Effects of Self-assembled Monolayer on PVP Gate Insulator for Organic Thin Film Transistors

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Abstract

In this work, the characteristics of organic thin film transistors (OTFTs) with self-assembled monolayers (SAMs) on polymeric gate insulator have been investigated. The SAMs were formed using atomic layer deposition (ALD) method onto gate insulator. Upon the investigations, it was observed that SAMs modify the wettability of polymeric insulator and influence the growth of subsequent organic semiconductor, and thereby, electric conductivity and roughness of the pentacene film are improved.

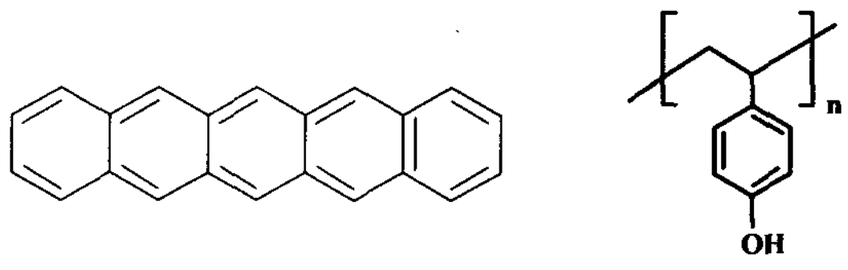
1. Objectives and Background

Some organic materials can offer substantial advantages in terms of the processing simplicity and competitive cost.[1,2] Moreover, all-organic TFTs can allow flexible active matrix displays by their integration with organic light emitting diodes or liquid crystal cells on polymeric substrates.[3]

The performance of OTFTs has been considerably improved for several years.[4] The optimized OTFTs show the electrical characteristics similar to those obtained with amorphous silicon devices. It has been reported that pentacene($C_{22}H_{14}$) shows the most pronounced properties for p-channel conduction, among many organic semiconductors. For this reason, the pentacene was usually employed as the active layer of OTFTs.[5]

On the other hands, the use of polymer dielectric gate materials, such as poly(4-vinylphenol) and poly(methyl-methacrylate), have been reported for the OTFTs, recently.[6]

One of critical factors for high performance of OTFTs is the characteristics of the pentacene-gate dielectric interface. Because of the hydrophilicity of the PVP layer in comparison to the hydrophobic pentacene film, PVP can deteriorate the vertical growth of the pentacene to the substrate. Therefore, in order to make the hydrophobic insulator surface the self-assembled monolayers (SAMs) using Octyltrichlorosilane ($CH_3(CH_2)_7SiCl_3$) were deposited via vapor phase onto PVP layer prior to the deposition of pentacene. The molecular structure of the pentacene and PVP is shown in Figure 1.



(a) (b)

Figure 1. Molecular structures of (a) pentacene and (b) PVP.

2. Experimental Details

The structure of fabricated device for the electric conductivity measurement of pentacene layers is shown in Figure 2.

PVP was spin-coated with 300nm thick, which was confirmed by α-step profilemeter. Ethanol was used as the solvent for 4wt. % PVP. The octyltrichlorosilane SAMs was deposited by ALD method at 180℃ under a pressure of 2 Torr. And the surface of the SAMs was swept by Hexane for purging. Pentacene, purified by sublimation, was thermally evaporated under a pressure of 10^{-6} Torr through shadow mask. The thickness of the pentacene was 60nm, and the deposition rate was 0.5 Å/sec. Gold was used as a electrode for measurement.

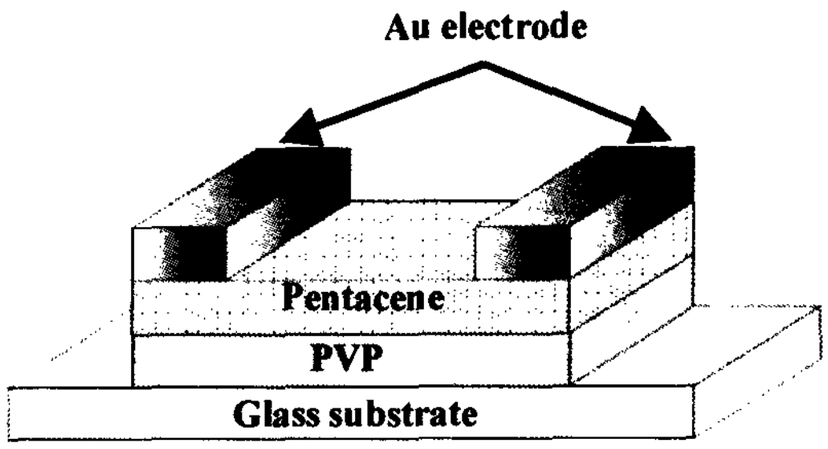
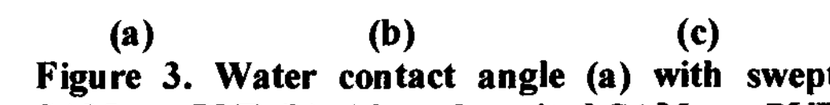


Figure 2. Structure for measurement

3. Results and Discussion

The hydrophobicity of the SAMs was checked by water contact angle as shown in Figure 3. Water contact angle of as-deposited PVP, SAMs onto PVP layer and swept SAMs onto PVP layer is 62°, 78° and 98° respectively. It is considered that the hydrophobicity is increased by SAMs, and surface sweeping of SAMs remove the physical absorption of octyltrichlorosilane.



(a) (b) (c)

Figure 3. Water contact angle (a) with swept SAMs on PVP (b)with as deposited SAMs on PVP and (c)with as deposited PVP.

Electric conductivity of pentacene film is improved by two orders of magnitude as shown in Figure 5, which indicates the improvement of the molecular ordering of pentacene film.

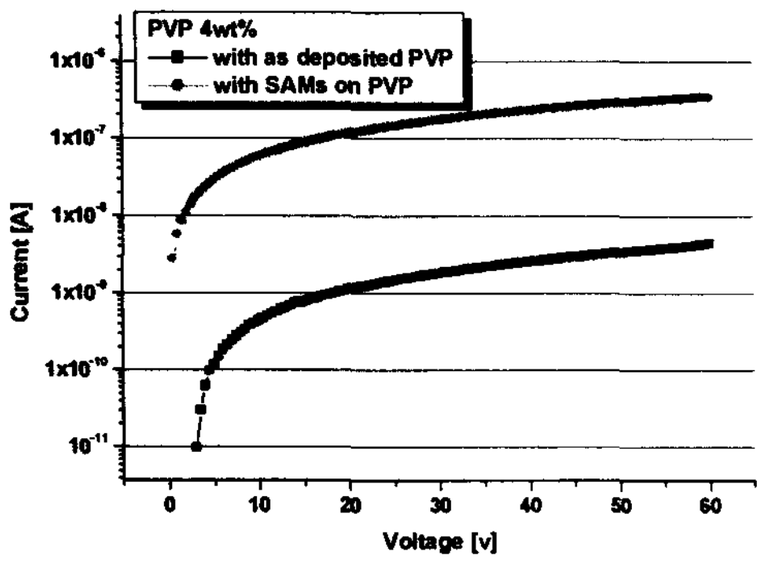


Figure 5. I-V characteristics of devices with / without SAMs.

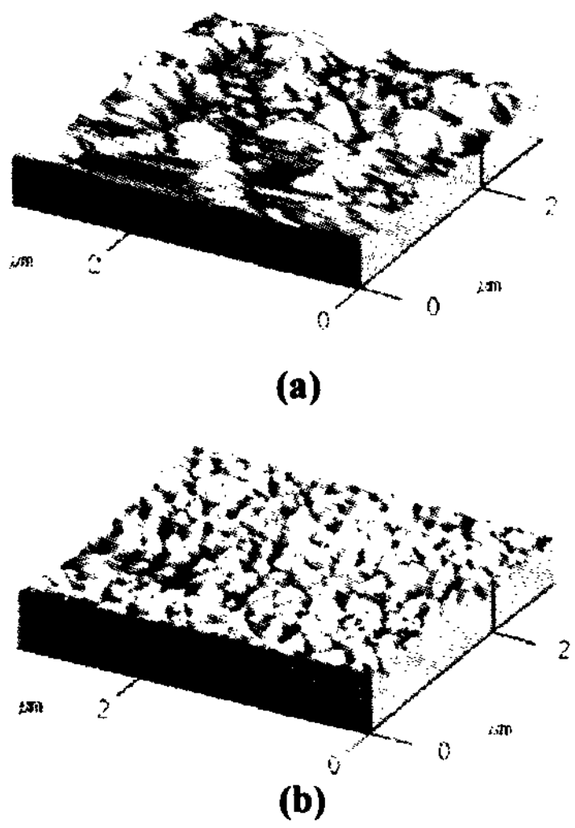


Figure 6. Atomic force microscopy (AFM) images of pentacene film deposited onto (a) as-deposited PVP, (b) with SAMs on PVP

The surface morphology of pentacene thin film with / without SAMs on PVP is confirmed by atomic force microscopy(AFM) as shown in Figure 6. Both pentacene films were thermally evaporated and the thickness of pentacene layer was 30nm. It is observed that the average roughness of pentacene film is improved by depositing SAMs. The grain size of pentacene film on SAMs is decreased. In this result, it is expected that SAMs affect the crystallinity and growth of pentacene in the interface. The further work for correlation between grain size and conductivity of pentacene film is necessary.

4. Conclusion

Structural and transport properties of polycrystalline pentacene onto SAMs on PVP have been investigated. The increase of hydrophobicity of substrate layer is confirmed by water contact angle. Also, hydrophobicity is increased by sweeping the surface of SAMs after deposition. It is consider that molecular ordering of pentacene is improved by SAMs and it causes the reduction of resistivity of pentacene film

5. Impact

The properties of the pentacene film are closely correlated with the characteristics of the dielectric layer. In this work, it is observed that the hydrophilicity of the insulator, which deteriorates growth of the pentacene on the insulator suface, is decreased by depositing SAMs onto PVP layer. Because hydrofobicity of the insulator layer influence the molecular ordering of pentacene film, it improves the characteristics of active layer. Also, It is expected that electrical characteristics of OTFTs can be improved..

5. Acknowledgements

This work was supported from Information Display R&D Program funded by the Ministry of Science and Technology of Korea

6. References

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