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**Research Article**

# Island size distribution study for rubrene thin films on muscovite mica and $SiO_2$ using scaling theory

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**Abstract**

For the application of various theories to find a growth model for rubrene, it is essential to analyze the nucleation process during initial stages of growth. Here we present a study of rubrene deposited by Hot Wall Epitaxy on mica and $SiO_2$ using different substrate temperatures and calculating the island size distribution for each temperature. In order to find a growth model for rubrene we apply scaling theory during these initial stages of growth.

*Keywords:*
Nucleation, Scaling theory.

## 1. Introduction

Impressive new developments using organic materials has resulted in organic light emitting diodes (OLEDs) [1–4] as well as flexible devices [5] with the future being of organic solar cells [6, 7] and organic field effect transistors (OFETs) [8, 9]. However, the efficiency of any such device is compromised by the low charge carrier mobility. There needs to be intensive research into the charge transport system in crystalline form of organic materials [10–18] as well as the defining of models governing their growth. The attempt to predict the conditions of optimum growth of rubrene thin films on muscovite mica requires finding of a growth model for rubrene deposition. For this it is necessary to understand the nucleation process during the initial stages of island formation followed by application of different existing theories to the results. Here the scaling theory [19, 20], first shown by Venables et. al. [21], which has been successfully applied for formulating a growth model for pentacene [22] is selected and applied to rubrene during the initial stages of its growth.

## 2. Materials and Methods

An organic material called rubrene was acquired from Aldrich and subjected to thermal sublimation for additional purification. The substance was 98% pure. After being transferred into the Hot Wall Epitaxy device, Rubrene was put within a quartz tube. Acquired from Segliwa GMBH, $15 \times 15 mm^2$ Muscovite Mica substrates were manually split in the air prior to being put into the HWE vacuum chamber. Once a vacuum of 10-6 mbar was reached, the substrate deposition temperature was preheated for 15 minutes. With this in situ heat treatment, all materials that have adsorbed onto the substrate surface are completely eliminated. Rubrene was then applied on mica (001) and freshly cleaned $SiO_2$ wafer ($SiO_2$ coated Si wafer) substrates at a vacuum of 10-6 mbar. For mica, substrate temperatures of 90°C and 120°C were used, while for $SiO_2$, substrate temperatures of 120°C. In addition to the source temperature, the wall temperature was always kept at 180°C. The growth durations of the samples were 1, 2, 4, and 8 minutes. Making use of atomic force microscopy was utilized to perform morphological examinations on regions with dimensions of $10 \times 10 \mu m^2$ and $50 \times 50 \mu m^2$, using SiC tip. (AFM) images of the deposited organic thin films with a Digital Instruments Dimension 3100 microscope in the tapping mode. Fig. 1 shows these AFM pictures of rubrene applied to $SiO_2$ and muscovite mica surfaces. This series of AFM scans was subjected to the analysis that follows. One way to determine the island density would be to count the grains per $10 \times 10 \mu m^2$. After a large number of cross sections were analyzed, the average height of these islands was found. The distribution of island heights was then computed using this information.

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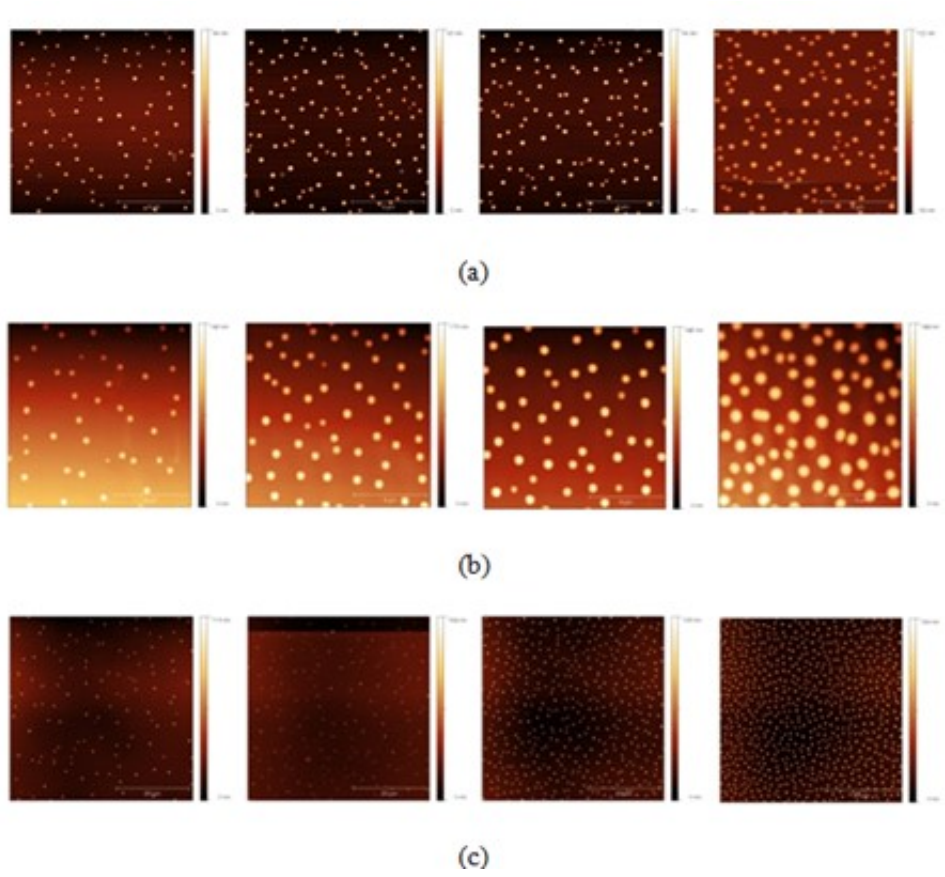


Figure 1. $10\times10\mu m^2$ AFM images of rubrene grown on mica for 1, 2, 4 and 8 minutes (left to right) at (a) $T_{sub}$ = 90°C and (b) $T_{sub}$ = 120°C and $50\times50\mu m^2$ AFM images of (c) $SiO_2$ for 0.5, 1, 2 and 4 minutes (left to right) at $T_{sub}$ = 120°C.

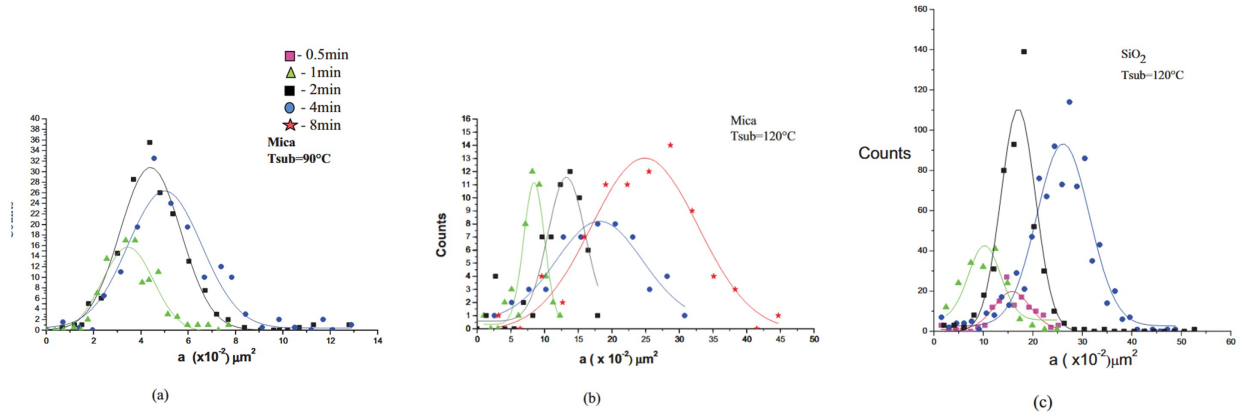


Figure 2. Island size distribution density for rubrene coverages of a few monolayers on mica at (a) $T_{sub}$ = 90°C, (b) $T_{sub}$ = 120°C and (c) $SiO_2$ at $T_{sub}$ = 120°C.

## 3. Results and Discussion

The growth rate in the two series of samples was found by plotting the measured film thickness versus the time of growth and which gave the corresponding growth rate in monolayers (ML) per minute. The coverages for all three series of samples calculated from their growth rates ranged from less than a ML to around 4 ML´s. Hence the scaling theory which holds for the first few monolayers of growth, was applied to these samples. The island size distribution density is calculated from the AFM micrograph´s frequency count analysis and is plotted for the first few monolayers of rubrene growth in Fig. 2

We have used the scaling law here and apply it to the island size distribution density and observe that all the curves collapse into fi(u) where fi(u) is the scaling function and i is the critical nucleus size. A critical island size of 2 for $T_{sub}$ = 90°$C$ and about 30 for all other cases was obtained by the application of the rate equation and scaling theory. However, the question

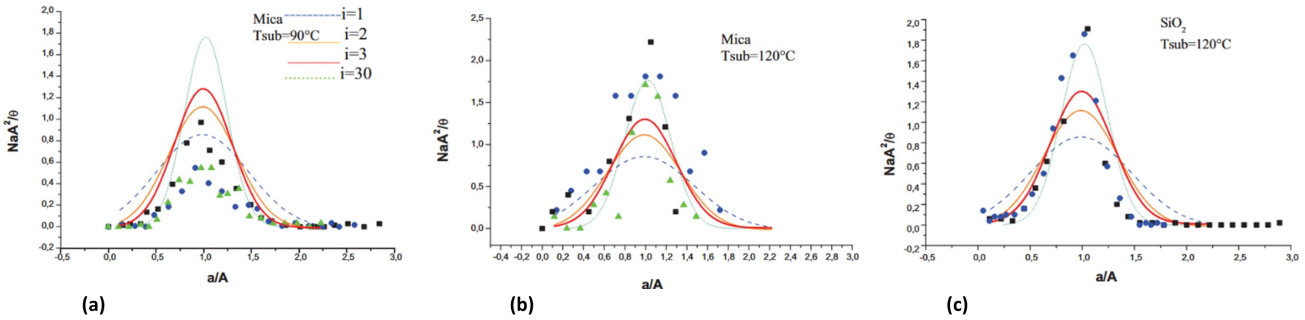


Figure 3. Scaled Island size distribution of rubrene grown on mica (a) $T_{sub}$ = 90°C, (b) $T_{sub}$ = 120°C and (c) $SiO_2$ at $T_{sub}$ = 120°C.

remains whether this theory can explain the growth mechanism of rubrene if island heights reach many monolayers

## 4. Conclusion

We have presented the study of the nucleation stage of rubrene layers which were grown by Hot Wall Epitaxy (HWE) on two substrates at different temperatures. The plots show an agreement between model and data in cases of fig. 3b and 3c where fi(u) = 30. However, this seems too high a value for critical island size for rubrene. Although we restricted our investigations to the first few monolayers of rubrene, it is important to mention that the island heights were much more than that. Hence, we conclude that the scaling theory cannot be applied to the investigation of materials which have island heights exceeding the first few monolayers.

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