LEEM/PEEM investigations of the nucleation and growth of thin organic films

Jerzy T. SADOWSKI

Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Aoba-ku, 980-8577 Sendai

Pentacene (Pn – $C_{22}H_{14}$) is attracting great interest since it has been successfully used in the organic field-effect transistors, having field-effect mobilities surpassing that of amorphous silicon. Pn films are becoming a promising material for the practical realization of cheap and versatile organic devices. However, a major challenge remains – we need to understand the growth of organic materials as thin films to fabricate high-quality films for the practical realization of the organics-based electronic devices.

Our low-energy electron microscope (LEEM) and photoemission electron microscope (PEEM) investigations of Pn growth show that a disordered, insulating wetting layer is formed initially by Pn molecules dispensing the Si dangling bonds, in the case of chemically active surfaces, such as Si(111)-7x7. Subsequently, monolayer-high, fractal-shaped islands form. Since diffusion of the molecules is inhibited by the rough interface (rough wetting layer), the anisotropy in the growth rate manifests itself by aligning the fastest growth direction with the ***b***-axis of the Pn in-plane unit cell. When pentacene is deposited on semimetallic Bi(001)/Si(111) template, it grows into a well ordered, “standing-up” layer, having a bulk-like structure and a “point-on-line” epitaxial relation with the substrate (Figs.1a and 1b). Moreover, the very low nucleation density observed in LEEM and the high diffusion mobility of Pn molecules on the Bi(001) surface result in first-layer Pn island growth exceeding 0.2 mm in diameter.

Upon the deposition of Pn on the hydrogen-terminated Si(111), the nucleation of the islands starts without forming the wetting layer. Pn island growth exhibits a three-fold symmetry (Fig.1c), having preferential growth orientations. Three distinctively different contrasts are observed within the individual dendritic branches of the fractal Pn islands (Fig.1d). Each individual contrast observed in the LEEM image can be assigned to the specific type of the three micro-beam low-energy electron diffraction (μ-LEED) patterns, corresponding to the three different Pn epitaxial domains. These observations suggest that the Pn grains are polycrystalline even though they develop from a single nucleus. This polycrystallization is a result of the kinetic growth processes in conjunction with the intrinsic anisotropy of the crystal (in crystal structure or bonding energy).

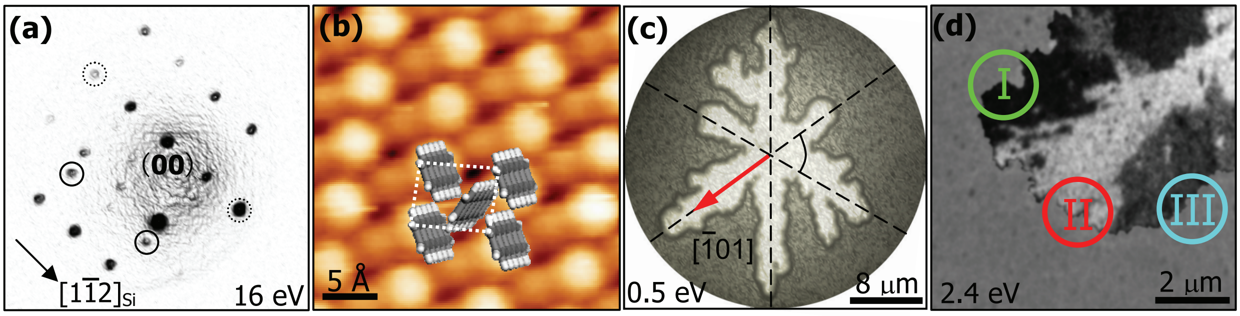

Fig.1. (a) LEED pattern taken from the Bi(001) surface partially covered by the first Pn layer; spots originating exclusively from the Bi(001) surface are marked with circles, while spots coming from the overlapping Bi and Pn patterns are marked by dotted circles; (b) High-resolution STM image (sample bias +1.6 V) of the Pn layer; each protrusion corresponds to a single Pn molecule; (c) LEEM image of the pentacene island grown on H-Si(111) surface; (d) Tilted-beam LEEM image showing three different domains: I, II, and III, within a single branch of fractal-shaped Pn island.

*In collaboration with Y. Fujikawa, G. Sazaki, S. Nishikata, A. Al-Mahboob, K. Nakajima and T. Sakurai.