Growth of super-grain pentacene by OVPD for AMLCD

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Abstract

We studied the growth of large-grain pentacene film by organic vapour phase deposition. The optimizations of the growth of pentacene are carried out by varying the gas pressure in the reactor and substrate temperature. We found that the grain size depends strongly on the gas pressure in the reactor. The grain size of 20μm has been obtained at the gas pressure of 200 Torr. The film was found to be strongly (001) oriented and its grain size decreases with decreasing the gas pressure.

1. Introduction

Recently, organic thin film transistors (OTFTs) have been of increasing interest for organic electronics.[1] Among many organic compounds, the pentacene shows the best TFT performance so far. The field-effect mobility of about $2.7cm^2/Vs$, threshold voltage of -1V and on/off current ratio of $>10^9$ have been demonstrated [4].

There are several deposition technologies for pentacence. On the other hand, a single-crystalline pentacence has been obtained from the organic vapour phase deposition (OVPD). In OVPD, the organic compound is thermally evaporated and transported by convection that is formed by temperature gradient and flowing inert gas.

In this work, we studied the deposition of the pentacene thin-films using OVPD. The gas pressure in the reactor and the substrate temperature were varied to achieve the condition giving the large-grain pentacence.

2. Experiments

Pentacene thin-films have been grown using organic vapour phase deposition. Figure 1 shows the temperature profile at the centre of the reactor tube. The quartz reactor is at the centre of a three-zone furnace, which was used to have a temperature gradient along the tube.

The source material was evaporated at the temperature of about 285°C. The pentacene thin films were deposited at the region of ~180°C. Note that the reactor tube is long and the left hand side is hot (285°C), and right-hand side is relatively cold (~ 180°C). The gas flow rate was varied to control the gas pressure in the reactor. The structural properties of the films were investigated by x-ray diffraction measurements (XRD), scanning electron microscope (SEM) and optical microscope.

2. Results and Discussion

There are two important deposition parameters of temperature gradient and gas pressure in the OVPD reactor. The buoyant convection is primarily formed by temperature gradient and the forced convection is secondarily formed by flowing gas in the deposition tube. The gas in the reaction chamber plays a role of carrying away impurities and changes the crystalline quality by controlling the transport velocity of the source to substrate [2]. Compared to the thermal evaporation, this method minimizes material waste and achieves uniform deposition of pentacene on a large-area substrate [3].

In order to examine the effects of flowing gas, we conducted the experiments with carrier gas and without carrier gas at the same pressure. When the film is deposited without carrier gas, the buoyant convection only affects the deposition. The evaporated source transports to toward the substrate. More material is deposited at the lower substrate temperature area, so that the grain size is less than that with flowing gas in the reactor.

When the pressure is varied from 10^{-4} Torr to 200 Torr, the effect of flowing gas is significant. Figure 2 shows the photo images of pentacene thin films deposited at various pressures. The grain size increases with increasing the gas pressure. The grain size of the pentacene is as large as 20 μm at 200 Torr.

Figure 3 shows the XRD data of the thin films deposited at a pressure of 2 Torr. The films are mainly <001> oriented and shows good crystalline quality according to XRD results. Figure 4 shows the full-width-at-half-maximum (FWHM) of XRD peak intensities. This also confirms that the grain size increases with the gas pressure [6].

According to the results by Laudise *et al.*, at low pressures volatilization and transport are so rapid that many nuclei are formed for the growth of polycrystalline pentance. This prevents forming a large grain pentacene film. At high pressures the transport is rather slower and thus the nucleation takes place at a high temperature, giving a large-grain pentacene [5].

3. Conclusion

We studied the growth of pentacene by OVPD. The grain size can be controlled by varying the gas pressure in the reaction chamber. It increases with increasing the gas pressure up to 20 um. The FWHMs of the (001) XRD peak intensities decrease with increasing the gas pressure because of the increase in the grain size.

References

[1] C. D. Dimitrakopoulos and D. J. Mascaro, IBM J. RES. & DEV. 45(2001)

[2] R. A. Laudise, Ch. Kloc, P.G. Simpkins, T. Siegrist, J. Crystal Growth 187 (1998) 449.

[3] Max Shtein, H. F. Gossenberger, Jay B. Benziger, S. R. Forrest, J. Appl. Phys. 89,1470 (2001)

[4]J. H. Schon, S. Berg, Ch. Kloc, B. Batlogg, Science 287 (2000) 1022.

[5] Ch. Kloc, P.G. Simpkins, T. Siegrist, R. A. Laudise, J. Crystal Growth 182 (1997) 416.

[6] Eric Lifshin, X-ray Characterization of Materials (Wiley-VCH, 1999), Chap. 1.7

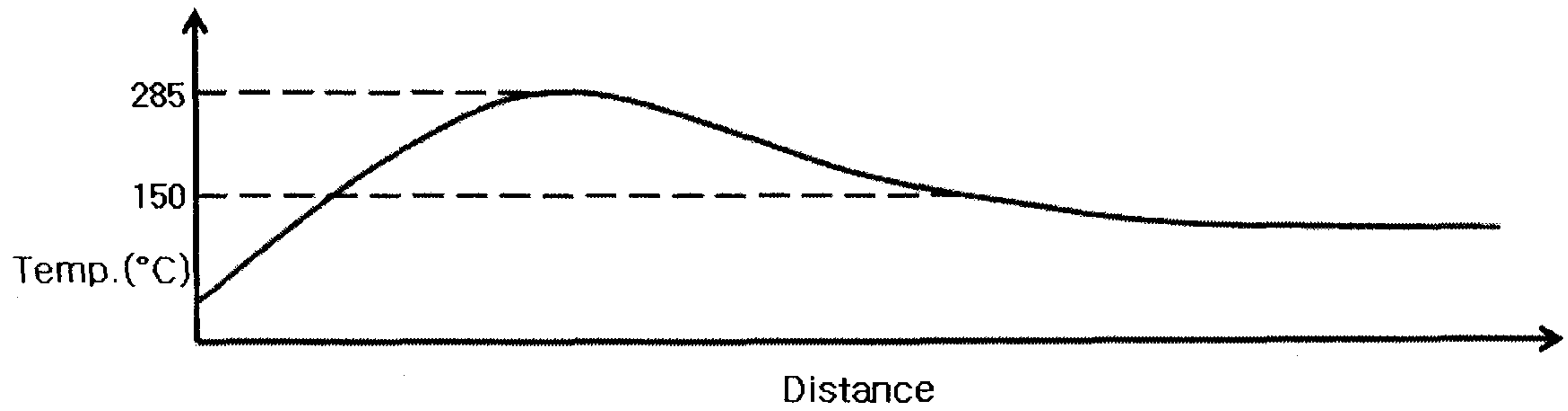
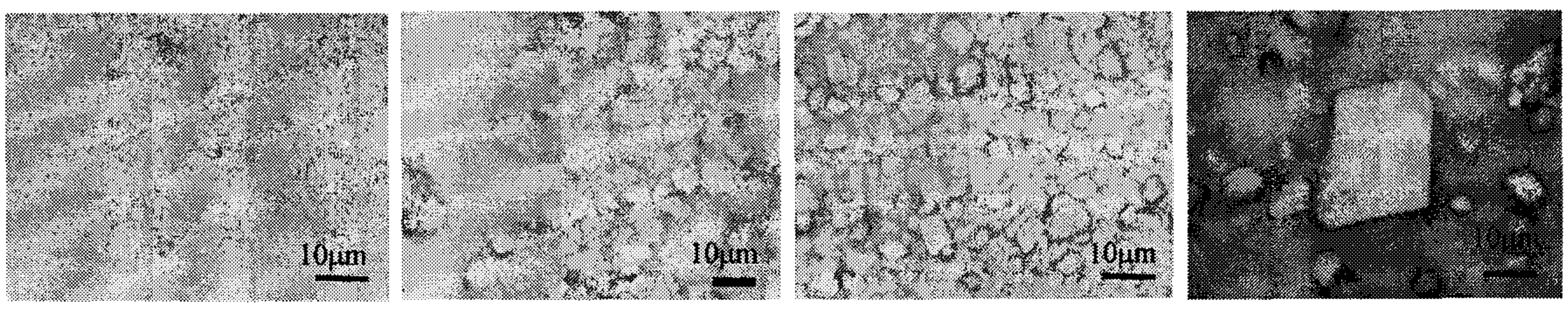


FIG. 1. Temperature profile of OVPD reactor for pentacene deposition



(a) 5 X10^{-4} Torr (b) 5 X10^{-2} Torr (c) 2 Torr (d) 200 Torr

FIG. 2. The photo image of pentacene thin films deposited as a function of gas pressure

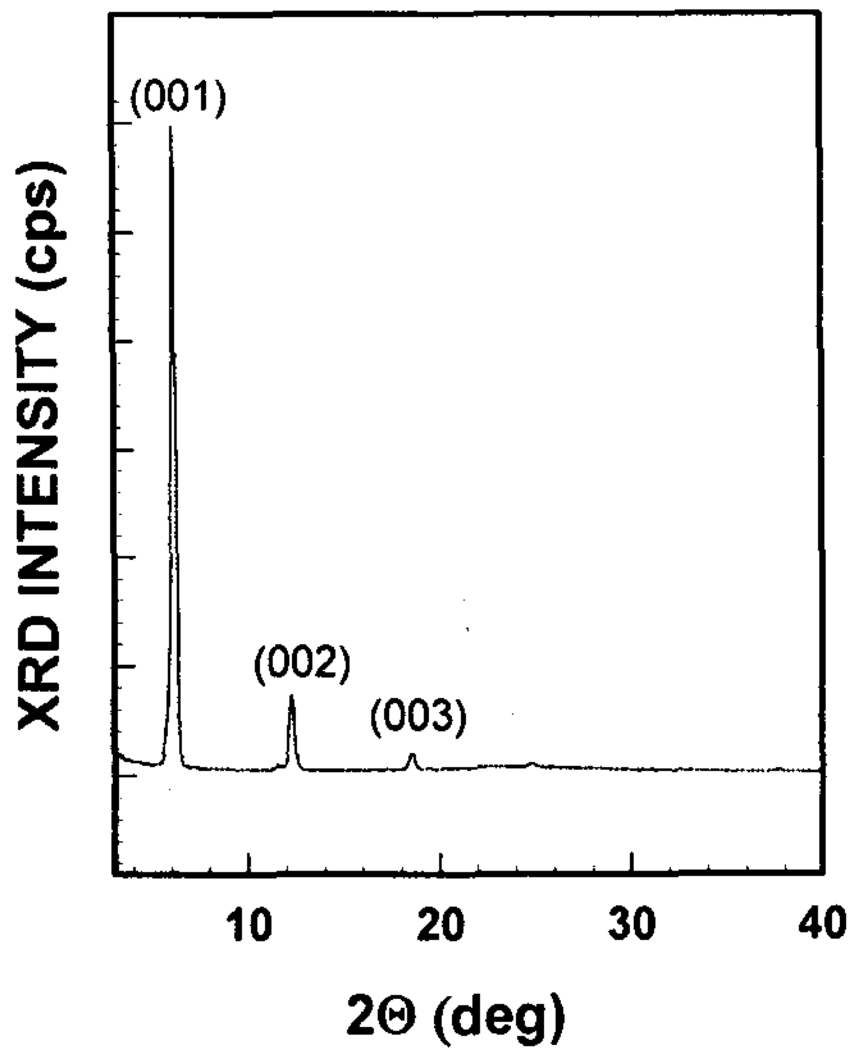


FIG. 3. The XRD intensity of pentacene thin films deposited at the pressure of 200 Torr

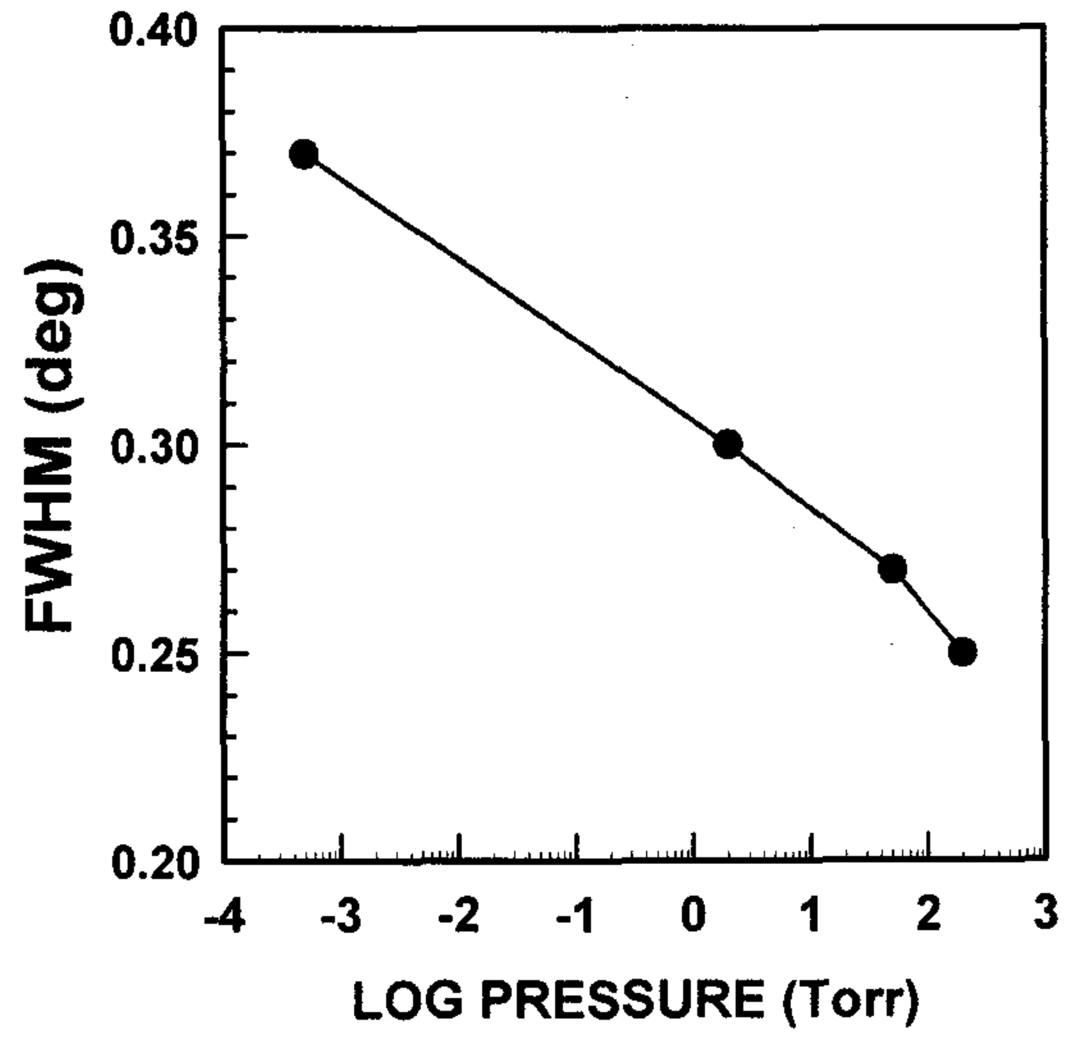


FIG. 4. Full width at half maximum of the (001) XRD intensity of the pentacene films