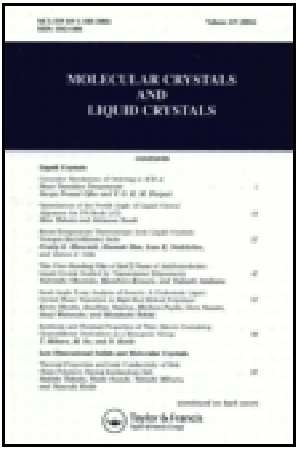

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Afm Studies On Polyimide Langmuir-Blodgett Films

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AFM STUDIES ON POLYIMIDE LANGMUIR-BLODGETT FILMS

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Abstract The polyimide films were formed by imidizing the polyamic acid long-chain alkylamine (dimethylhexadecylamine) salts (PAAS) films with a thermal treatment up to 300℃ for 1 hour, where the polyamic acid alkylamine salt films were formed on mica substrates at various surface pressures of 5 mN/m, and 25 mN/m, respectively, by using Langmuir-Blodgett (LB) method. Atomic Force Microscopy (AFM) has been used to investigate the surface morphology of PAAS and imidized films with a thickness of one monolayer at various surface pressures, where AFM was operated in non-contact mode for the surface morphology of the PAAS and imidized films, and in contact mode for the molecular structure of the imidized films, respectively. It was found that a uniform monolayer of the PAAS film was formed even at the surface pressure of 5 mN/m and the root mean squared (rms) roughness of PAAS films formed at 5 mN/m was slightly higher than that of PAAS films at 25mN/m, but the rms roughness of the former became slightly lower than that of the latter after the imidization.

INTRODUCTION

Polyimides are well-known dielectric materials for microelectronic and electronic packaging applications because of their excellent thermal and chemical stability, good mechanical properties, low dielectric constant and their processability.[1,2] In order to obtain high performance materials for microelectronic applications, it is necessary to prepare ultra-thin polyimide films.[2] There are several methods to prepare ultra-thin polyimide films such as molecular beam epitaxial growth, ion beam assisted deposition techniques, and spin coating method. Another simple way of preparing ultra-thin polyimide films is Langmuir-Blodgett (LB) technique which has recently drawn much attention. Since polyimide itself is not processable, a precursor method is normally used.[3]

In this study, the polyamic acid long-chain alkylamine (dimethylhexadecylamine) salt (PAAS) films, precursor films, were prepared onto mica substrate by LB technique and these films were imidized to form PMDA-ODA polyimide LB films. The surface morphology of the PAAS and imidized films at different surface pressures and the molecular structure of the imidized films were also studied by using AFM.

EXPERIMENTALS

Polyamic acid dimethylhexadecylamine salt (PAAS) was prepared as reported in elsewhere[3] and the LB films of PAAS were deposited as z-type at 5 mN/m and 25 mN/m, respectively, on mica (15 mm × 20 mm) purchased from Spruce Mine Mica company, where the transfer ratio constant was almost 1. Further details on the preparation condition of LB films will be presented in elsewhere.[4] The surface morphology of the PAAS and imidized films was investigated under air ambient conditions with a commercial Atomic Force Microscope (Park Scientific Instruments). For the surface morphology analysis of the LB films, AFM was operated in a non-contact mode with a scanning rate of 2 Hz in order to avoid damage problems. Typical amplitudes were on the order of 10 Å, using a 5 μm scanner. On the other hand, for the molecular structure analysis of the imidized film, AFM was operated in contact mode, where typical forces were on the order of 10 nN and scanning rates were from 16 Hz to 32 Hz with a 5 μm scanner.

RESULTS AND DISCUSSION

AFM is a very useful analytical tool to investigate the surface morphology and nanostructure of insulating materials because of its high spatial resolution and its capability of nondestructive observation. Fig. 1 (a), and (b) show typical three-dimensional AFM images of one monolayer of PAAS films formed on mica at 5 mN/m, and 25 mN/m, respectively, with a scanning area of 0.35 μm × 0.35 μm. The comparison between Figure 1 (a), and (b) indicates that the surface of the PAAS monolayer film formed at 25 mN/m was smoother than that of the PAAS monolayer film formed at 5 mN/m. The root mean squared (rms) roughness values of the PAAS LB films formed at 5 mN/m, and 25 mN/m were 1.1 Å, and 0.73

Å, respectively, which indicates that the PAAS LB film formed at 25 mN/m was more packed than the PAAS film formed at 5 mN/m. Fig. 2 (a), and (b) show also three-dimensional AFM images of the imidized films formed at 5 mN/m, and 25mN/m, respectively, with a scanning area of 0.3 μm × 0.3 μm. After the imidization, on the other hand, the rms roughness value of the LB film formed at 5 mN/m was even greater than that of the LB film formed at 25 mN/m, where the rms values of the LB film formed at 5 mN/m, and 25 mN/m were 0.60, and 1.3 Å, respectively. During the imidization process, the long alkyl chain components, hexadecyl amine, are supposed to be removed subsequently. The well-packed PAAS LB film should contain more long alkyl chain components per unit area in LB films, which would be removed during the imidization. Therefore the higher rms value of the LB films formed at 25 mN/m compared to that of LB films formed at 5 mN/m may be due to these effects.

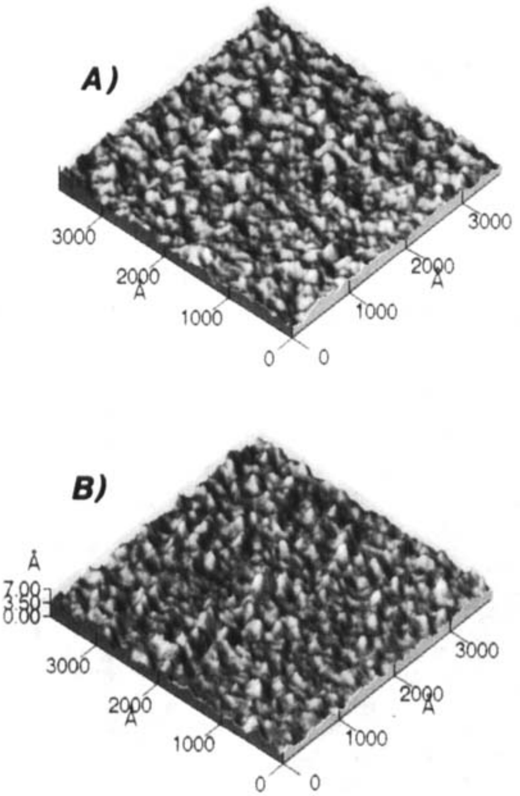

Figure 1. 0.35 μm × 0.35 μm three-dimensional AFM images of (a) the PAAS LB films formed at 5 mN/m, and (b) the PAAS LB films formed at 25 mN/m.

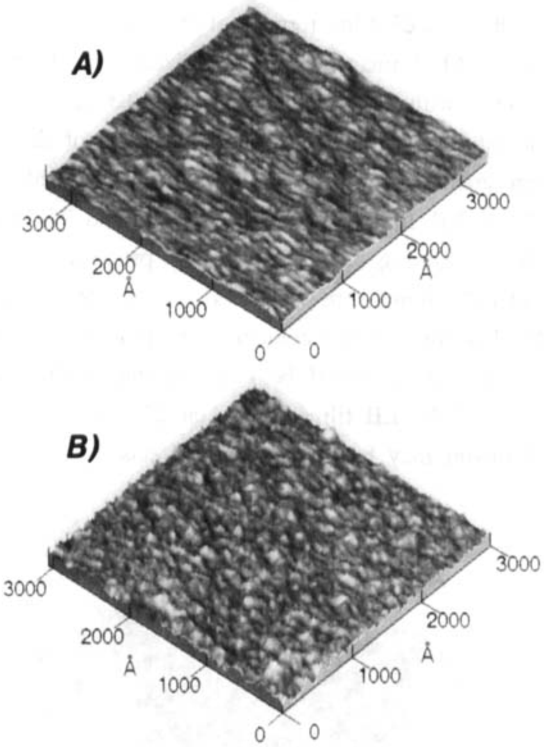

Figure 2. 0.3 μm × 0.3 μm three-dimensional AFM images of (a) the imidized LB films formed at 5mN/m, and (b) the imidized LB films formed at 25 mN/m.

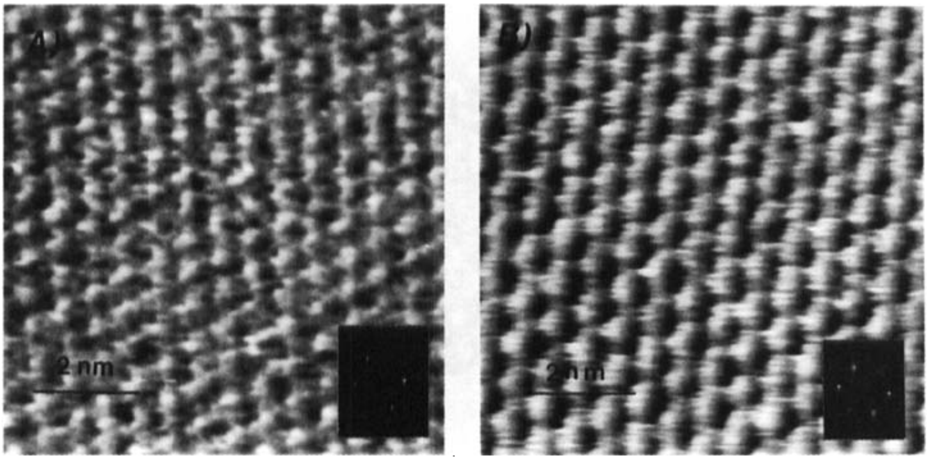

Figure 3. Unfiltered AFM images (80 Å × 80 Å) of (a) one monolayer of the imidized LB film, and (b) mica substrate itself for comparison. The insets are Fourier transforms of each AFM image.

Fig. 3 (a) shows the unfiltered AFM image (80 Å × 80 Å) of a monolayer of the PMDA-ODA polyimide on mica surface. This image shows a regular array structure with periodicities in two directions and it has also a certain degrees of smearing in scanning direction which may be due to the interaction between the cantilever and the film. On the basis of the molecular dimensions from the one published previously[5,6], the PMDA-ODA polyimide should have a zig-zag structure, but it is hard to say here that such a structure is shown in this figure. Nevertheless it shows a considerable degree of two dimensional order and periodicities in one direction was about 6.2 Å, which may be interchain distance and is in a good agreement with the results of semiempirical calculation.[6] Fourier transform of a polyimide AFM image was also shown in Fig. 3 (a) as the inset. The Fourier transform of the polyimide AFM image shows a rectangular lattice, which is different from that of mica AFM image with hexagonal lattice as shown in Fig. 3 (b).

CONCLUSION

We have investigated the surface morphology of polyimide LB films formed at different surface pressures before and after the imidization, and molecular structure of the imidized films by using AFM. The rms roughness of the PAAS LB film formed at 5 mN/m was higher than that of the PAAS LB film formed at 25 mN/m. On the other hand, the rms roughness of the LB film formed at 5 mN/m became smaller than that of the LB film formed at 25 mN/m after the imidization. The imidized LB film formed at 25mN/m has well-ordered structure, of which the Fourier transform shows a rectangular lattice.

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