Effect of deposition temperature on the structural and surface properties of AlN by plasma enhanced atomic layer deposition

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Abstract: The influence of growth temperature on the properties of aluminum nitride (AlN) films are grown by plasma enhanced atomic layer deposition (PEALD) at different deposition temperature. NH_3 and trimethylaluminum (TMA) were used as precursors, 200, 500, 800, 1 000, 1 500 cycles AlN layers were deposited at 300 ℃, 350 ℃ and 370 ℃, the growth rate, crystallinity and surface roughness were discussed. Deposition rate and crystallization of the films increased whereas the surface roughness decreased in the growth temperature range of 300−370 ℃.

Key words: Aluminum nitride; plasma enhanced atomic layer deposition; growth rate; crystallization; surface roughness; deposition temperature

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PEALD 沉积温度对 AlN 的结构和表面特性的影响

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摘 要: 研究通过等离子增强原子层沉积(PEALD)在不同沉积温度下生长的 AlN 温度对其特性的影响。前驱体是 NH_3 和 TMA,在 300 ℃、350 ℃和 370 ℃沉积温度下分别沉积了 200、500、800、1 000、1 500 周期的 AlN 层,并讨论了 AlN 薄膜的生长速率、结晶化和表面粗糙度。结果表明,在 300~370 ℃范围内,随着温度的上升薄膜的沉积速率和结晶化增加,而薄膜表面粗糙度减小。

关键词: 氮化铝; 等离子增强原子层沉积; 生长速率; 结晶化; 表面粗糙度; 沉积温度

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0 Introduction

Good thermal conductivity and high band gap makes Aluminum nitride (AlN) become an excellent material for several applications. AlN has been used in UV range light emitting diodes[1], high-k stacks[2], dye-sensitized solar cells [3], and for gallium arsenide and silicon carbide passivation[4-5]. AlN[6-8] has been grown by metal organic vapor phase epitaxy(MOVPE), plasma enhanced chemical vapor deposition (PECVD) and molecular beam epitaxy (MBE). Due to the accurate thickness control, uniformity and especially high conformality[9], plasma enhanced atomic layer deposition (PEALD) processes have also been developed for AlN using trimethylaluminum(TMA) as the aluminum source and ammonia(NH_3) as the source for nitrogen. However, in order to get a sufficient growth rate with NH_3, the growth temperature has to be above 400 ℃[10]. Therefore, for lower temperature deposition it is reasonable to use plasma to improve the reactivity of NH_3.

Although the growth process of PEALD AlN based on TMA and NH_3 plasma has been published by Liu et al.[10], the properties of the PEALD grown AlN films at different temperature have not been extensively studied previously. In this paper the effect of the growth temperature on the growth rate, surface roughness and crystallization of the AlN films was investigated.

1 Experimental detail

PEALD processes have been developed for preparing AlN using trimethylaluminum (TMA) as the aluminum source and NH_3 plasma as the source for nitrogen, which were grown by a LabNano PE TM Plasma/Thermal ALD reactor equipped with a capacitive plasma source. TMA and NH_3 enhanced by argon (Ar_2) plasma were used as precursors while Ar_2 was used as the carrier gas. Ar_2 flow was controlled by mass flow controllers(MFCs). TMA was pulsed for 0.8 s and NH_3 for 10 s while the purge times after the TMA and NH_3 pulses were 3 and 1 s, respectively. Plasma power was set to 300 W and turned on before the NH_3 pulse and off before TMA pulse in each cycle. To investigate the influence of growth temperature on the AlN film properties, 200, 500, 800, 1 000, 1 500 cycles AlN layers were deposited at 300 ℃, 350 ℃ and 370 ℃.

In this paper, we study the properties of the AlN film deposited on Al_2O_3 surface at different temperatures. Atomic Force Microscope (AFM) is applied to characterize the topography and the roughness of the deposited films at different temperatures. X-ray Diffraction (XRD) was used to determine the crystallinity of the AlN films (Bruker AXS D8 DAVINCI) with Cu Kα radiation of 0.154 06 nm.

2 Results and discussion

The film thickness as a function of the ALD cycles is shown in Fig.1. One can see that the film thickness has almost linear dependence on the ALD cycles but the growth temperature affects the growth rate. Deposition rate increased linearly from 0.74, 1.04, 1.32 Å/cycle in the growth temperature of 300 ℃, 350 ℃ and 370 ℃. The result in this paper is corresponded with the previous reference[11].

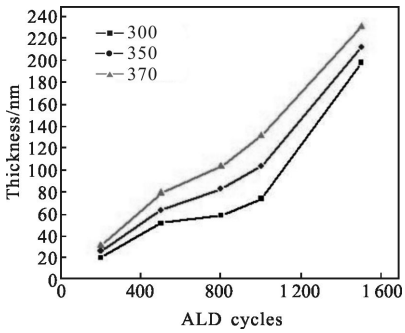

Fig.1 AlN film thickness as a function of the ALD cycles at different temperatures

X-ray diffraction curves from the AlN films grown at 300 ℃, 350 ℃ and 370 ℃ are shown in Fig.2. It can be clearly seen that there formed AlN crystal

for AlN(102), AlN(110), AlN(103) and AlN(112)[12-15] diffraction peaks are found, and diffraction peaks can be seen clearer with the temperature improvement, the crystallization of AlN films grown at 370 ℃ is the most signifcant.

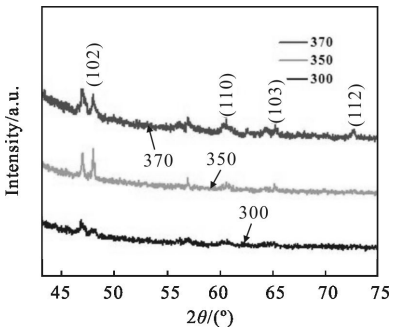

Fig.2 X-ray diffraction scans from 1 500 cycles AlN films grown at 300 ℃, 350 ℃ and 370 ℃

The surface morphology of PEALD AlN deposited on Al_2O_3 at different temperatures was also investigated by AFM. As shown in Fig.3, 1500 cycles AlN films grown at 300 ℃(Fig.3 (a)), 350 ℃(Fig.3 (b)) and 370 ℃ (Fig.3(c)). The AlN layers grown on sapphire substrates

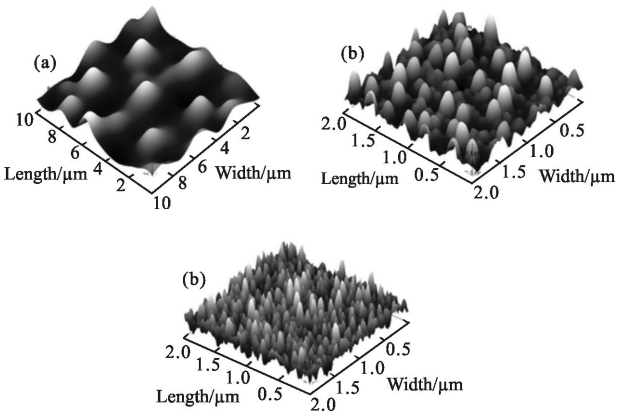

Fig.3 AFM images of 1500 cycles AlN films grown at 300 ℃ (a), 350 ℃ (b) and 370 ℃ (c), respectively

showed a very interesting feature. The growth is very similar to that observed ZnO layers grown on sapphire substrates[16]. It is evident from all the images that the AlN exhibits an island-like growth on sapphire substrates. There are AlN islands scattered over the surface. It also can be seen that the AlN layers deposited on different temperatures significantly affect the surface morphology of the samples. The roughness of the samples is 5.98 nm, 1.77 nm and 0.376 nm which deposited on 300 ℃, 350 ℃ and 370 ℃, respectively. Thus, we can know that the roughness decreased with the temperature improvement.

3 Conclusion

In summary, the structural and surface properties of AlN films grown in the temperature range of 300-370 ℃ by plasma enhanced ALD using TMA and NH_3 precursors. Deposition rate increased linearly from 0.74, 1.04, 1.32 Å/cycle in the growth temperature of 300 ℃, 350 ℃ and 370 ℃, respectively. The surface roughness decreased with the temperature improvement. The films grown at each temperature were found to be crystalline and the highest growth temperature the AlN film crystalline significantly.

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