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Structure of Cu-Phthalocyanine Vacuum Deposited on Inclined Glass Substrates

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Abstract

Cu-phthalocyanine is widely studied as a hole-transport layer in organic electronic devices. Since Cu-phthalocyanine is a molecular solid, the crystal structure depends on a circumstance to a great extent. Vacuum deposited layers were known to consist of two consecutive layers. In this article, Cu-phthalocyanine was deposited on the glass substrate inclined at several angles. The thickness of the first layer was found to be dependent on the substrate angle.

Keywords

Cu-Phthalocyanine, Vacuum Deposition, Crystal Structure, Inclined Substrate

1. Introduction

Cu-phthalocyanine is a non-toxic material and then widely used as a blue pigment. It is nowadays attractive to the application to electronic devices. It is because organic electronic devices have become widely studied these days. Organic materials can be produced by a variety of chemical reactions, without especial elements such as rare earth. It is a great advantage to environmental friendliness. It can be easily disposed of by burning it. The disposable electronic circuit will possibly be realized in the future.

The most well common application of Cu-phthalocyanine is a hole transport material in electroluminescence devices; it is a p-type semiconductor. Since Cu-phthalocyanine is an easily sublimated molecular material, it is convenient to use the material in forming electroluminescence devices by means of a vacuum deposition method.

Cu-phthalocyanine is also studied as a material for solar cells [1] [2] [3]. Although elemental silicon is now widely used as a material for solar panels, the production of the panel costs so much that the material should be purified. Contrarily, the vacuum deposition method is a low-cost method to form thin films. The problem is the low efficiency of the power transformation.

Cu-phthalocyanine has been also studied to form an organic field effect transistor [4] [5] [6]. The drain current is in the order of nA that is far smaller than silicon-based field effect transistor. However, when molecular electronics come into being, the technology would play an important role. Another prototype of transistor has been also fabricated, named a permeable-base transistor also called a static induction transistor [7] [8].

Further, Cu-phthalocyanine is expected to apply to photodetectors [9], phototransistors [10], and optical recording media [11]. Chemical gas sensing properties have been also studied [12] [13].

The easiest way to deposit Cu-phthalocyanine is a vacuum deposition method by sublimation. Since the molecule nearly has a square sheet form, the physical structure of the deposited film is of interest. The interesting feature of the deposited film on silicon wafer was reported to have a two-layer structure by M. Ohmukai *et al.* [14]. In this paper, Cu-phthalocyanine was deposited on silicon wafer installed at several angles to the sublimation source cell. The obtained films were analyzed by an X-ray diffraction measurement.

2. Experimental

A starting material of Cu-phthalocyanine is commercially available and has the purity of 98.8%. The substrate is a p-type silicon wafer with a resistivity of 0.01 Ω·cm and was installed 0.1 m above the sublimation source. The angle of the substrate was varied between 0 and 60 degrees. The 0 degree is where the substrate faces down the sublimation source. The whole chamber was evacuated by a diffusion and a rotary pumps up to the base pressure of 7×10^{-5} Torr. In all experiments filling weight of Cu-phthalocyanine powder was under 120 mg. The deposition time was around 10 minutes.

The thickness of the film was determined by a surface roughness analyzer (Surfcom 590-A) by Tokyo Seimitsu. The X-ray diffraction measurements were performed with a diffractometer (MJ200DX) by Rigaku with a Cu target.

3. Results and Discussion

At first, the film thickness is shown in **Figure 1** as a function of filling amount of Cu-phthalocyanine. At the same filling amount, the thickness has maximum value at the angle of 0 degree. As the angle increases, the thickness decreases at the same filling amount. At the angle of 60 degrees, the solid angle of the substrate decreases down to a half. It is followed by the fact that the thickness of the 60 degrees is roughly a half of the 0 degree values. It could be understood theoretically in this way.

It is described next the X-ray diffraction results. Cu-phthalocyanine shows the 2 types of structures [14]: one peak at 7 degrees and four peaks between 24 and

28 degrees. The peak at 7 degrees corresponds to the structure where the molecular sheet is perpendicular to the substrate surface. On the other hand, the other four peaks are detected from the inclined states. The literature indicated that the first layer consists of the perpendicular configuration and the second layer of the inclined one. The first layer has the thickness of about 0.7 μm.

Figure 2 shows that the integrated intensity of the X-ray diffraction at 7 degrees as a function of the film thickness. The intensity corresponds to the thickness of the first layer. It is clear from the figure that the intensity increases as the angle increases. And over 0.7 μm, the intensity was saturated regardless of the thickness. It can be explained in such a way that the diffraction derives from the first layer. The intensity at 60 degrees is 6 times stronger than that of 0 degree. It is speculated that the first layer thickness increases with the substrate angle during the deposition as is shown in Figure 3 schematically. From this fact, the first layer thickness can be controlled by the substrate angle.

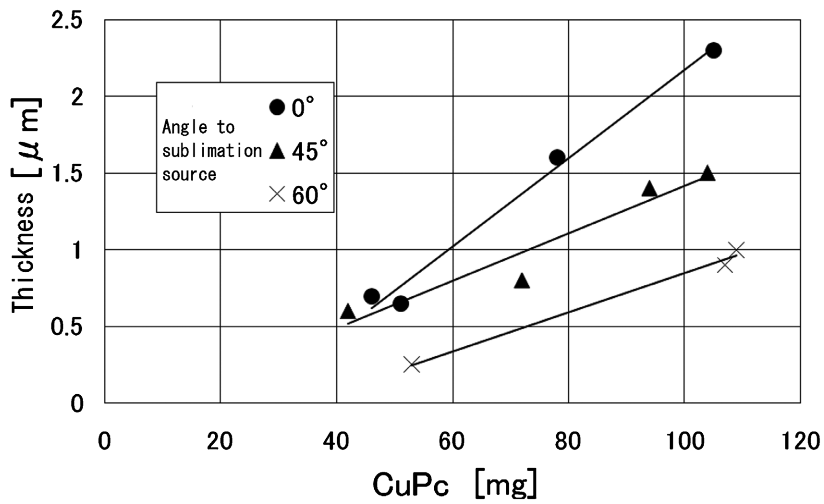

Figure 1. Film thickness as a function of filling amount of Cu-phthalocyanine. The angle of 0 degree indicates that the substrate faces the sublimation source in the very front.

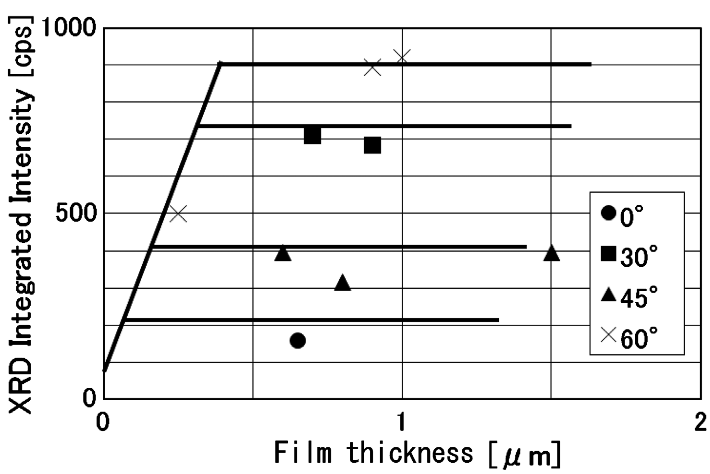

Figure 2. The integrated intensity of X-ray diffraction at 7˚ as a function of film thickness. The angle to the sublimation source.

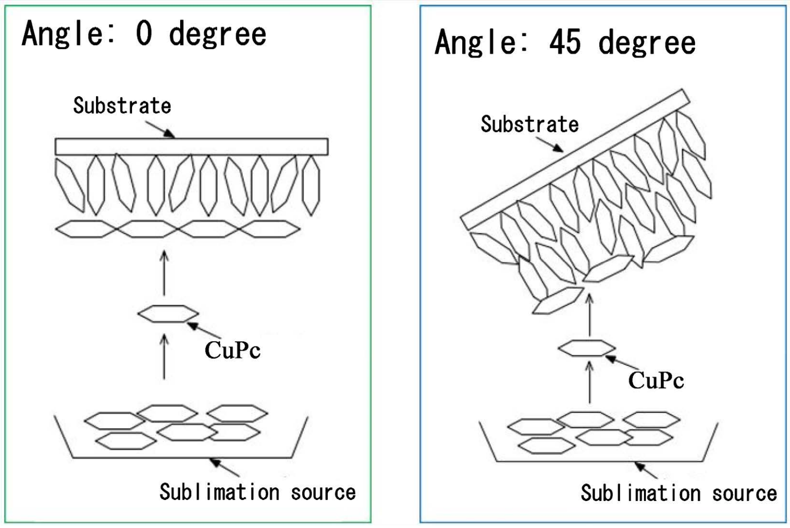

Figure 3. The schematic illustration of the CuPc molecule deposition outlook.

Next interesting point is how the electric current behavior depends on the physical structure. The anisotropic structure surely induces the anisotropic current flow. The current flowing property is a critical issue for the application to the electronic devices. So the physical structure is similarly of importance. Most field effect transistors treat current along the film surface. In static induction transistors or solar cells, the current flow is normal to the surface. It is expected that the physical configuration of the Cu-phthalocyanine molecules will be well controlled in the future with good reproducibility.

4. Conclusion

Cu-phthalocyanine was deposited by a vacuum deposition method and studied on the effect of substrate inclination. X-ray diffraction studies showed that the diffraction at 7˚ increases when the angle to the sublimation source increases. This diffraction corresponds to the molecular configuration where the molecular sheet is deposited normally to the substrate surface. A previous study reported that this configuration forms the first layer that is deposited in the beginning. The second layer consists of the inclined configuration that the molecular sheet is nearly parallel to the substrate surface. The obtained results in this article indicate that when the inclination increases, the first layer becomes thicker as the angle increases. It can be concluded that the thickness of the first layer can be controlled by the substrate angle to the sublimation source.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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