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Surface Modified Chitosan Films as Dielectric Material for New Generation Integrated Circuits

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Abstract: The unexplored feature of chitosan and composite films, the dielectric property was calibrated to utilize the films to substitute currently used silicone dielectric layers in integrated circuits. Fortunately, we found that chitosan films exhibited dielectric values less than 3.9, the dielectric constant of currently used SiO_2 material. The performances of new generation integrated circuits are inversely related to dielectric values of inter layer insulating materials. Hence we modified the surface of chitosan by incorporating nanoZnO particles so as to make it surface coarse and patchy to reduce its dielectric constant lower than naive chitosan film. The dielectric values of composite films were lower than that of naive chitosan film.

Introduction

The feature of size of integrated circuits is scaling down to the nano size inducing new challenges like low electrical resistance, time delay caused by wire capacitance and cross talk between circuits. In this regard, the material chemists have been active to develop new functional materials to comply with the performance of new generation dielectric materials (Zhao & Liu, 2010). The major setback experienced by the researchers while reducing the size of integrated circuit is the inductive cross talk between the circuits. It consists of signal delay during the transmission due to undesirable capacitive effects in the neighbouring circuits. The inter connect delay can be calculated as

$$T = RC = 2\rho\varepsilon\varepsilon_0[(4L^2/P^2) + (L^2/T^2)] \quad (1)$$

where T = signal delay time, R = resistance, C = capacitance, ρ = specific resistance of the conductor, ε = the dielectric constant of the material, ε_0 = the dielectric constant of the vacuum, L = length of the conductor, T = thickness of the conductor, P = distance between the conducting lines. As per the relation (1), the smooth signal transmission can be achieved in three different ways, (i) tuning the ratio of length to thickness of circuit (L/P), (ii) decreasing the specific resistance (ρ) and (iii) reducing the value dielectric constant (ε). The focus on the second aspect has aboard the materialist in the replacement of aluminium metal with the copper in silicone inter-layer circuits. But the direct use of copper in the place of aluminium in presently using Al-SiO_2 integrated circuits is not an easy task since it created new troubles like slow diffusion of copper into silicone inter layer. So far, no further advancement in this regard was reported.

An alternative approach is the use of a low dielectric material in the place of currently using SiO_2 film. The dielectric constant of silica is 3.9 and it was deposited on aluminium metal by chemical vapourdeposition at high temperature (Maier, 2001).Any material with lower dielectric constant than silicon dioxide is the better choice if it would satisfy the following conditions a) posses low dielectric constant, b) good chemical stability, c) high thermal stability-glass transition temperature

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greater than 250^{0}C, d) good adhesion to various substances, e) high mechanical strength and f) low water adsorption. Material chemists all over the world are on the search to find out an ideal film which complies with all above specifications (Zhao *et al*., 2008). The hunt on the new material has produced a lot of synthetic organic films but the achievements are still far away from the ideal material (Maier, 2001). The dielectric constants of different polymers are listed in Table 1.

Table 1. List of polymers with dielectric constant.

Sl. No	Polymer	Dielectric constant
1	Non –fluorinated aromatic polyimides	3.3-3.6
2	fluorinated aromatic polyimides	2.6-3
3	Poly phenyl quinoxalin	3.0
4	Poly acrylene ether	2.6-3.0
5	Poly quinoline	2.8
6	Silsesqiuoxane	2.8-3.0
7	Polyindane	2.6
8	Parylene N	2.6
9	Poly norborene	2.4
10	Perfluorocyclobutane	2.4
11	Poly naphthalene N	2.4
12	Teflon	1.9
13	Polythene	2.5

The value of dielectric constant of a material is directly related to the polarizability of a material. The polarizability is the measure of ability of the material to respond to an electric field and to manage an electric dipole moment, The relation between the dielectric constant and the polarization properties of the molecules is

$$(\varepsilon_r-1) / (\varepsilon_r+2) = N/3\varepsilon_0 \; (\alpha_e + \alpha_d + \mu^2/3kT) \quad (2)$$

where ε_r = dielectric constant, N = the number of molecules per unit volume, α_e = electronicpolarization, α_d= distortion polarization ,μ = orientation polarization, k= Boltzmann constant. The above relation clearly exhibited schematically presented in Figure 1.

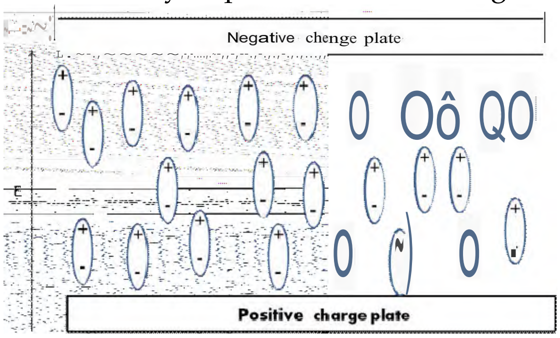

Fig.1. Scheme of polarization in the presence of applied field.

that the dielectric constant of any material can bring down either by lowering the number of polarisable molecules per unit volume of material or by reducing the polarization ability of the material. The polarization ability was reduced by decreasing the number of polar bonds in the molecule, where as the notion of lowering the number of molecules per unit volume was materialized by surface modification of material. This surface modification was achieved by introducing pores in the surface of material. When these surface pores are trapped with air (ε=1), the density of material decreases and consequently net dielectric constant is lowered (Maex *et al*.,2003).

In the present work we selected naive chitosan film (C) and surface modified chitosan films with different quantity of nanoZnO particles (CZ1, CZ2, CZ3 and CZ4). The dielectric constant values of all the films were determined at different temperatures.

Experimental

The composite films were prepared in a similar procedure as reported earlier (Rahman *et al.*, 2015). Dielectric constant of films was measured at different temperatures using an impedance analyzer. The impedance was measured with HOIKY 3532-50 LCR HI-Tester, interfaced to a computer by applying alternating current (AC) signals across the film with blocking silver electrode. The frequency range (100 - 5MHz) was set to assess the impedance and phase angle. The dielectric constant was calculated from the measured data using the value of thickness of the film.

Results and discussion

The result of dielectric constant of films C, CZ1, CZ2, CZ3 and CZ4 at room temperature, 50, 100 and 200⁰C were shown in the figures (2, 3, 4 & 5)

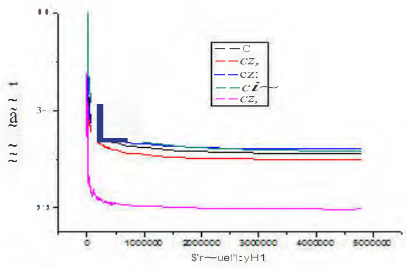

Fig. 2. Dielectric constant values at room temperature.

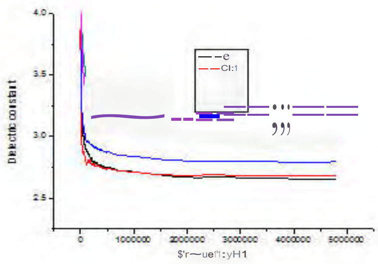

Fig. 3. Dielectric constantvalues at 50⁰C

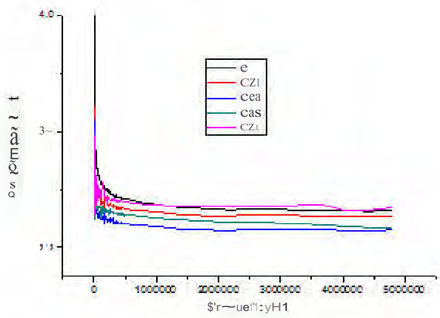

Fig. 4. Dielectric constant values at 100⁰C

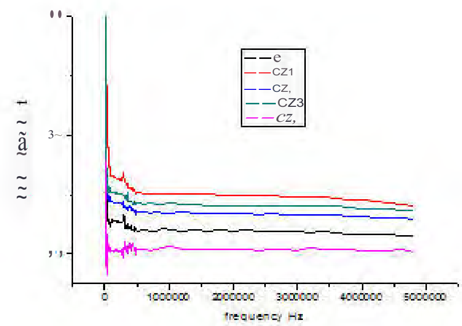

Fig. 5. Dielectric constant values at 200⁰C

As shown in the figures (2, 3, 4 & 5) all the films exhibited the dielectric value below 4; the dielectric constant of SiO_2 film; in a wide range frequencies. In general case, the trend of variation of dielectric constant along with the frequency was a continuous decrease of dielectric value with the increase of frequency and this property was attributed to the inability of polarisation to respond with fast changing electric field (Cetiner*et al.*,2015). Surprisingly, our films showed an anomalous trend as compared to common features. In the case of all films, the dielectric constant values maintained almost constant throughout a wide range of frequencies. This unnatural phenomenon was ascribed to the ability of films to maintain a constant polarization irrespective of frequency of change of external electric field.

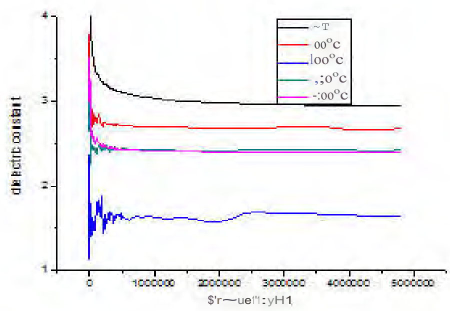

Fig. 6. Dielectric constant values of CZ2 at different temperatures.

As shown in the **Fig. 6**, the films exhibited lower dielectric constant values at higher temperatures as compared to room temperature. When the temperature of the films increases, two phenomena; dehydration and thermal mobility would take place. Dehydration of films would decrease the dielectric values whereas enhanced thermal mobility would increase the dielectric constant values. The nonlinear variation of dielectric constant values of the films observed in Fig. 6 at different temperatures was attributed to the inter play of both these opposing effects (Psarras, 2006).

Conclusion

First ever the dielectric properties of chitosan as well as its nano composite were explored. The dielectric values of the nano composite films at different temperatures were determined. All the films exhibited lower dielectric constant values than currently using inter layer material SiO_2 films. The result would open up new avenues of research in the field of new generation inter connecting circuits.

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