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Morphology and ellipsometry study of pentacene films grown on native SiO_2 and glass substrates

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Abstract

We have studied the morphology and optical properties of pentacene films in the thickness range of 300–600 nm using atomic force microscopy and spectroscopic ellipsometry. The films were grown on native SiO_2 and glass substrates at room temperature and 80 °C. Surface images showed that the films were formed by the grain growth. The grains were bigger when the films were grown at 80 °C, but this was accompanied with the diminished crystalline ordering. Even though the thickness was the same, the ellipsometry spectra were different for the samples grown under different condition. When the room temperature sample was annealed at 150 °C for 1 h the ellipsometry spectrum did not change indicating that the pentacene film is thermally stable.

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1. Introduction

Organic materials can be implemented in a wide variety of electronic devices. Easy process, low cost, flexibility, novel properties of organic materials are attracting an increasing interest [1]. The application of organic electronics can range from polymer micro-electronic-mechanical-systems to organic superconductors. Among the possible applications, organic thin film transistors for organic displays or smart cards seem to be the first target.

The main obstacle to the realization of the organic field effect transistors was the low mobility. However, the mobility of some organic materials has been improved on the order of 10^4 during the past two decades [1]. Especially after the discovery that the mobility of vacuum-evaporated pentacene could reach that of amorphous Si [2], pentacene has become a subject of heavy investigation. Despite the large effort, the crystal quality of pentacene film sets a limit to the higher mobility. Reports on pentacene films grown by vacuum evaporation showed a grain growth. How the grains and grain boundaries affect the carrier transport is not known yet, but control of the grain seems to be an essential factor for high quality pentacene devices.

Morphology of pentacene film is a sensitive function of growth condition. In this study we looked at how the substrate temperature was related to the size and shape of the grain and the crystal quality. When the films were grown at 80 °C, atomic force microscopy (AFM) images showed bigger grains but X-ray diffraction (XRD)

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measurement indicated that the crystalline quality of the larger grains was worse. Ellipsometry measurement showed a peak at 1.8 eV for samples grown at both room temperature and 80 °C, but the overall shape of the spectra were different reflecting the different morphology.

2. Experimental

Pentacene films were vacuum evaporated on a piece of Si wafer and on a slide glass inside a vacuum chamber pumped with a turbo molecular pump to 10^{-7} Torr pressure. We filled a boron nitride crucible with a small amount of 97% pure pentacene powder purchased from Sigma-Aldrich, and heated it using a tungsten filament. The deposition rate was 0.3 nm/s. Because the deposition rate was low and the sample holder was bulky, the substrate remained at room temperature during the evaporation. For 80 °C growth, we heated the substrate with a halogen lamp inside the chamber. We monitored the deposition rate using a crystal oscillator, which was calibrated using a scanning electron micrograph of the cross section of a pentacene film. The substrates were cleaned by ultrasonic washing in alcohol, acetone and deionized water.

The films were analyzed using atomic force microscope (AFM), X-ray diffraction (XRD) and spectroscopic ellipsometry in air. The slide glass substrate was used for the measurement of transmission ellipsometry. Because there is no interference between the light reflected from pentacene and substrate surface in the transmission spectrum, the analysis easier.

3. Results and discussion

3.1. Native SiO_2 substrate

The samples were first probed with AFM, of which the images are displayed in Fig. 1. The grains on the room temperature films are smaller than those on the 80 °C films. In the case of room temperature films the grain size did not change from the 300 nm to the 600 nm film, but in 80 °C films the grains were bigger on the thicker film. Nucleation of pentacene is a sensi-

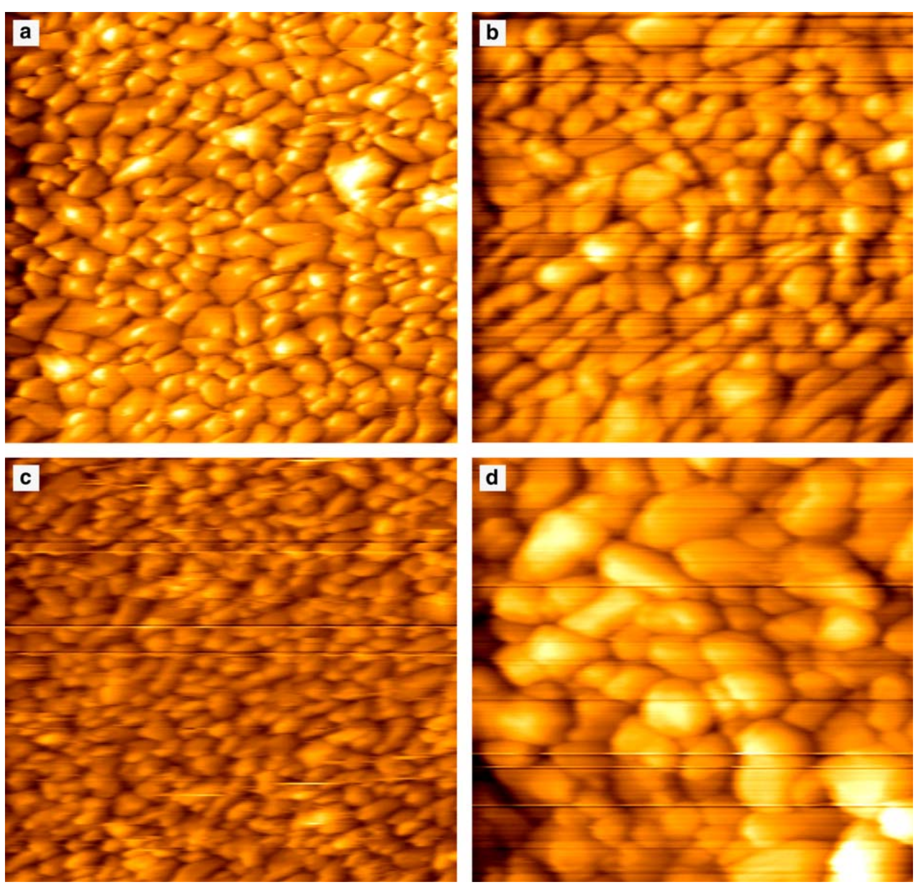

Fig. 1. Contact mode AFM images of pentacene formed by vacuum evaporation on a Si wafer covered with native SiO_2. Scan size is 5.7 μm × 5.7 μm for all images. The growth temperature and film thickness are (a) room temperature, 300 nm, (b) 80 °C, 300 nm, (c) room temperature, 600 nm, (d) 80 °C, 600 nm.