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Comparative Analysis on the Morphology of Pentacene Thin Films Fabricated by Thermal and Spin Coating

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ABSTRACT: The morphology of the thin films fabricated by thermal evaporation coating and spin coating are analysed. The particle size and surface roughness are studied using scanning electron microscope and atomic force microscope. The above parameters of spin coated thin films annealed at different at temperatures are also analysed using the same characterisation method.

KEYWORDS: Vacuum coating, Spin coating, particle size, Surface roughness

I. INTRODUCTION

Organic electronics is currently developing in the field of technology because of the availability of materials and reduction in cost [1]. Structurally they are based on carbon and can be used to replace silicon which is the basic semiconductor element used in the development of electronic industry. Organic diodes can be used as modulators in communication devices and also as rectifiers. The major application of organic rectifiers is in radio frequency identification (RF-ID) tags [2]. The high frequency rectifiers fabricated by organic devices can act as rectifiers in RF-IDs [3-4]. Other types of organic devices are organic photovoltaic devices, organic solar cells and organic thin film transistors.

Two different methods can be used for fabrication of organic rectifiers. It is based on vertical organic diodes and organic thin film transistors (OTFT) with short channel length [5]. The length of the channel is a factor which can affect the speed of the device. The vertical diode is fabricated using different thin films one over the other and it may be more effective in its speed.

The two different fabrication methods used to synthesis pentacene thin films are vacuum thermal evaporation coating and spin coating [6]. Powder sample is used for thermal coating and liquid sample is used for spin coating. Within the two methods spin coating is more preferable in the sense of cost effectiveness. The traditional method of synthesis of thin film

is thermal coating due to the high thermal stability of pentacene which is used as the material [7]. The purity of the material is one of factor which can affect the electrical property of thin films. The structural defects that may occur at the time of growth of the thin film can also affect the quality and property of the thin film [8]. For a vertical diode surface topology is important while depositing one film over the other.

II. EXPERIMENTAL

In the present study topological investigations are conducted by Scanning Electron Microscope (SEM) [9]. The topological and elemental information at different magnifications is observed.

Pentacene thin films are deposited on the ultrasonically cleaned glass substrate using vacuum thermal physical vapour deposition technique. The glass slide and pentacene are placed in a vacuum chamber. Distance between the glass substrate and the boat in which the material placed is less than the mean free path of the material. The vacuum evaporation is done under a pressure of 2×10^{-5} mbar and the substrate is kept at a room temperature 240C.

Vacuum avoids the collision of material particles with other gases present in the chamber and avoids contamination. Evaporation rate of Pentacene is kept as 0.1nm/s. Thin films of thickness from 70nm to 400nm and active area of 10x10mm are fabricated. The process conditions are kept same for all films in the same evaporation chamber. The prepared thin films are annealed at different temperatures ranging from 100⁰ C to 300⁰ C and characterisation techniques are adopted to analyse morphological property.

Pentacene thin film also be fabricated by spin coating using the precursor sulfinylacetamidopentacene (SAP)[10]. Pentacene in solution form is made by dissolving 5mg of sulfinylacetamidopentacene precursor in 1ml of tetrahydrofuran solution in nitrogen ambient. Ultrasound agitation is used to increase the dissolving rate of the precursor in the solution. The solution is poured on the ultrasonically cleaned substrate and rotated at a speed of 1500 rpm for 60 sec and preheated for 100⁰ C to thermally convert the precursor into a thin film. The process is repeated 10 times. The film is annealed at different temperatures from 70⁰ C to 300⁰ C and different characterisation techniques are employed to determine the morphological property. After annealing, colour of the film will turn into blue from purple.

III. RESULTS AND DISCUSSIONS

This paper explains the comparative study of particle size and surface roughness of pentacene thin films coated by thermal coating and spin coating. The analysis of the above parameters in different annealing temperatures is also included.

Figure 1 represents the SEM micrograph of pentacene with thickness of 100nm annealed at 250⁰C. The analysis of these thin films provided clear images with less electrostatic distortion. The spatial resolution reached 0.97nm for the 100nm thin film annealed at 250⁰C. It is found better than 400nm thin film with same annealing temperature. Thin film seems uniformly distributed with rod shaped particles [11]. The average particle size is found varying from 15nm-40nm. Figure 2 represents the SEM micrograph of pentacene thin film fabricated by Spin coating and annealed at 250⁰ C.

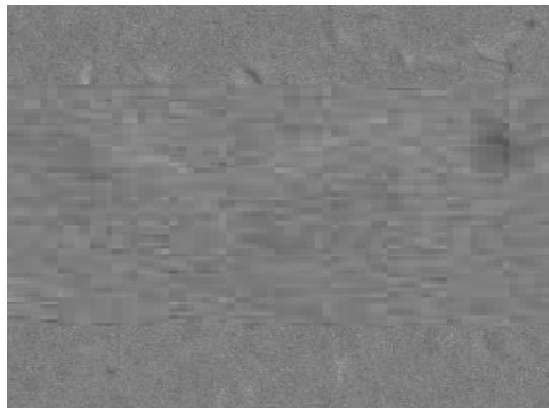


Fig 1 SEM micrograph of Pentacene thin film fabricated by vacuum thermal coating with thickness 100nm and annealed at 250⁰ C

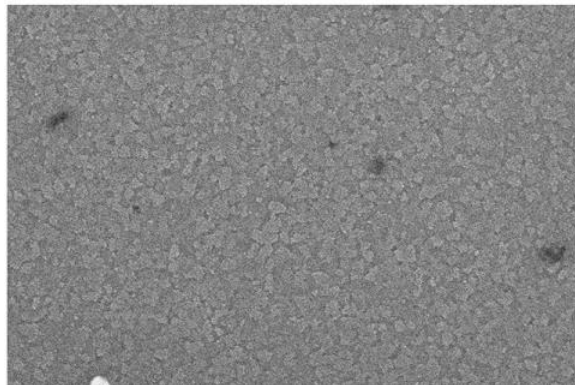


Fig 2 SEM micrograph of 70 nm thick pentacene thin film fabricated by Spin coating and annealed at 250⁰ C.

The particle size and surface roughness of thermal coated thin film with thickness 100nm is shown in table 1. The particle size is high and surface roughness is low for spin coated thin films than vacuum thermal coated thin films. The increase in particle size increases the conductivity due to less void space and lattice defects [12]. The material is deposited with high energy in vacuum thermal coating and this may cause penetration on the film underneath while coating. The low surface roughness makes the film smoother and the film over it becomes adhesive while in fabrication. The conduction of current from one film to other is high when both are smooth.

Table 1 particle size and surface roughness of vacuum thermal coated thin film

Method	Particle size before Annealing(nm)	Particle size annealed at 250 ⁰ C(nm)	Surface roughness(nm)
Thermalcoating 100nm	30.18	32.45	
Spin coated 70nm	20.12	31.26	1.85

A smooth uniformly distributed thin film of 70nm thickness which is annealed at temperatures ranging from 50⁰ C to 250⁰C is observed by SEM micrograph and the particle size is found to increase from 20.12nm to 31.26nm. At the same time the surface roughness (root-mean square roughness) is found increased from 1.85nm to 3.10nm with increase in annealing temperature is tabulated in table2.

Table 2 Variation in particle size and surface roughness of spin coated thin film of 70nm thickness with different annealing temperatures

Annealing temp.	Non annealed	50 ⁰ C	150 ⁰ C	250 ⁰ C
Particle size(nm)	20.12	23.53	28.89	31.26
Surface roughness(nm)	1.85	2.14	2.56	3.10



The synthesized thin film annealed at different temperatures and its particle size and surface roughness are analysed. Table 2 shows the analysis of particle size and surface roughness of spin coated thin film. The particle size is found increased with respect to increase in annealing temperature while surface roughness of the thin film decreases. Figure.3 and 4 are the graphical representations of the variation in particle size and surface roughness of the spin coated thin film respectively.

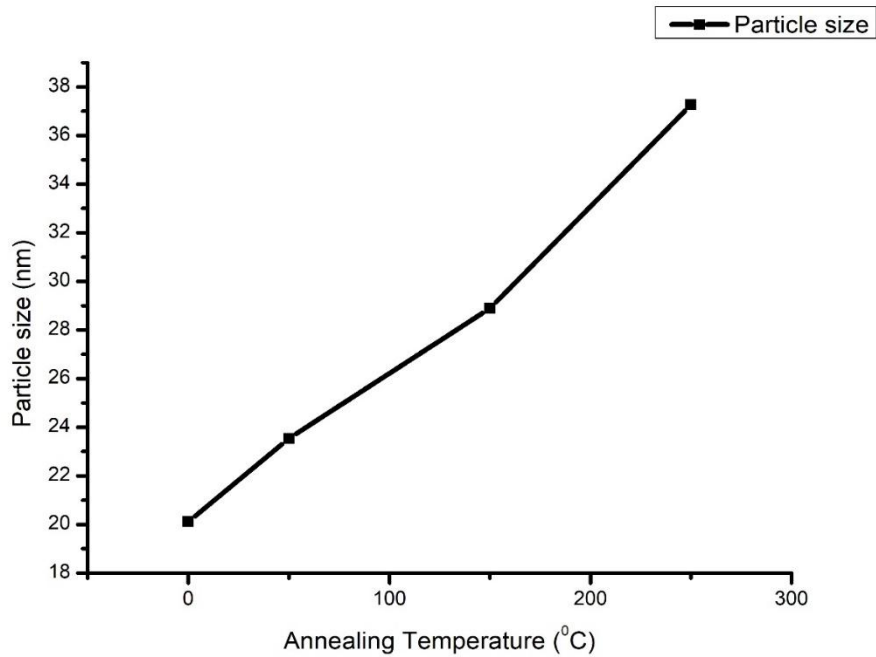


Fig.3 Variation in particle size of spin coated thin film of 70nm thickness with different annealing temperatures

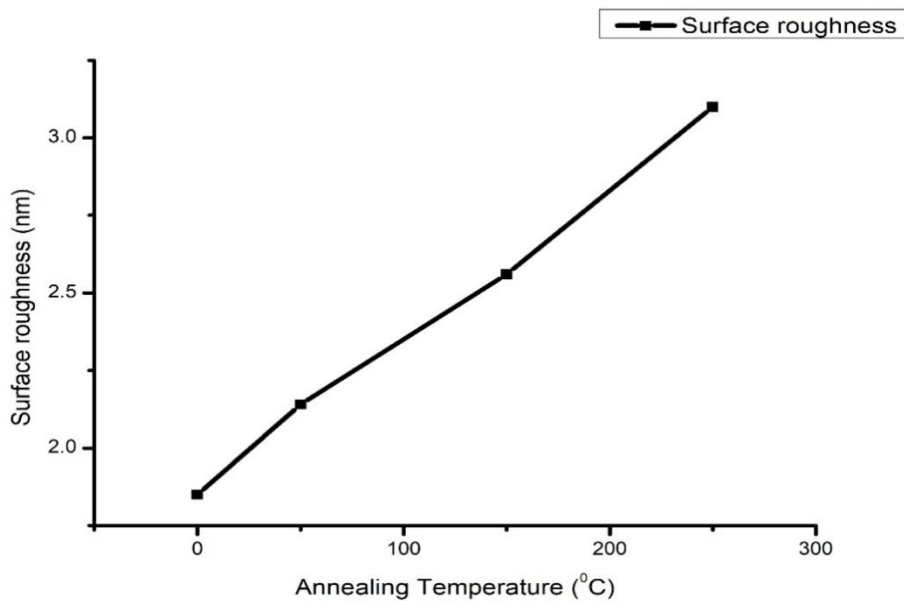


Fig.4 Variation in surface roughness of spin coated thin film of 70nm thickness with different annealing temperatures.



IV. CONCLUSION

In conclusion the particle size and surface roughness of the thin films synthesized by vacuum thermal coating and spin coating are studied. The variation in same parameters of spin coated thin film with different annealing temperatures is also studied. The particle size found increased and surface roughness decreased in spin coating. The particle size increased and surface roughness decreased with respect to increase in annealing temperature. So, spin coating is found as the cost-effective fabrication of pentacene thin films.

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