IV-G Field Effect Transistors with Organic Semiconductors

The mechanism of carrier transport in organic semiconductors and carrier injection from metal electrodes becomes the most important subject to be elucidated for the construction of high performance organic thin film devices. We have studied electrical properties of organic films using field effect transistors.

IV-G-1 Electrical Properties of Phathalocyanine films Prepared by Electrophoretic Deposition

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Optical and electrical properties of phthalocyanine (Pc) films have long been studied because of their potential applications to gas sensors, organic light emitting devices and electronic devices including field effect transistors (FETs). Since most Pcs are insoluble in aqueous and organic solvent, Pc films studied so far were prepared by vacuum evaporation technique. We prepared Pc films onto interdigital electrodes by electrophoretic deposition of protonated Pc molecules in the mixture solution of trifluoroacetic acid and dichrolomethane. Contaminations in the films were removed by annealing treatment, and the films exhibited FET behaviors of p-type semiconductors (Figure 1). Carrier mobility, conductivity and carrier density of the films were 1.4×10^{-5} cm^2/Vs, 7.7×10^{-7} S/cm and 6.6×10^{16} cm^{-3}, respectively. These values are almost the same as those of vacuum evaporated films examined so far. It is found that electrophoretic deposition is useful for selective growth of active layers in organic devices.

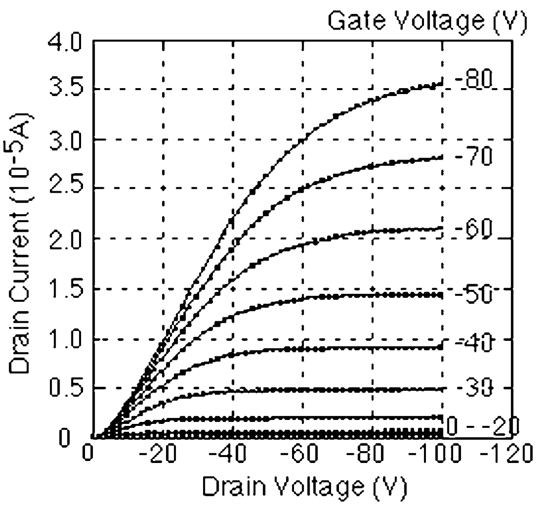

Figure 1.

IV-G-2 Field Effect Transistors with BTQBT Films

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The carrier mobility of organic single crystals are in the range of 1 cm^2/Vs which is comparable to that of amorphous silicon. However, most organic films in devices exhibited the mobility less than 10^{-3} cm^2/Vs due to the existence of grain boundaries. It is thus important to control molecular packing in the films of well-designed molecules. We have choosed BTQBT as the candidate for active layers of field effect transistors (FETs), since the single crystal showed large mobility and highly oriented films were prepared on various substrates. It was found that BTQBT showed p-type semiconducting behavior in air with the mobility of 0.01–0.5 cm^2/Vs, depending on growth conditions.

IV-H Preparation and Characterization of Highly Ordered Molecular Films on Silicon Bound Through Si–C Covalent Bond

Self-assembled monolayers (SAMs) have received considerable attention because of their potential applications to molecular scale electronic devices. Covalently bond alkane SAMs formed by reaction between alkene and hydrogen terminated silicon are of increasing interest as nano-interface for molecular electronics devices fabricated on silicon microstructures. We have studied the growth manner and electronic structure of Si–C junction using scanning probe microscope such as STM (scanning tunneling microscope), AFM (atomic force microscope) and KFM (Kelvin force microscope).

IV-H-1 AFM Studies of Organic Monolayers on Silicon (111) Surfaces

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Surface morphorogy of SAMs formed by the reaction between 1-dodecene, octadecene and methyl 10-undecenoate and hydrogen terminated silicon (111) surfaces were studied with contact mode AFM. Both p and n type Si(111) surfaces with atomically flat terraces were obtained by chemical etching with NH4F solution. Atomically flat surfaces were also observed in AFM images of SAMs on silicon, indicating that the molecules formed highly-oriented films. We found differences in adhesion force and contact angle depending on the molecules and density of molecules. Electronic structure at the interface will be revealed with KFM studies as well as ultraviolet photoelectron spectroscopy.

IV-I Nanolithography of Organic and Inorganic Materials for Molecular Scale Electronics

Great progress is being made in integration and miniaturization of electronic devices by various techniques of micro- and nano-lithography. Modification of chemical structure of organic compounds with scanning probe microscopes is one of the most promising ways for nano-fabrication. We have studied nano-modification of self-assembled monolayers (SAMs) grown on silicon.

IV-I-1 Microscopic Patterning on the Polysilane Films by the Laser Induced Grating Technique

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Microscopic patterning on polysilane thin films was observed after photoexcitation with an optical interference pattern using a nanosecond pulsed laser. The patterning processes were monitored by the diffraction of the probe beam. The observed diffraction signals consist of the transient grating component due to the temperature change and the permanent grating component due to a chemical reaction. It was found that the microscopic pattern was destroyed with prolonged laser radiation. The created microscopic pattern was observed by the optical microscope.

IV-I-2 AFM Lithography of Organic Monolayers Bound Covalently on Silicon

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The alkane monolayer on silicon was degraded by applying a positive bias voltage at the substrate, which resulted in the oxidization of silicon surfaces (Figure 1). The height of the silicon oxide depends on the applied voltage, the width on the curvature radius and the humidity of the atmosphere of the AFM tip. The patterned area is available for different kinds of advanced techniques: 1) covering the oxide with other self-assembled monolayer by trichloro- or trimethoxy siliyl compounds; 2) removing of the silicon oxide by NH_4F-solution and using the established hydrogen terminated silicon for light or heat induced reaction with other alkenes or using the electrical conductive for metal plating; 3) etching of ditches by NH_4F/H_2O_2 solution and fill this ditches with metal by plating.

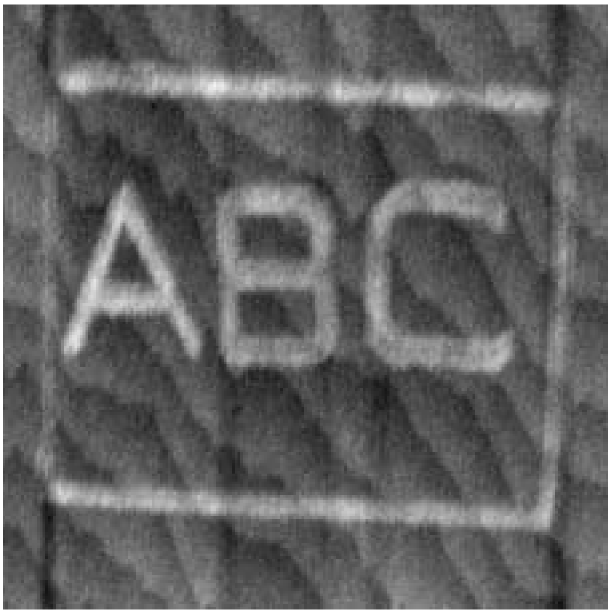

Figure 1.