

High Mobility OTFTs With Monocrystalline Rubrene Channels Prepared by Horizontal Hot Wall Deposition

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As promising candidates for future low-cost and flexible display applications, organic thin film transistors (OTFTs) have attracted considerable research interests for the past few decades. Recent advances in organic semiconductor theory and organic film growth/deposition techniques have resulted in OTFTs based on single crystalline organic films with performance approaching or even exceeding the present day's dominant amorphous silicon TFT technology.

In this work, efforts have been made to explore suitable methods for the fabrication of thin film transistors based on high mobility organic semiconductors, such as rubrene and pentacene.

In the early stage of this work, OTFTs with rubrene single crystals grown by PVT method were fabricated and measured with $\mu_{\text{max,eff}} = 1.07 \text{ cm}^2/\text{V}\cdot\text{s}$, $I_{\text{ON}}/I_{\text{OFF}} \sim 10^5$ and $V_{\text{T}} = 0 \text{ V}$. However, it is noticed that these rubrene films are usually fragile and the adhesion to the substrates is often poor, leading to low reproducibility of functional devices. Hence, direct deposition of organic thin films to the substrates is a necessary measure to solve these problems.

In this work, a horizontal hot wall deposition (HHWD) method has been developed to directly deposit high quality rubrene films onto the substrate under low pressure ($P \sim 10^{-6}$ torr). The resulted films are continuous with good coverage, however different structural phases from amorphous to mono-crystalline are present. Through intensive studies on the film morphology and crystallinity of rubrene films deposited under different conditions, it is concluded that various factors can greatly affect the organic thin film growth, including surface treatment conditions, substrate orientations, source evaporation temperatures as well as substrate temperatures. Under the optimal deposition conditions, rubrene films are mono-crystalline with planar structure and grain sizes as large as $0.1 \times 2 \text{ mm}^2$. OTFTs based on these highly-ordered rubrene films showed excellent device performance with $\mu_{\text{max,eff}} = 2.47 \text{ cm}^2/\text{V}\cdot\text{s}$, $I_{\text{ON}}/I_{\text{OFF}} \sim 10^6$ and $V_{\text{T}} = 0 \text{ V}$.

Preliminary results of OTFTs with pentacene films deposited by HHWD method showed that the device performance are not as good as rubrene-based OTFTs with $\mu_{\text{eff}} = 0.22 \text{ cm}^2/\text{V}\cdot\text{s}$, $I_{\text{ON}}/I_{\text{OFF}} = 10^5$ and $V_{\text{T}} = 0 \text{ V}$. But it still demonstrated the general applicability of HHWD method for the deposition of organic materials. However, further investigation on deposition conditions is needed for device performance optimization.

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