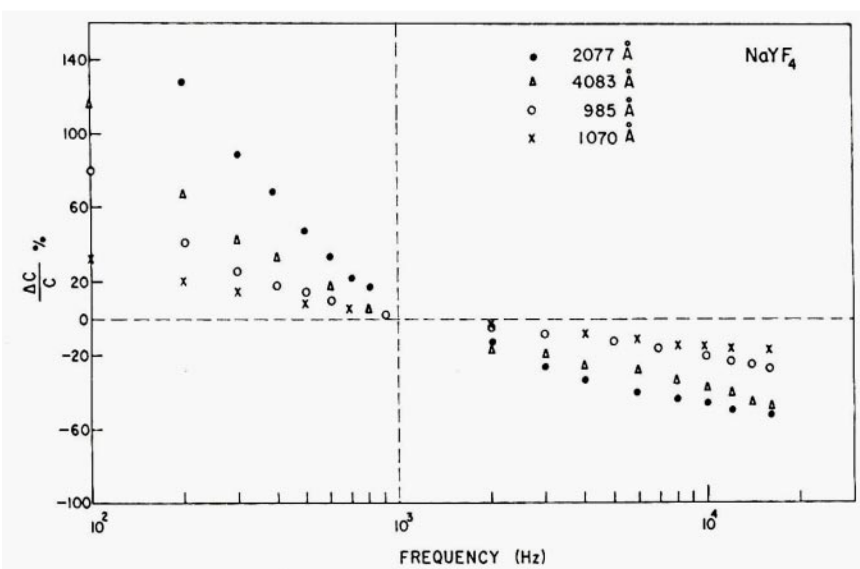

Figure 3: Percentage variation of capacitance with frequency normalized at 1kHz

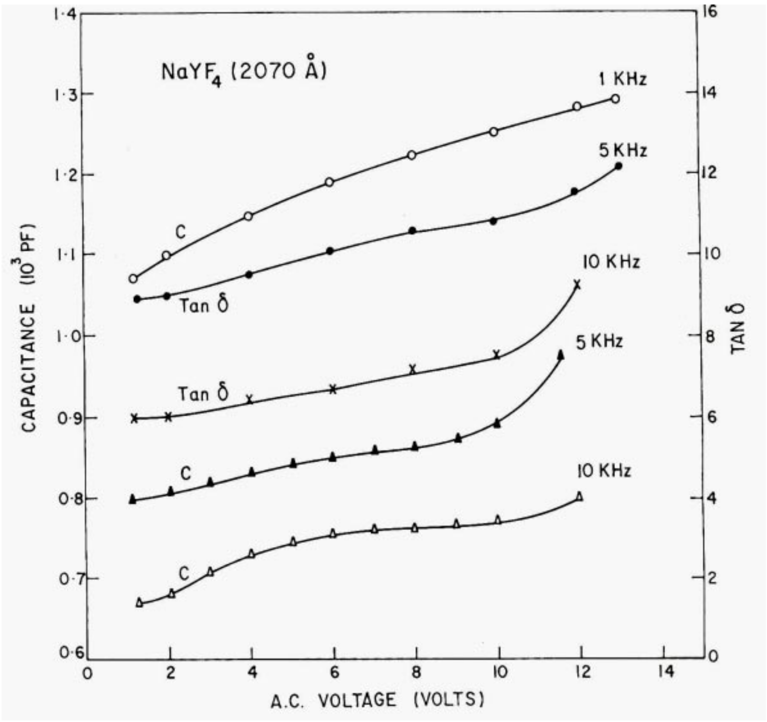

Figure 4: Variation of C and tan δ with AC voltage

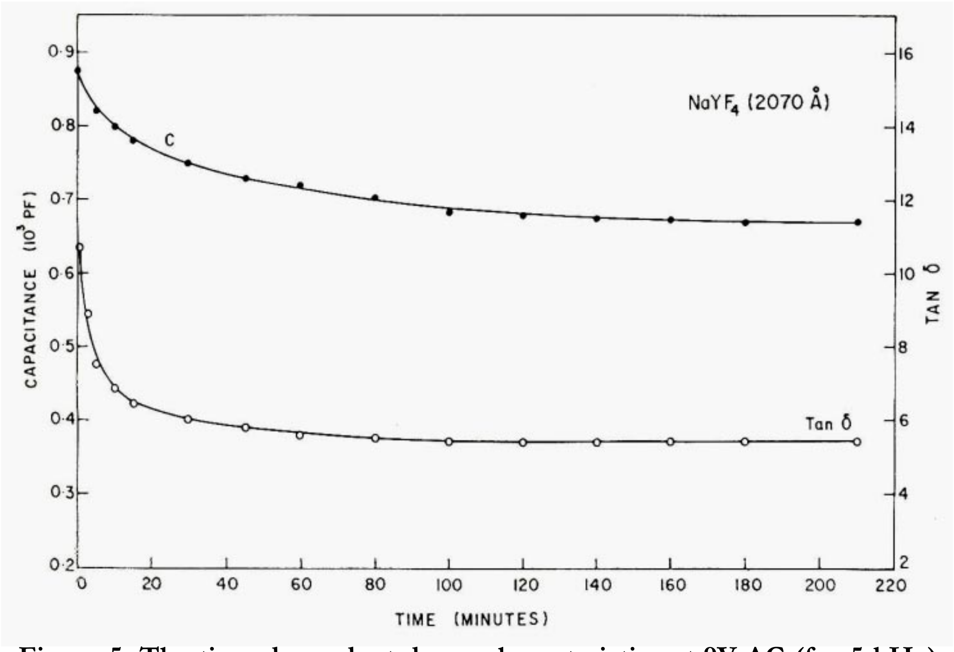

Figure 5: The time dependent decay characteristics at 9V AC (f = 5 kHz)

fall in capacitance and tan δ is rapid at the beginning and this again may be due to the rapid decrease in the density of defects. The gradual variation in capacitance and tan δ afterwards may be due to the gradual anneal of other defects.

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