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# Texture of Al/Ti thin films deposited on low dielectric polymer substrates

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**Abstract**

The texture of Al/Ti thin films deposited on low-dielectric polymer substrates has been investigated. Fifty-nm-thick Ti films and 500-nm-thick Al-1%Si-0.5%Cu (wt%) films were deposited sequentially onto low-k polymers and $SiO_2$ by using a DC magnetron sputtering system. The texture of Al thin film was determined using X-ray diffraction (XRD) theta-2theta ($\theta$-$2\theta$) and rocking curve and the microstructure of Al/Ti films on low-k polymer and $SiO_2$ substrates was characterized by Transmission electron microscopy (TEM). Al/Ti thin films deposited on $SiO_2$ had stronger texture than those deposited on low-k polymer. The texture of Al thin films strongly depended on that of Ti films. Cross-sectional TEM revealed that grains of Ti films on $SiO_2$ substrates had grown perpendicular to the substrate, while the grains of Ti films on SiLK substrates were formed randomly. The lower degree of 111 texture of Al thin films on low-k polymer was due to Ti underlayer.

## 1. Introduction

One of the major trends in recent microelectronics is that the device dimension has kept shrinking. As the size of ultralarge-scale-integration (ULSI) devices decreases, the RC delay, the power dissipation, and the crosstalk rapidly increase [1-5]. To accommodate these requirements, low dielectric constant (low-k) materials have been proposed to replace CVD-$SiO_2$, which is currently used as an interlayer dielectric (ILD) [6-8]. The spin-on polymers are promising among the low-k materials, because of their low dielectric constant, local planarization capability and easy processability [8]. Various materials and process integration methods are

being developed for the implementation of low-k polymers into multilevel interconnect structure [9-10]. Electromigration (EM) reliability is one of major concerns for implementing the low-k polymers. To improve electromigration resistivity of Al based interconnection, the higher degree of 111 preferred orientations with minimal mosaic spread is essential [11]. Among them, a high degree of 111 preferred orientation and minimal mosaic spread has been shown to be essential for longer electromigration lifetime in Al interconnects. It is reported that Ti underlayer improves Al texture [12-13]. Texture enhancement is due to increase of surface energy, which improve Al wettability to the substrate [13-14] and lattice matching of Ti and Al [15]. We studied the texture of Al/Ti thin films.

## 2. Experimental

The low-k polymers used in this study were PI2610 (BPDA-PDA) and SiLK™-G. Thermal oxide ($SiO_2$) was also used to compare with the low-k polymer dielectrics. The thickness of PI2610 and SiLK was 1 $\mu m$ and $SiO_2$ was 0.5 $\mu m$. Fifty-nm-thick Ti films and 500-nm-thick Al-1%Si-0.5%Cu (wt%) films were deposited sequentially onto low-k polymers and $SiO_2$ by using a DC magnetron sputtering system (base pressure = $5\times10^{-7}$ torr). Substrates was not heated nor cooled during thin film deposition.

The relative 111 intensity of Al thin film was determined using X-ray diffraction (XRD) 2 theta-theta ($2\theta$-$\theta$) and rocking curve. Transmission electron microscopy (TEM) was used to characterize the microstructure of Al/Ti thin films on low-k polymers and on $SiO_2$.

## 3. Results and Discussion

Fig. 1(a) shows a typical series of $\Theta$-$2\Theta$ diffraction patterns of Al/Ti thin films deposited on $SiO_2$ and low-k polymer substrates. Deposition power was 300 W and deposition rate was 0.34 nm/sec during Al deposition. In Al/Ti/$SiO_2$, the intensity ratio of Al 111 and 200 was 31.9, while, in Al/Ti/SiLK and Al/Ti/PI2610 it was 3.4 and 3.3, respectively. Rocking curves from the same samples of Fig. 1(a) are represented in Fig. 1(b). All rocking

curves were found to be symmetric with respect to the 111 peak position at $2\Theta=38.47^{\circ}$ and well described with Gaussian distributions as shown. The full width half maximum (FWHM) of Al/Ti on $SiO_2$ was much smaller than that of Al/Ti on low-k polymer. From Fig. 1(a) and 1(b), the Al/Ti thin films on low-k polymer had weaker texture than those on $SiO_2$.

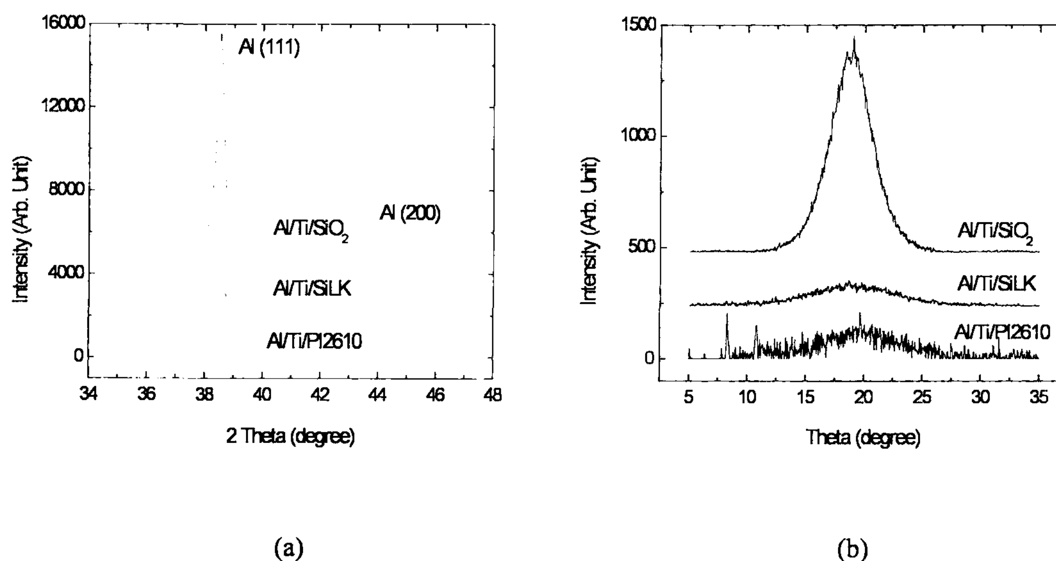


Fig. 1. (a) XRD $\Theta$-$2\Theta$ scan and (b) rocking curves of Al on various substrate.

Fig. 2 shows the dependency of deposition power on the FWHM of Al thin films from rocking curves for Al/Ti/$SiO_2$ and Al/Ti/SiLK specimen. The FWHM of both samples increased as the deposition power increases. Lower deposition rates generally favor textures because there is enough time or energy available for the film to obtain equilibrium or near equilibrium shapes [16]. At the same deposition power, Al/Ti/$SiO_2$ had smaller value of FWHM than Al/Ti/SiLK, which means the texture of Al/Ti on low-k polymer substrates was lower value comparing with Al/Ti on $SiO_2$.

From Fig.1 and Fig. 2, Al/Ti/low-k polymer had lower degree of texture than Al/Ti/$SiO_2$. It was reported that Al texture grown on Ti underlayer was enhanced as the degree of preferred orientation of Ti was improved, because Ti (0002) underlayer has high lattice matching to Al (111) underlayer [15]. We measured texture of Ti

(0002) on $SiO_2$ and low-k polymer with ω-rocking curves. In Fig. 3, Ti/low-k polymer had lower FWHM than $Ti/SiO_2$, which means $Ti/SiO_2$ was stronger texture than Ti/low-k polymer. Therefore, the lower 111 texture of Al/Ti/SiLK was due to the lower texture of Ti underlayer.

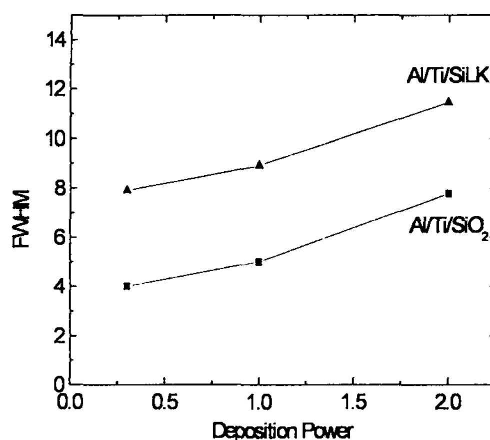


Fig. 2. The FWHM from 111 ω-rocking curves for $Al/Ti/SiO_2$ and Al/Ti/SiLK as a function of deposition power.

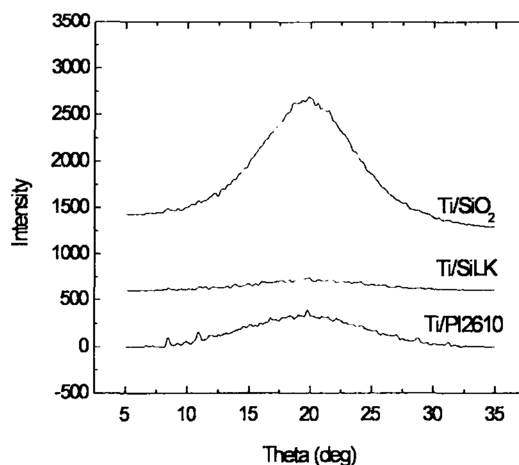


Fig. 3. Rocking curves of Ti (0002) on $SiO_2$, SiLK, and PI2610. The Ti thickness was 50 nm, and deposition temperature was room temperature.

Fig. 4(a) and Fig. 4(b) shows the cross-sectional TEM of Al/Ti/$SiO_2$ and Al/Ti/SiLK, respectively. Fig. 4 reveals that Ti thin films deposited on $SiO_2$ substrate had columnar microstructure and Ti grains grew perpendicular to the substrate, while many equiaxial grains were observed in the Ti thin films on SiLK substrate. It can be concluded that the lower Ti texture of Ti/SiLK came from the randomly oriented grains.

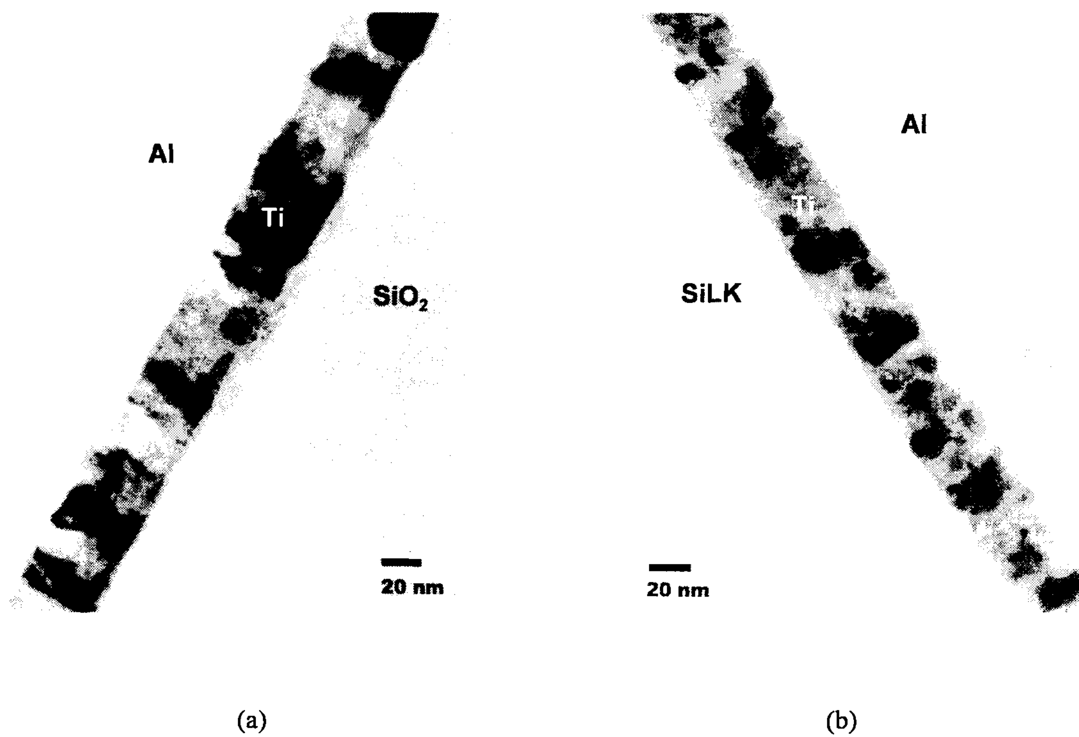


Fig. 4. XTEM of (a) Al/Ti/$SiO_2$ and (b) Al/Ti/SiLK.

## 4. Conclusion

We measured the texture of Al/Ti on $SiO_2$ and low-k polymer substrate with XRD $\Theta$-$2\Theta$ scan and rocking curve. Al/Ti deposited on low-k polymer had lower level of texture comparing with Al/Ti on $SiO_2$ substrate. The grains of Ti films on $SiO_2$ substrates had grown perpendicular to the substrate, while the grains of Ti on SiLK substrates were formed randomly. The lower degree of 111 texture of Al thin films on low-k polymer was due to Ti underlayer.

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