

Nano Organic Transistor with SiO₂ / Poly VinylPyrrolidone Dielectric

S. A. Hashemizadeh

Department of Physics, Payame Noor University, P.OBOX 19395-3697, Tehran, Iran

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ABSTRACT

In this paper, the morphology, roughness and nano structural properties of SiO₂/Poly Vinyl Pyrrolidone synthesized with sol gel method, characterized by using scanning electron microscopy, atomic force microscopy and GPS132A techniques. The main material taken from oxide silicon with weight percentage of 20, 40, 60, 80 and from poly vinyl pyrrolidone with percentages of 80, 60, 40, 20 is synthesized and are called sample 1, 2, 3 and 4 respectively. The samples using lower poly vinyl pyrrolidone (PVP:SiO₂; 2:3 in Weight) can be suitable choices in producing organic field-effect transistors due to their better structural quality, less energy loss, less roughness sample surface, higher dielectric constant (K=15.99) and better surface morphology as determined with applying DME SPM software and above techniques. This sample can be thus considered as a good element of the future organic field-effect transistors devices.

INTRODUCTION

In the last years, many organic materials to enhance the performance of organic field-effect transistors have been reported [1-5], many researchers have focused on improving the efficiency of the gate dielectric materials. Moreover, the main objective of the research studies was on composite organic materials, especially hybrids organic hybrids and inorganic hybrids in order to determine whether these materials are able to be used as organic field-effect transistors (OFETS) elements.

On the other hand, researchers conducted in recent years [6-9] show that in the organic semiconductors unlike inorganic semiconductors, and organic semiconductors have different properties in comparison to inorganic semi-conductors. This is because, the molecules with weak inter-molecular interactions are formed [10, 11]. Due to weak interaction, molecular orbitals are formed with weakened the interaction between adjacent molecules [12]. The relatively larger molecules in such semiconductors lead to a lower motilities in OFET substrate and/or channel.

Therefore, the charge transfer between them causes some potential barriers which can reduce carrier mobility [4-6]. We therefore concerned to search a suitable gate dielectric material for future of the OFETs. In addition, many benefits for organic field-effect transistors can be specified which include: low cost, flexibility, large-area fabrication and the process of synthesis in a low temperature. These advantages enhanced make a great motivation for some researches to study the hybrid organic and inorganic composite materials to see if they can fill silicon dioxide gate dielectric gap. Therefore, development of new hybrid organic/ inorganic, here: PVP/SiO₂ composite is key to achieving and fabricating a nano chip and OFET with nanocomposite PVP: SiO₂; 2:3 in weight composite.

MATERIALS AND METHODS

In the presence of acetic acid, water and 0.8 moles of tetraethyl orthosilicate (TEOS) are stirred up for 30 seconds. After 6 hours the reaction is complete and the gel will be formed. Then, it will be dried in a furnace, ground in a mortar until obtain nanosilicon dioxide.

✉ *Corresponding author

Email address: ahashemizadeh@yahoo.com

Tel.: +98 2122484837

For the purpose of synthesis, we mix silicon dioxide, Tetraethyl orthosilicate (TEOS) together and put them in a mixer. In the same time, in another mixer poly vinyl Pyrrolidone with ethanol solution on a hot palate included a magnet, are mixed too. We let keep on steaming until they became homogeneous. Then, the poly vinyl pyrrolidone solution is added drop wise to dioxide silicon to get a homogeneous gel. Next, we put it in a furnace to dry. Shortly after that, we put the resulted powder in a mortar to obtain particles of the

same powder. The processes have been reported 7 times and the better results are reported here. The main material taken from oxide silicon with weight percentage of 20,40,60,80 and from poly vinyl pyrrolidone with percentages of 80, 60, 40, 20 is synthesized and are called sample 1,2,3,4, respectively.

RESULTS AND DISCUSSION

The surface morphology study in SEM images (Figs. 1 through 5) revealed that sample 3 has better

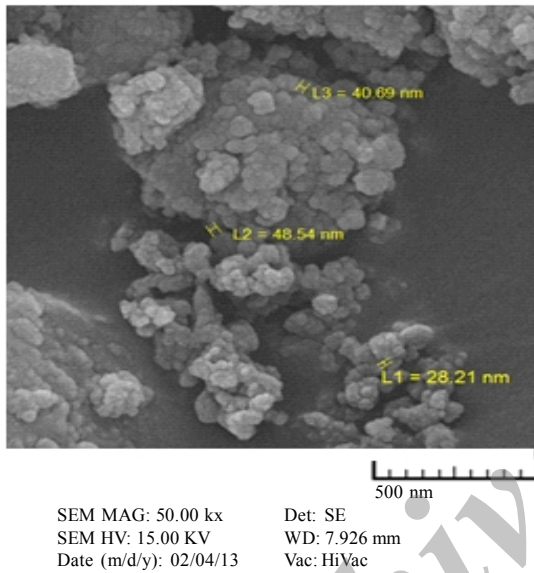


Fig. 1. SEM image of just silicon dioxide (SiO_2)

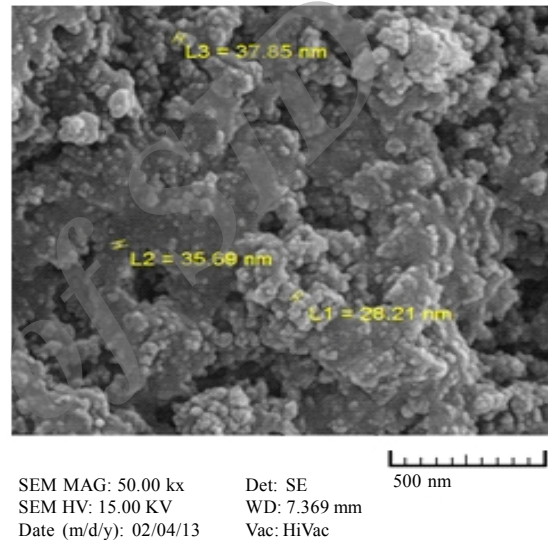


Fig. 2. SEM image of nanocomposite PVP: SiO_2 ; 4:1 in weight (sample 1)

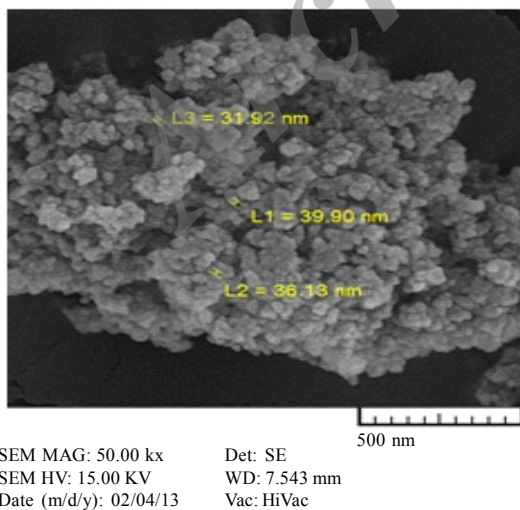
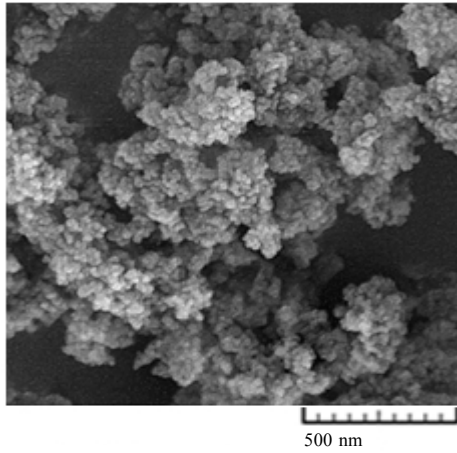


Fig. 3. SEM image of nanocomposite PVP: SiO_2 ; 3:2 in weight (sample 2)



Fig. 4. SEM image of nanocomposite PVP: SiO_2 ; 2:3 in weight (sample 3)



SEM MAG: 50.00 kx Det: SE
 SEM HV: 15.00 KV WD: 7.919 mm
 Date (m/d/y): 05/19/15 Vac: HiVac

Fig. 5. SEM image of nanocomposite PVP: SiO₂; 1:4 in weight (sample 4)

surface structure and fewer barriers which can enhance the carrier mobility on the surface. As it can be observed in SEM images, the samples curd together and from amorphous particles and/ or nano crystallite with no regular structure are obtained. Particles stick together and the outer layers plunge together to form larger agglomerates of individual particles which are inseparable, and their size range is between 25 to 40 nm in length scale. By reviewing SEM images, it can be seen that the particles with weight loss PVP (PVP: SiO₂; 2:3 in weight) will change into distinctly spherical volumes with nano-metric structure which are more regular and form denser clusters.

AFM images of the samples are also exhibited in Figs. 6 through 10 in both 2 and 3D. The roughness parameters are measured with using DM-SPM software and the measurement results presented in Table 1.

There are many different parameters. The surface root-mean-squared roughness parameter (Sq) of the sample nanoparticles into cement is determined with using Nanosurf software tool. The opposite of roughness is smoothness. Throughness causes light dispersion and absorption. The square of the difference will be in nm² and represents the application area of nanoparticle which may be meant to change the function of the entire surface of the sample as opposed to producing discrete structures.

The tool result section displays the roughness values (The Roughness Average (S_a) Mean Value (S_m)

Table 1. Roughness parameters determined by DM-SPM software.

Sample 3	Sample 2	Sample 1	Roughness parameters
2.10nm	9.61mm	98.3mm	S _a
2.84nm	12mm	118mm	S _q
19.10nm	81.5mm	701mm	S _y
79.4fm	257nm	14.9nm	S _m
10.6nm	52.3mm	363mm	S _v

S_a:roughness average, S_q:root mean square
 S_y:peak valley height, S_m:the mean value, S_v:valley depth

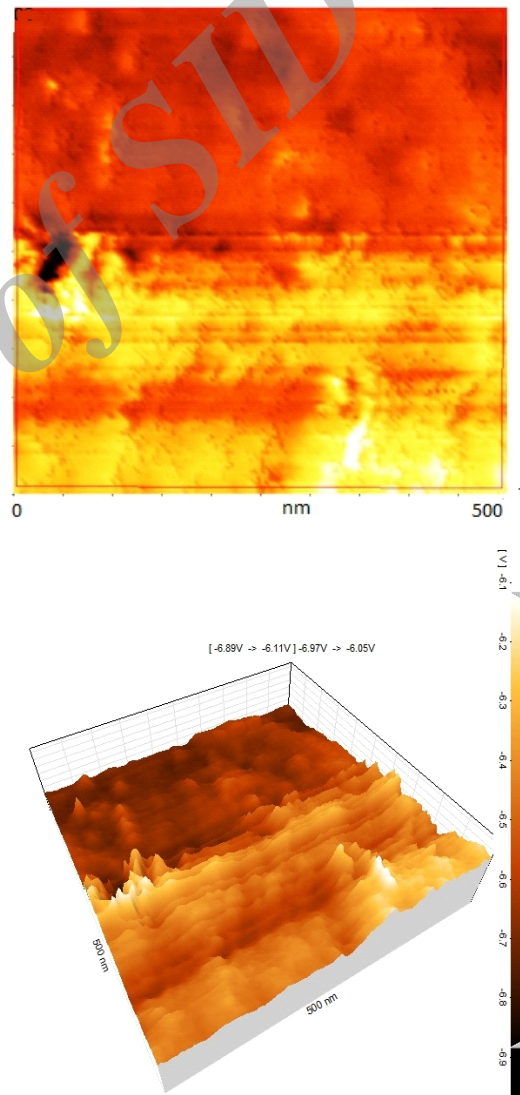


Fig. 6. AFM image of SiO₂ two dimensional (2D) view

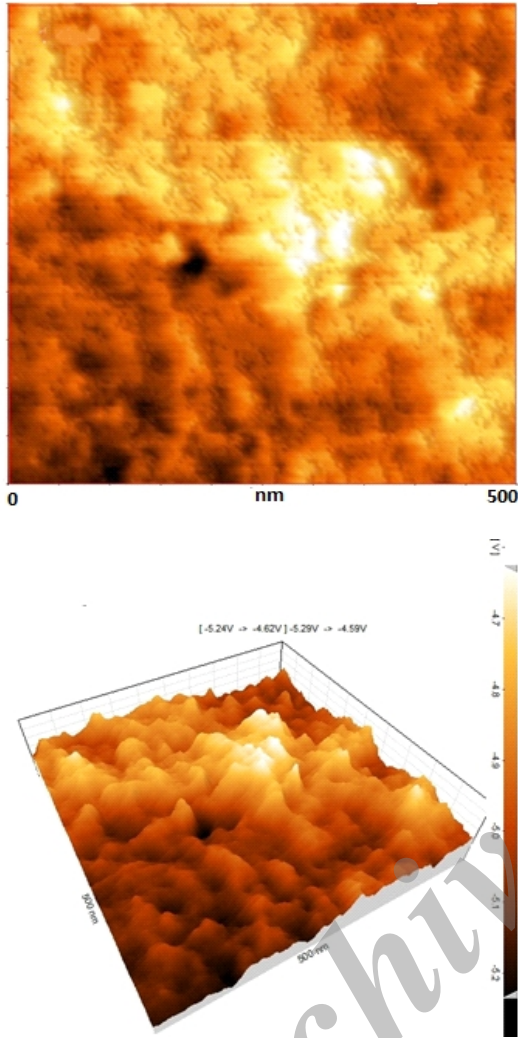


Fig. 7. AFM image of nanocomposite PVP: SiO₂; 4:1 in weight (sample 1); (up): two dimensional (2D) and (down): three dimensional (3D) view

and Root Mean Square (S_q) that are calculated from the data according to the following formulas:

$$S_a = \frac{1}{N} \sum_{l=0}^{N-1} |z(x_l)| \quad (1)$$

$$S_m = \frac{1}{N} \sum_{l=0}^{N-1} z(x_l) \quad (2)$$

$$S_q = \sqrt{\frac{1}{N} \sum_{l=0}^{N-1} (z(x_l))^2} \quad (3)$$

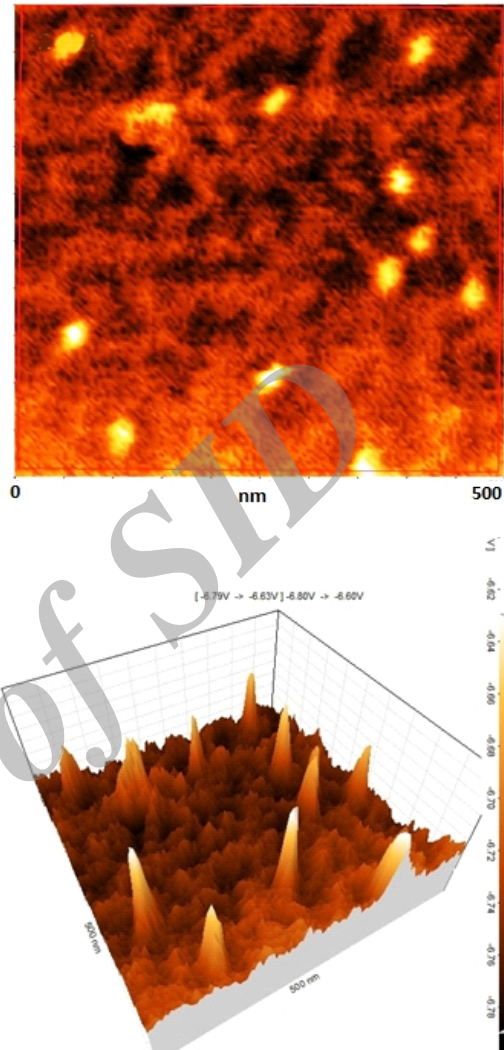


Fig. 8. AFM image of nanocomposite PVP: SiO₂; 3:2 in weight (sample 2); (up): two dimensional (2D) and (down): three dimensional (3D) view

The Valley depth, S_v ; is lowest value and the Peak Height, S_p ; is highest value, in that the Peak-Valley Height, S_y ; is $S_y = S_p - S_v$. It is clear that, the particles begin to form a secondary layer around themselves. Some grow earlier and become larger due to uncompleted synthesis processes, whilst there are still some other particles which can form new nucleus. The latter nucleus crystallites can enter the growing phase and make thus non-uniformity in particle size. Hence, this problem is main issue for losing controlling on the surface roughness parameters and crystallite sizes (the particle size range: 20 to 40 nm). The nano particles therefore

Table 2. Dielectric constant of the samples measured with using GPS 132 A technique

Sample 4	Sample 3	Sample 2	Sample 1
13.34	15.99	12.11	12.26

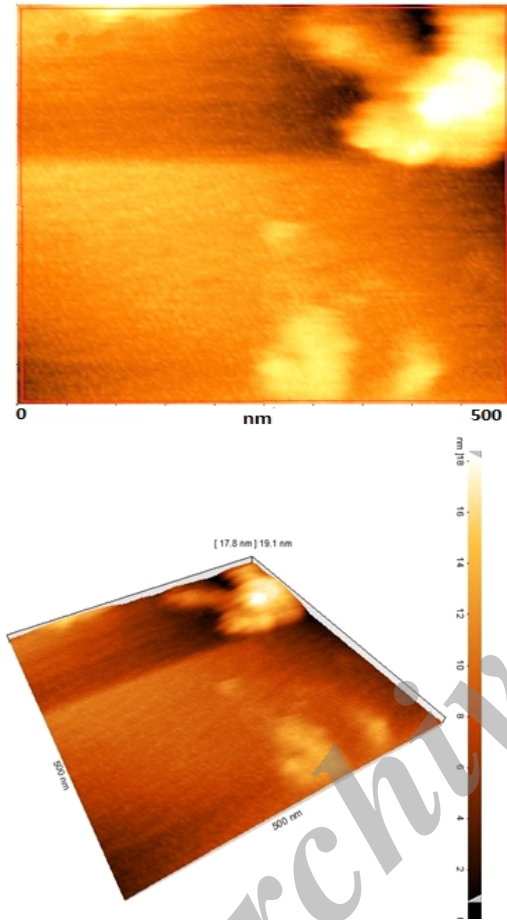


Fig. 9. AFM image of nanocomposite PVP: SiO₂; 2:3 in weight (sample 3); (up): two dimensional (2D) and (down): three dimensional (3D) view

formed onto the samples, due to their high surface to volume ratio. It can reduce the total current energy. Since they are joined together, the nano-particles will reduce the area of carrier movements, too.

In parallel to SEM study, we studied the roughness and mechanical stability of the sample with using AFM technique. AFM images (Figs.7-10) show the arrangement of nano particles on the surface. By examining software review of (DME SPM) the surfaces; we can get the average roughness, peak height (S_y)

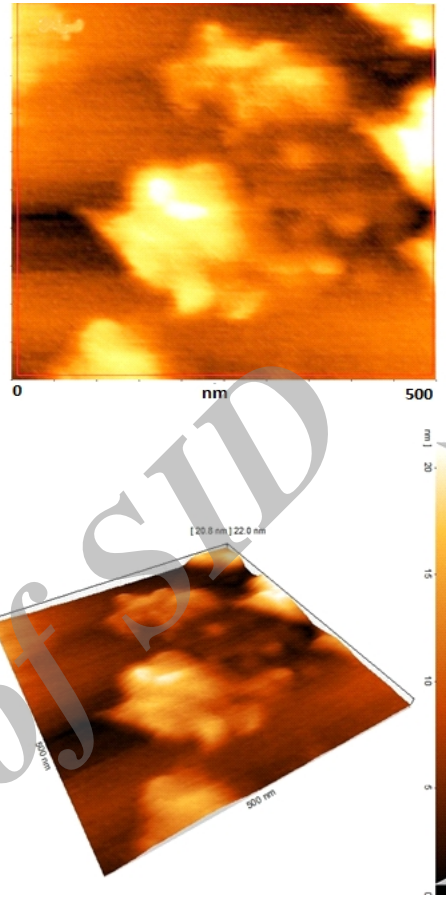


Fig. 10. AFM image of nanocomposite PVP: SiO₂; 1:4 in weight (sample 4); (up): two dimensional (2D) and (down): three dimensional (3D) view

and the depth of valleys (S_v). AFM images of the samples indicate that the particles tend to curdle. By looking at the roughness parameters measurements given in table 1, the reduction of average roughness in samples with less organic materials can be shown. In table 1, the mean average roughness, root mean (S_a) coarser, peak height, depth of canyons and maximum height of the valleys for each sample can be investigated, separately.

This shows the desirability of sample 4 in terms of roughness level. Through the study of three-dimensional topography of samples, we can clearly observe table 1. For samples 1, 2 and 4 in contrast to sample 3 (Figs. 7-10), we see that the average roughness is very high. Hence, the roughness of sample 3, decreased tangibility, means a smooth surface with low dams and wells as well as good surface morphology.

This surface can increase the carrier mobility. Since carrier mobility is directly proportional to the electrical conductivity coefficient, the current flow can be seen more in samples in such transistors as organic field effect. We made a capacitor with two aluminum plates and nanocomposite PVP/ SiO₂ dielectric materials. The dielectric constant of the samples, measured with GPS 132 A technique, is given in table 2. It is shown that sample 3 has a higher dielectric constant respect with other presented samples and can reduce tunneling and leakage currents. It means that sample 3 can be used as a gate dielectric of OFET transistor.

CONCLUSION

The obtained results in the present work demonstrated that the sample PVP: SiO₂: 2:3 has better surface morphology, higher dielectric constant and the superior mobility of charge carriers and less energy loss in this sample in comparison to other samples (sample 1,2,4) can be more suitable in electronic applications.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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AUTHOR (S) BIOSKETCHES

Hashemizadeh, A., Ph.D., Assistant Professor, Department of Physics, Payame Noor University, P.OBOX 19395-3697, Tehran, Iran.
Email: ahashemizadeh@yahoo.com

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