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DIELECTRIC PMMA THIN LAYERS OBTAINED BY SPIN COATING FOR ELECTRONIC APPLICATIONS

Elena Emanuela HERBEI
Interdisciplinary Research Centre in the Field of Eco-Nano Technology and Advance Materials CC-ITI, Faculty of Engineering, "Dunarea de Jos" University of Galati, 47 Domneasca, 800008 Galati, Romania
e-mail: elena.herbei@ugal.ro

ABSTRACT

Thin polymeric films with dielectric properties become a very important part of today's devices, being indispensable in industry, electrical applications and not only. Nowadays polymeric materials have attracted attention in academic and industrial research due to the miniaturization at the micro and nanoscale of different electronic devices. Polymers in general are used for their light weight, good mechanical strength, dielectric properties, and optical properties, which make them multifunctional materials.

This paper presents research on polymethyl methacrylate (PMMA) thin films obtained by the sol-gel method. The optimization of thin film PMMA layers has been a problem due to the importance of using the polymer in the different electronic domains. Thin films of PMMA with different thicknesses were deposited onto glass and silicon wafers in order to measure dielectric properties. For dielectric properties, the PMMA thin layer was inserted in a metal-insulator-metal structure (MIM). In order to observe the morphology and roughness of thin film, optical microscopy, scanning electron microscopy and atomic force microscopy have proceeded.

The dielectric constant (k) was calculated using the electrical capacitance formula. The I-V and C-V curves showed a dielectric behavior with a leakage current between 10^{-11} and 10^{-8} A and a constant capacitance in the bias range ± 5 V.

KEYWORDS: thin films, polymeric films, dielectric properties, polymethyl methacrylate

1. Introduction

The development of TFTs devices based on thin layers of polymer compounds by sol-gel became a good solution and gain special attention to the low cost obtaining.

Because of its low cost and high output like transparency, thermal stability, electrical insulation, and mechanical resistance, the thin film layer of PMMA has sparked interest for use as an insulator in electronic and optoelectronic devices [1]. It has also good optical properties (transparency in a wide range of wavelengths from near ultraviolet to near-infrared) [2, 3]. For the preparation of polymeric thin films, different types of PMMA in anisole [4] toluene, DMF [5], chloroform [6], benzoyl peroxide (BPO 98%) to start the polymerization of MMA and to obtain PMMA solution at 70 °C [7] or alcoholic solution [8], or with the value of molecular weight from 495 to 996 Kw were used. There are several methods in order to obtain thin layers of PMMA as ALD [9, 10], ink-jet printing [11] but the most used is sol-gel process due to its versatility and low-cost method [10, 12].

In order to use PMMA as dielectric gate in TFTs requires a lot of conditions to be promising materials.

Transistors parameter depend on the interface formed between dielectric and semiconductor layers, where the trapped charge has a strong influence on the device's electrical behavior [13].

The low leakage current density is highly desirable for the fabrication of stable TFTs for low-power consumption electronic devices [7, 14].

In different papers [3, 15, 16], the capacitance density of the polymeric dielectric layer was measured on the same MIM device in the frequency

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range from 1 kHz to 1 MHz and the results are promising in order to use PMMA gate in TFTs.

In this paper, we have investigated a PMMA anisole solution to prepare thin films by spin coating method, one of the most used sol-gel method, for the simple and low- cost process. We fabricated a MIM device, represented by Al top-electrode/PMMA films/Si/Ta layer substrate, to study the dielectric properties of the obtained polymeric thin films and to calculate their dielectric constant.

2. Experimental

2.1. Preparation of sols and thin films

PMMA (495 kw) in anisole was purchased from MICRO CHEM and used for the preparation of hybrid films. Polymeric solution (25%) was prepared by magnetic stirrer at room temperature. First the solution was deposited on glass substrate to have one and two layers of PMMA with 100-150 nm thickness. The deposition was done by spin-coating method at 2000 rpm for 30 seconds.

After optimisation of the thickness the solution was spin coated for 30 seconds in air, onto the n-doped Si substrates covered with a layer of 100 nm tantalum (Figure 1a). The as-deposed films were thermally treated on hot plate at 120 °C for 30 minutes.

Before film deposition, the substrates were cleaned using the following procedure: washed in water for three times, dipped in isopropanol for 1 minute and cleaned with water, dried with nitrogen stream and hotplate for 5 minutes at 120 °C. To have a MIM structure, after PMMA deposition (Figure 1b), metallic aluminium contacts (Figure 1c) were thermally evaporated through a shadow mask with different areas (180, 320 and 680 μm diameters) resulting a multi-layer structure (Figure 2).

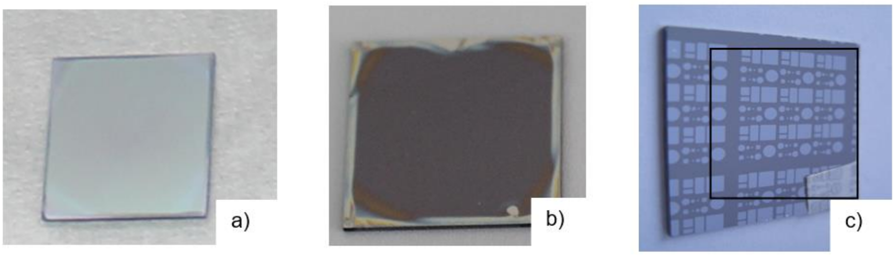

Fig. 1. *a) Si substrate with Ta (100 nm); b) PMMA layers on Si substrate; c) MIM structure*

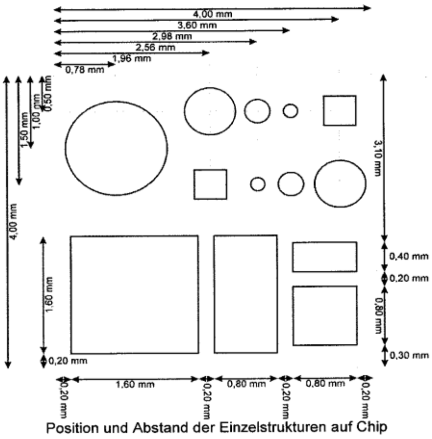

Fig. 2. *Schematic representation of electrodes areas*

2.2. Thin films characterization

The roughness was investigated with atomic force microscopy and for surface and cross-section morphology of the polymeric thin films was used a scanning electron microscopy (SEM) using a EOL JSM-7500F/FA microscope.

The I-V and C-V curves of the hybrid films were measured by including them into a Metal-Insulator-Metal (MIM) structure (Fig. 3), using Agilent 4156 and HP 4277A Analysers, respectively, at 1 MHz.

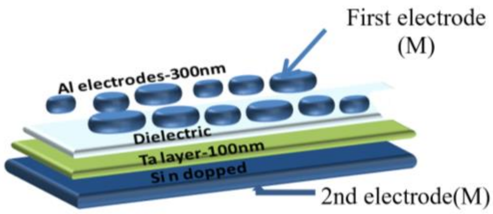

Fig. 3. *Schematic representation (a, b) of MIM structure used for the measurement of I-V and C-V characteristics of thin films*

3. Results and discussion

In Figure 4a and 4b are presented the AFM and SEM images of PMMA layer by comparison. The

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structure of film is homogenous the entire surface having a specific relief as a honeycomb do to the high molecular weight. The thermal treatment applied for stabilisation is modifying the structure.

From the AFM roughness we can observe that is between 15 to 25 nm (Figure 5).

Figure 6 shows the I–V and C-V characteristics of the investigated films, at gate voltages from 4 to +4 V. The leakage current density is 10^{-6} to 10^{-1} A/cm^2 Further studies are considered to correlate the dielectric behaviour of films with the effect of temperature, number of layers and duration of post-deposition thermal treatment.

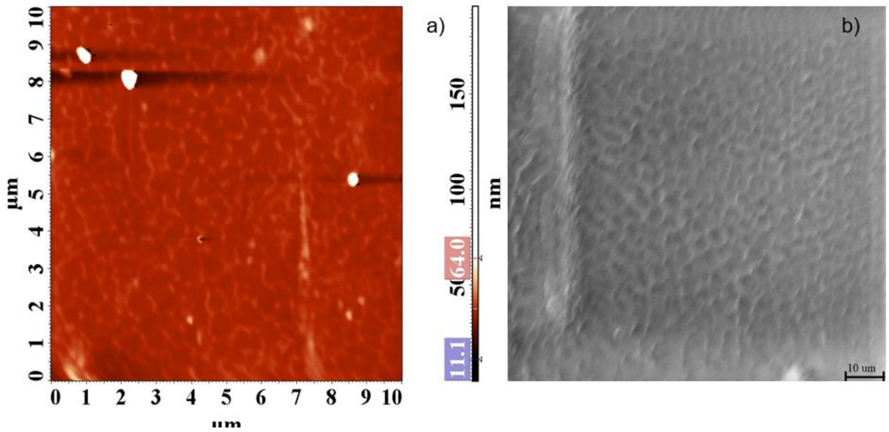

Fig. 4. *a) AFM and b) SEM images of PMMA layer*

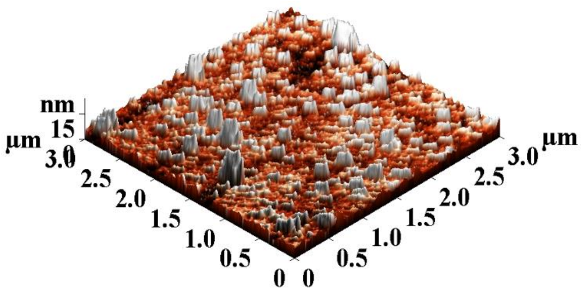

Fig. 5. *AFM image of a central PMMA layer*

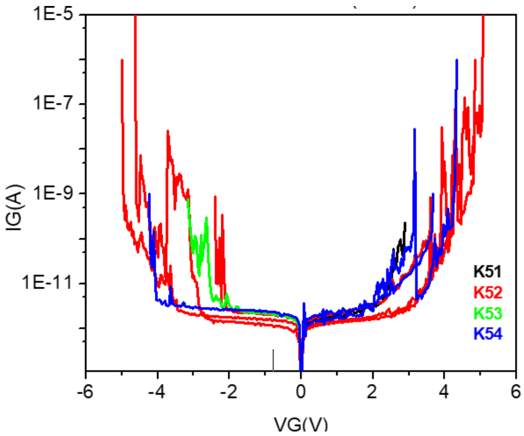

Fig. 6. *I-V characteristics for PMMA layer*

From C–V (Figure 7) curves of the investigated PMMA film, dielectric constant was calculated. The values were determined in the voltage range from -55 to + 55 V, at 1 MHz. The dielectric permittivity of a material is proportional to its electronic polarization.

The measurements showed a dielectric behaviour enough homogenous without breakdown leakage. The values of dielectric constant measured on different electrodes area varied from 3 to 4 as in Table 1.

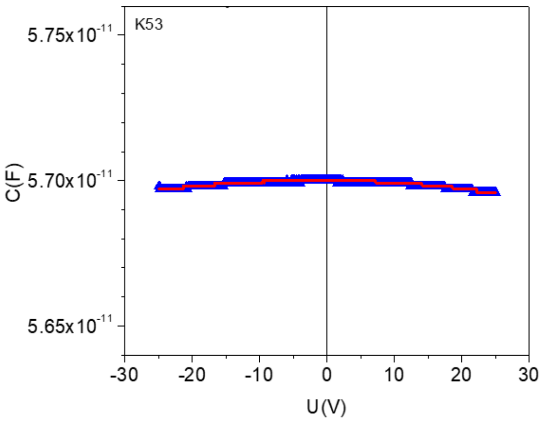

Fig. 7. *C-V characteristics for PMMA layer*

Table 1. *Electrical capacitance and dielectric values of PMMA layer for different electrodes area*

Electrode area $*10^{-4}$ cm^2	**Electrical capacitance C (F) $*10^{-11}$**			**ε_r**
	Area 1	**Area 2**	**Area 3**	
2.054 (K1)	42.32	42.04	40.67	3
8.043 (K2)	1.536	1.464	1.504	3.2
32.17 (K3)	5.511	5.295	5.291	3.8
128.7 (K4)	0.2049	0.1972	0.1971	4

4. Conclusions

PMMA dielectric thin films for flexible electronics were successfully prepared by sol-gel methods below 200 °C. The I-V curves show a leakage current between 10^{-11} and 10^{-8} A and a constant capacitance in bias range ± 4 V. Dielectric constant varying from 3 to 4 was obtained for different electrodes area films. Further investigation will be continued to establish the variation of dielectric constant on different point of thin film of the sample.

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