Preparation of Poly (methyl methacrylate) thin film Capacitors on ITO-glass substrate

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Abstract: In electronic devices, some important materials having a high dielectric constant can be used. Polymer-ceramic composites have a high dielectric constant and are widely used for embedded capacitor applications. It is critical to use polymer poly methyl methacrylate (PMMA) as thin films capacitors for the gate dielectric in organic field-effect transistors (OFETs). In this work, thin films of polymer PMMA were prepared by using spin coating at different speeds (1500, 2000, 2500, 3000 and 3500 rpm) to control the film thickness and study the effect of the thickness on the dielectric properties. Thin film thickness was measured by using field emission scanning electron microscopy (FESEM) to take cross-section images. We found that the film thickness decreased with increased rotational speed from 27387 nm at 1500 rpm to 10600 nm at 3500 rpm. The values of the capacities were nearly stable with increasing frequencies when thickness equal to or larger than (14366 nm), but their increased with increased frequency at thickness (10600 nm), and the dielectric constant also decreases with increasing thin films thickness. The best result of capacitance value was at thickness 10600nm which equal to (5.753 nF) and dielectric constant equal to (3.511) which represents best value that can be used as dielectric gate for Organic Field Effect Transistor (OFET).

***Keywords*: PMMA, Spin speed, ITO-glass, Dielectric constant, Capacitance.**

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1. Introduction

The polymer is a large molecule that composed made of many small chemical molecules called Monomers that are linked together by chemical bonds to form the polymer. Organic polymers used as gate dielectric for organic field effect transistors (organic electronics) include polyvinyl phenol (PVP), polyvinyl- alcohol (PVA), polymethacrylate (PMA), polyimide, polycarbonate, polynorbornene, poly(a-methylstyrene), parylene, benzocyclobutene, and polymethylmethacrylate (PMMA) [1,2,3]. The development of thin film as a dielectric gate for field effect transistors can be improved by using PMMA and PVA, whose chemical structures are shown in Fig.(1) [4, 5]. The dielectric polymer can be prepared by dissolving it in organic solvent, then using spin coating or drop casting to introduced organic thin film transistors (OTFT)[6,7]. Glass and Si wafers are rigid substrates used to improve the performance of OTFT with inorganic gate dielectrics in polymer gate insulators. Polymer gate insulators must have a high breakdown voltage, good resistance against moisture, a high dielectric constant, and a good surface alignment effect for active materials [8]. Passivation layers are necessary for long-term current stability in the operation of thin-film transistors (TFTs). So far, various organic or inorganic passivation layers such as polymers, SiO_2, SiNx, and Al_2O_3 have been used. The dielectric polymer PMMA can be prepared by sputter-deposited thin films as a gate dielectric in TFTs these appears more suitability of passivation layers for producing electrically stable InGaZnO4 TFTs on a plastic substrate[9].

Liwei et al, 2009 used polymethyl methacrylate (PMMA)/ZrO_2 dielectric in copper-phthalocyanine (CuPc) organic field-effect transistors (OFET). They found that the typical field-effect transistor mobility , threshold voltage , on/off current ratio and subthreshold slope of OFETs with bilayer dielectric were 5.6×10^{-2} $cm^2/V{\cdot}s$, 0.8 V, 1.2×10^3 and 2.1 V/dec, respectively [10]. D. Yang et al, 2013 used a thin film dielectric layer of PMMA to synthesize an OFET as a photo detector field effect transistor. They found that the photo detector (520 nm) PMMA showed a maximum responsiveness of (149 mA/W) under monochromatic light (450 nm) at V_{DS}=-20V [11]. Ismail et al, 2018 were fabricating of p-type organic field effects transistor (OFET). The p-type OFETs were fabricated using poly (methyl methacrylate): titanium dioxide (PMMA:TiO_2) nanocomposite material as the gate dielectric, The I-V characteristics showed that the fabricated p-type OFET has a moderate performance with threshold voltage V_{TH} of (-3V) and mobility μ of (2.01 cm^2 V^{-1} s) [12]. The aim of this work was to prepare thin films polymethyl methacrylate (PMMA) with different thicknesses that are measured using FESEM and study their dielectric Properties.

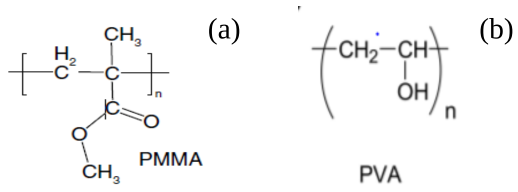


Fig.(1): Chemical structure of (a) PMMA [13] (b) PVA [14].

2. Procedure

2.1. Preparation of PMMA thin films

Fabrication of the capacitor using the spin coating method for the thin film as dielectric with different speeds of rotation was performed on ITO-glass substrate, the other electrode was aluminum prepared by vapor deposition. The structure of the synthesized capacitor is shown in Fig.(2). At the first, 0.6g of PMMA is dissolved in 10 ml of toluene and mixed by magnetic stirrer at room temperature for 3hr., then the solution was filtered using syringe filter (0.45um) and coated on ITO-glass by spin coating at different spin rates for 60sec. PMMA spin coated films dried at 80 ^{o}C in oven for 60 min. The thickness of the thin films was measured using the FESEM technique.

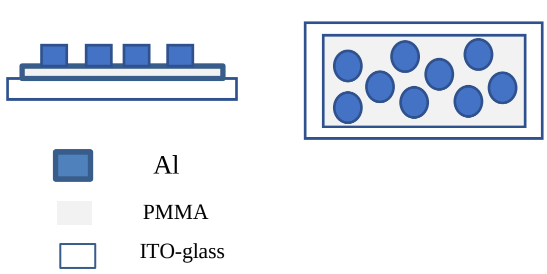


Fig. (2): The structure of capacitor (ITO/PMMA/Al).

2.2. Thickness measurement

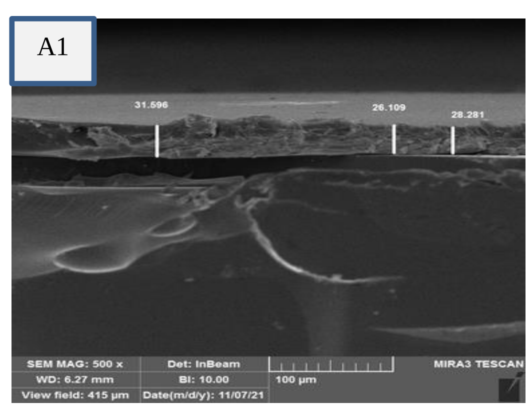
The technique of cross-section is very widespread and relatively simple to use. In this work the samples (A1, A2, A3, A4 and A5) were prepared from polymer PMMA on ITO-glass substrate using spin coating for different rotational speed and then annealing for (60 min) at (60-80) ^{o}C. These samples are cut into two small pieces and observing it transversely along the layers, where the cut edge was perpendicular to the surface of thin films and the thickness measured directly.

3. Results and Discussion:

Fig.(3) represents the image for cross-sections of thin films which are taken by FESEM; all data are illustrated in table (1).

Table (1): Relation of rotational speed with the thickness.

No. of Symbol	Rotational speed (rpm)	d(nm)	C(nF)	ε_r
A1	1500	27387	0.34073	0.53728
A2	2000	19927	0.3787	0.434495
A3	2500	17840	1.374	1.41133
A4	3000	14366	1.206	0.99754
A5	3500	10600	5.753	3.511



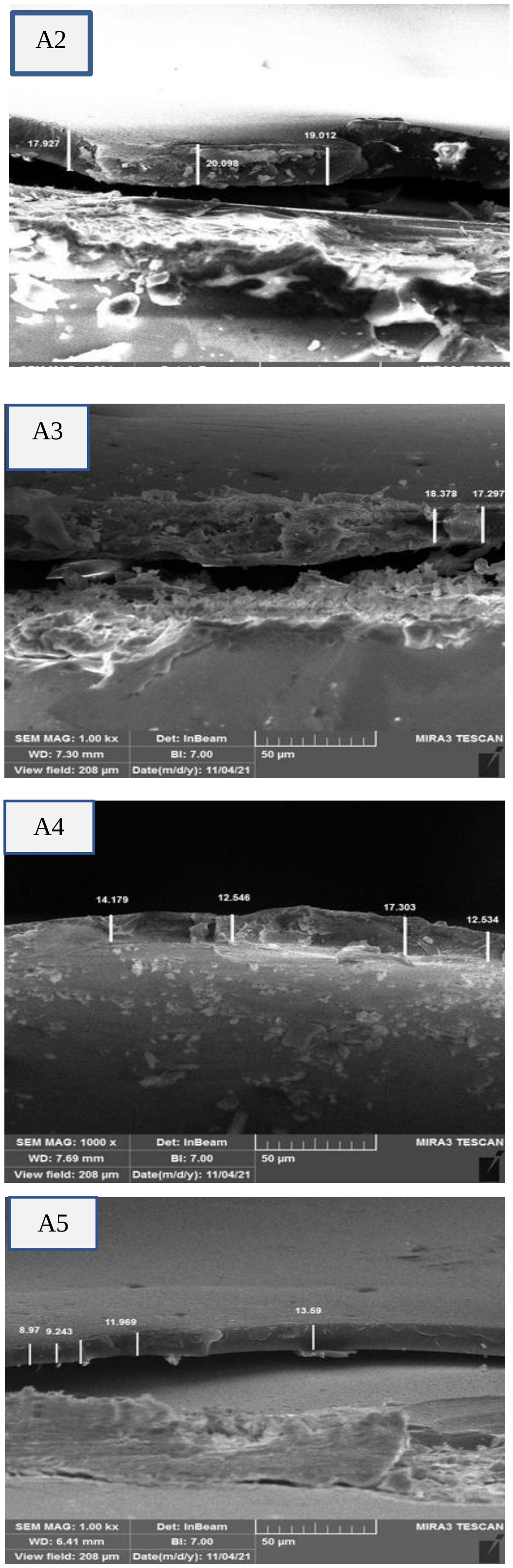


Fig. (3): FESEM cross-section for PMMA thin filmsA1(1500rpm), A2 (2000rpm),A3(2500rpm), A4 (3000rpm), and A5(3500rpm).

The variation of the capacitance as a function of frequency of Polymer PMMA thin films at room temperature with different thickness are shown in Fig.(4), from this figure it notice that the values of the capacities were nearly stable with increasing in frequencies for all films that having thickness equal to or larger than (14366nm). But for the thickness (10600 nm) the behavior was different from other samples, where it was increased with increasing the frequency, that was happened occurred because of increasing in rotational speed at (3500 rpm). these results are compatible with those obtained by Bendu et al. [6].

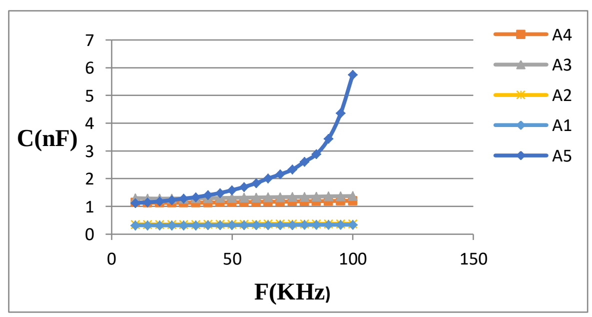


Fig.(4): the capacitance vs. frequency for polymer PMMA thin films.

From the relation between the capacitance of the dielectric material (C) and thin film thickness (d) the dielectric constant (ε_r) can be calculated using the following equation (1) [15]:

$$\varepsilon_r = C\frac{d}{\varepsilon_o A} \ldots\ldots\ldots\ldots\ldots..(1)$$

Where: ε_o, represents the permittivity of free space. A, represents the area of the pellet (capacitor).All data was inserted in Table (1), the relationship between the dielectric constant and thin film thickness is shown in Fig.(5),

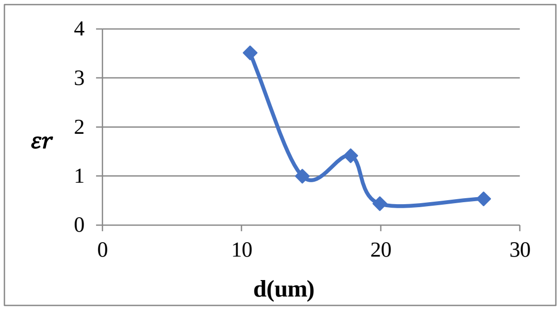


Fig.(5): The dielectric constant versus thickness for PMMA.

from figure 5 we note that the dielectric constant (ε_r) decreased with increasing thickness of thin films, the result was the same as reported by (Lyly et al.) [16].

Figure 6 shows some of various parameter of thin film thickness for polymer PMMA as a, function of rotational speed and capacitance from Fig.(6-a) it seems that the thickness of thin films of polymer PMMA was decreased with increasing rotational speed (spin speed). And at the same time there was increasing in capacitance with increasing of rotational speed and decreases with thin film thickness this was illustrated in Figs.(6-b and c) because of thickness of thin films was decreases with increase of rotational speed for constant concentration of solution of polymer PMMA.

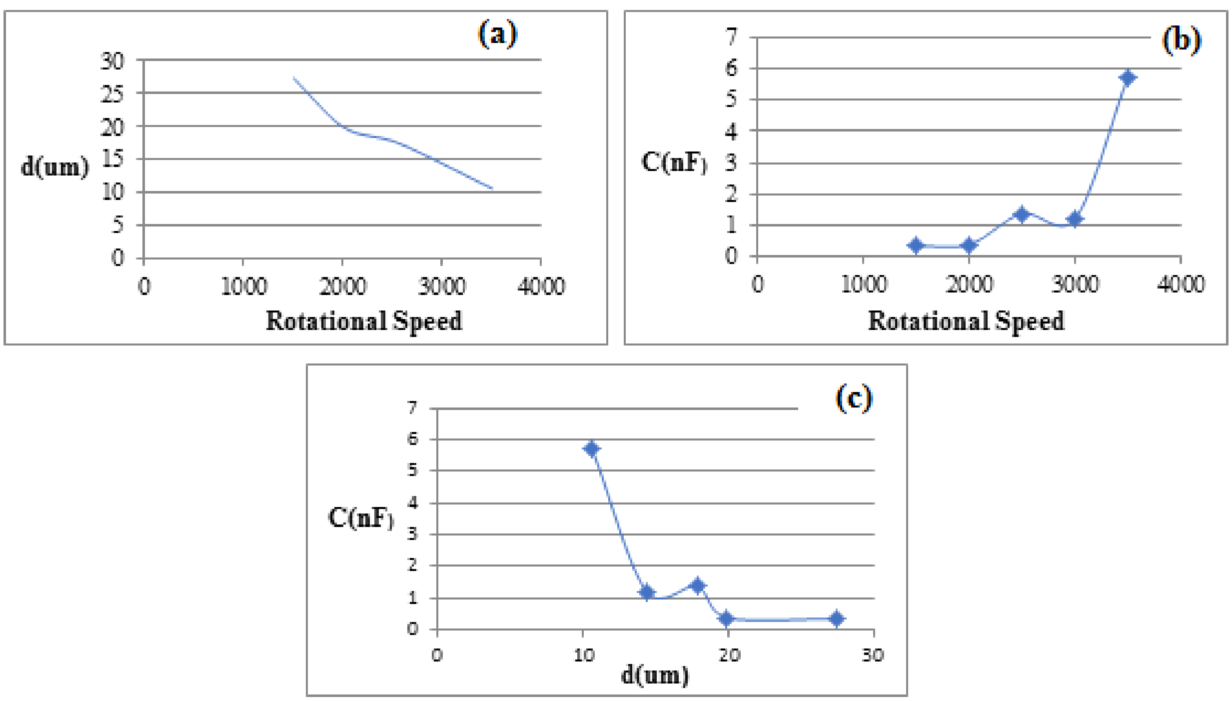


Fig. (6): Thin film thickness for PMMA: a) film thickness versus Rotational speed, b) capacitance versus Rotational speed, c) capacitance versus thickness.

4. Conclusions

Thin film thickness was decreased from 27387 nm to 10600 nm with increasing the rotational speed. The best values of capacities and dielectric constant were in the thickness (10600 nm) and it was increased with increasing frequencies. The dielectric constant was decreased with increasing thin films thickness. The best result was at the spin speed (3500rpm) having capacitance equal to (5.753nF) and dielectric constant equal to (3.511).

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