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Abstract (Doctor)

Title of Thesis	Study on Growth and Characteristics of Thermally Evaporated Organic Semiconductor Layers (加熱蒸着した有機半導体層の成長と特性に関する研究)
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Approx. 800 words

The organic semiconductors have been employed in electronics and optoelectronic devices because of their wide range of properties. A great number of organic materials have been used as the active layer for applications in organic electronics such as organic light emitting diodes (OLEDs), organic field effect transistors (OFETs), and organic photovoltaic devices (OPVs). Organic layers have been prepared by using several methods of solution process such as spin-coating, and vacuum process such as vacuum thermal evaporation. The structure and quality of the resultant organic layers affects the performance of the electronic devices, and the amorphous and bulk-heterojunction structure that was a nano-scale mixture of the n-type and p-type organic semiconductor have been employed for organic PV devices.

Organic semiconductors of π -conjugated small molecules are promising and versatile organic semiconductors for the electronics and optoelectronic devices including organic PV devices because of the high mobility relating to the diffusion length of the carrier. The transporting phenomena of the mobility is affected by the molecular arrangement in the organic semiconductor layers, and the arrangement of the thin layers installed into the devices has been controlled by adjusting the growth including the preparation technique, substrate and under-layer material, and the deposition rate. The heteroepitaxial growth has been generally employed for the fabrication of electronics and optoelectronics devices constructed of inorganic semiconductors, and the lattice relationship at the hetero-interface between the layer and substrate material affects the atomic arrangement of the resultant inorganic layer. The information and knowledge on the growth of organic semiconductors is still insufficient compared with that for inorganic semiconductors.

In this thesis, the structure of single layers and bi-layers of π -conjugated small molecules of 2,7-dioctyl[1]benzothieno[3,2-b][1]benzothiophene (C8-BTBT) and N,N'-dioctyl-3,4,9,10- perylenedimide (PTCDI-C8) prepared on single crystal substrates by a vacuum thermal evaporation was investigated with X-ray diffraction (XRD) and atomic force microscopy (AFM). The purpose of this work is to characterize the growth of organic semiconductors including the effects of the under-layer material and orientation and to propose the tentative growth model applicable for the development of next generation π -conjugated small molecular based devices.

In Chapter 1, the background and purpose of this study was mentioned.

In Chapter 2, the preferred orientation and growth behavior of C8-BTBT deposited on quartz glass, (11 $\bar{2}$ 0)A-, (0001)C-, (11 $\bar{2}$ 0)R-single-crystal Al₂O₃ (sapphire), (100)-, and (111)-single-crystal MgO substrates were investigated by XRD and AFM. The (001) out-of-plane orientation with a similar in-plane orientation was developed irrespective of the substrate material and orientation, and the degree of the development was reflected by the grain structure of the substrates.

In chapter 3, effects of the layer thickness and preparation temperature of the C8-BTBT layer on C-sapphire substrate on the growth and characteristics have been investigated with XRD, AFM, optical absorption measurement, and resistivity measurement with and without light irradiation. The C8-BTBT layers with the optical bandgap energy around 3.3 eV possessed the (001) out-of-plane

orientation irrespective of the layer thickness and preparation temperature. The C8-BTBT layers were growing up in direction parallel to the substrate surface keeping almost constant height, and the continuous layer was formed by the coalescence of the C8-BTBT grains. The electrical resistivity decreased with increase in the preparation temperature due to the increase in the grain size, and the light irradiation induce the drastic decrease to 42-28 Ωcm . The tentative growth mechanism governed by π - π -stacking-induced molecular ordering and diffusion of molecules on the substrates was proposed based on the experimental results.

In chapter 4, the preferred orientation and structure of PTCDI-C8 layers on the Al_2O_3 and MgO substrates were investigated by XRD and AFM observation. The (001) out-of-plane orientation was developed irrespective of the substrate material and orientation, and the continuous layer composed of needle-like grains was formed at the thickness of 15 nm followed by the grain growth with the thickness. The growth of the PTCDI-C8 layer was similar to that for C8-BTBT layer, and the proposed growth mechanism is adequate to the PTCDI-C8 growth.

In Chapter 5, the surface state of C8-BTBT/PTCDI-C8 bi-layers prepared on C-sapphire substrate were investigated by XRD, AFM, and Kelvin Force Microscopy (KFM). The lattice relationship of (001)-C8-BTBT// (001)-PTCDI-C8 was developed irrespective of the stacking order, but the C8-BTBT/PTCDI-C8 bi-layer showed an excellent performance in the surface morphology and potential homogeneity compared with the PTCDI-C8/C8-BTBT bi-layer, suggesting the importance of the stacking order in the fabrication of the bi-layer and the π - π -stacking-induced molecular ordering of each layer on the growth.

In Chapter 6, the results obtained in this study was summarized. The tentative growth mechanism proposed based on the experimental results was adequate to the growth of the single layers and bi-layers of C8-BTBT and PTCDI-C8, and the growth model and experimental results obtained here will support to the improvement of the performance of future π -conjugated based organic semiconductor layers and device fabrication for organic-based applications.