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Research Article

Study of island height distribution for rubrene thin films deposited at different substrate temperatures using hot wall epitaxy

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Abstract

In organic thin film transistors, the hydrocarbon rubrene, due to its remarkable carrier transport capabilities has been a constant source of research and has attracted much attention. Here we have conducted a study based on the preparation and analysis of thin film deposition of rubrene on two dielectric materials, SiO_2 and mica resulting in island formation and growth. A study of island growth dependence on substrate temperatures has also been conducted. To analyze the dynamics of molecular growth of rubrene films on these substrates, we used atomic force microscopy to characterize them and studied the pattern of island growth on different substrate temperatures and substrates. In our work we observed a marked increase in island height distribution with increase in substrate temperature. This increase in island height distribution is also observed for substrates which have better sticking coefficients like mica.

Keywords:
Island growth, island count, thin films, epitaxy.

1. Introduction

One of the remarkable achievements in the field of organic electronics has been the promising results shown by field effect transistors built on single crystals of rubrene with hole mobilities as high as 15 cm^2/Vs being reached [1–6]. An average of 20 cm^2/Vs with a high of 30 cm^2/Vs hole mobility has been reported in some cases [7] which is one of the highest values recorded in similar experiments [8, 9]. However, reaching such high mobility values has its difficulties such as a reduction in measured values occurring due to oxidation when exposed to air [10]. Furthermore, since mobility values depend upon dielectric characteristics, temperature of film deposition and methods of measurement, their accuracy remains within limits [11, 12].

In contrast to the impressive results seen for single crystal form of rubrene, the results for thin films are an area of concern [6, 9, 13–18]. This is because the thin films have an amorphous form with only small regions of polycrystalline nature [19–21]. To understand the morphology of these thin films it is important to study the different stages of growth. These stages are island formation, the growth and coalescence of these islands, thin film formation and the initiation of small polycrystalline regions in these films [13–15, 20–33]. In our work presented here we have studied the initial stages of growth of rubrene thin films using inorganic substrates of mica and SiO_2 to study the dependence of island density and island growth on substrate temperatures.

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2. Materials and Methods

Organic material rubrene of 98% purity was obtained from Aldrich which when treated by thermal sublimation was further purified. Rubrene was transferred to a quartz tube in the Hot Wall Epitaxy setup. Muscovite Mica substrates of size $15 \times 15mm^2$ obtained from Segliwa GMBH were freshly hand cleaved in air and transferred to the HWE vacuum chamber. After reaching a vacuum of 10-6 mbar a preheating procedure was carried out for 15 minutes at substrate deposition temperature. This in situ heat treatment completely rids the surface of the substrates from all adsorbed materials. Rubrene was then deposited on mica (001) and freshly cleaned SiO_2 wafer (SiO_2 covered Si wafer) substrates at the vacuum of 10-6 mbar. The substrate temperatures used were 90°C and 120°C for mica while for SiO_2 it was 120°C. The source temperature for both cases was kept at 180°C while keeping the wall temperature

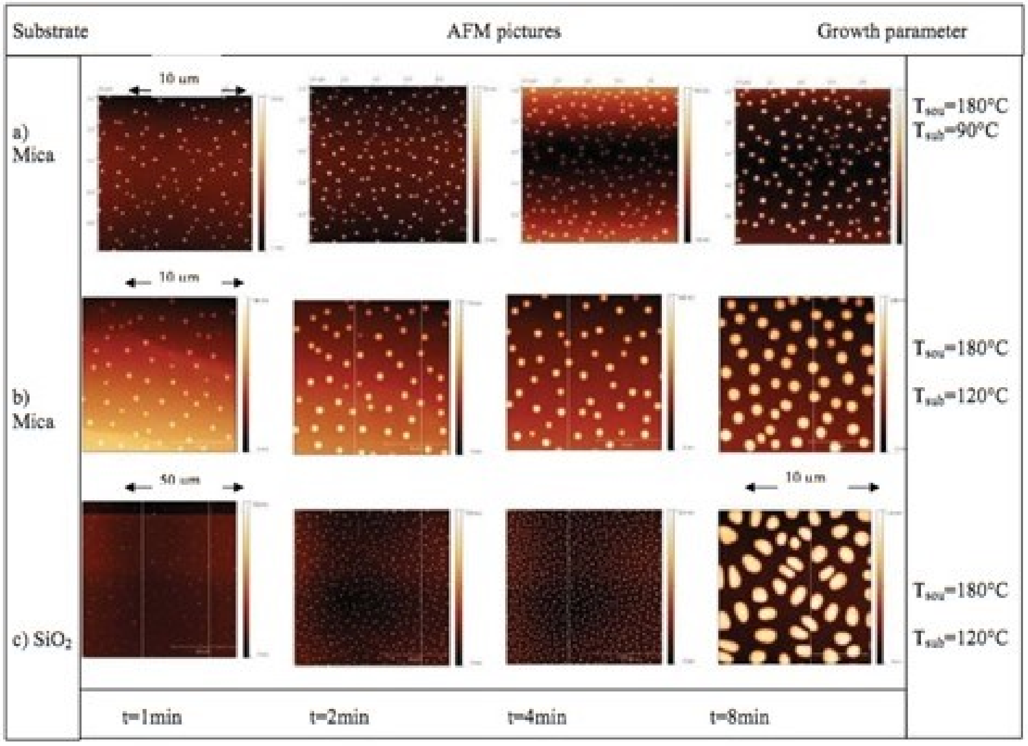

Figure 1. AFM images of rubrene grown on (a) mica surface at T_{sou} =180°C and T_{sub} = 90°C, (b) mica surface at T_{sou} =180°C and T_{sub} = 120°C and (c) SiO_2 surface at T_{sou} = 180°C and T_{sub} = 120°C, for growth times 1, 2, 4 and 8 minutes. The magnifications of images are (a) $10 \times 10 \mu m^2$, (b) $10 \times 10 \mu m^2$ and (c) $50 \times 50 \mu m^2$.

also at 180°C. Growth time for the samples was 1, 2, 4 and 8 minutes. Morphology studies were carried out by obtaining atomic force microscopy (AFM) images of the deposited organic thin films in the tapping mode of Digital Instruments Dimension 3100 microscope, where a SiC tip was used on areas of $10 \times 10 \mu m^2$ and $50 \times 50 \mu m^2$. Fig.1 shows these AFM scans of rubrene deposited on muscovite mica and SiO_2 substrates. These series of AFM scans were analysed in the following way. The island density was evaluated by counting the number of grains per $10 \times 10 \mu m^2$. By analysing a representative number of cross sections of the islands formed, the average height of these islands was evaluated which was then used for island height distribution calculations.

3. Results and Discussion

Rubrene was deposited on mica (001) and SiO_2 wafer substrates by using hot wall epitaxy at a vacuum of 10-6 mbar. The substrate temperatures used were 90°C and 120°C for mica while for SiO_2 it was 120°C. The source temperature for both cases was kept at 180°C. Morphology was assessed by getting the AFM scans. Fig.1 shows these AFM scans of rubrene deposited on muscovite mica and SiO_2 substrates.

Fig.2 shows that increase in substrate temperatures results in increased island heights while island count decreases for higher substrate temperatures. This can be understood by the different diffusion lengths of rubrene molecules. At high substrate

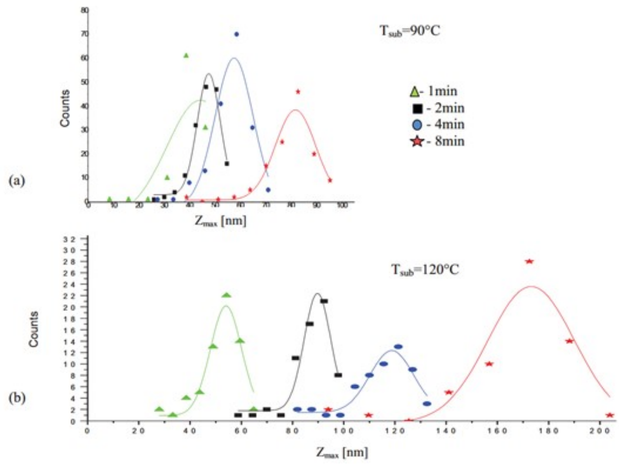

Figure 2. The comparison of the island height distribution Z_{max} for samples grown on mica at substrate temperature of (a) 90°C and (b) 120°C, and source temperature of 180°C.

temperatures diffusion length is in the range of the average island distance, so each impinging molecule can reach its optimum position at the edge of an island. On the other hand, at lower substrate temperatures the diffusion length of the impinging rubrene molecules is smaller and consequently in the beginning of growth, new islands are formed. This continues until the density of islands reaches a limit at which all molecules can reach the islands to be incorporated and consequently a satura-

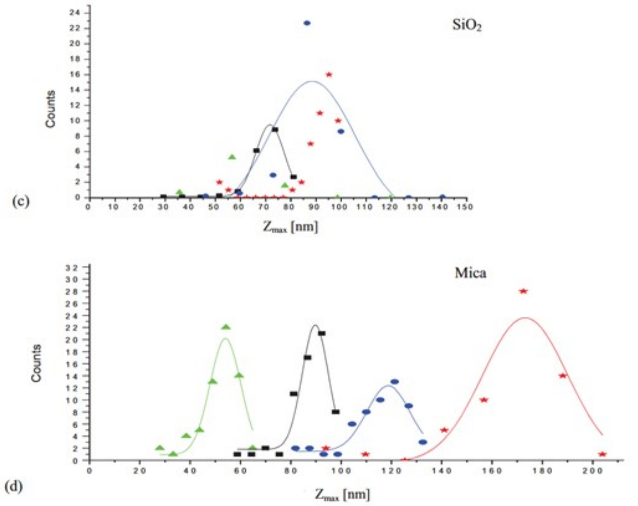

Figure 3. Comparison of the island height distribution for rubrene samples grown on mica (c) and SiO_2 (d) at substrate temperature of 120°C and source temperature of 180°C.

tion at higher island density was observed for lower substrate temperature.

A comparison is shown in Fig.3 for samples grown at source temperatures of 180°C and substrate temperature of 120°C but on different substrates of SiO_2 and mica. The corresponding AFM pictures are shown in Fig.1 b) and c). Due to a smaller sticking coefficient of rubrene on SiO_2, by using the same evaluation process as described above, we can see why the island height distribution for SiO_2 is lower as compared to mica for the same substrate temperature.

4. Conclusion

We have investigated the island height distribution of rubrene deposited on two different substrates by using the method of Hot-Wall-Epitaxy at different substrate temperatures. Keeping the deposition rate constant for all our experiments, we see that the island height distribution shows dependence on the substrate temperatures, increasing as we reach higher temperatures. Furthermore, sticking coefficients of substrates play an important role in the growth process and must be taken into consideration when choosing the optimum substrate temperatures for film growth.

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