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Evaluation of LOCOS Induced Stress Using Raman Spectroscopy with an Al-Mask

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Abstract

We evaluated the mechanical stress of Si substrate using a Raman spectrum through the small square window on Al-mask. Using this method, we were able to measure the mechanical stress distribution across the active region of Local-oxidated-silicon (LOCOS) structure with a spatial resolution of 200 nm. There are distinctive differences in the mechanical stress distribution depending on the type and size of the LOCOS structures.

1. Introduction

The evaluation of mechanical stress in deep-submicron devices is important in controlling the threshold voltage of MOSFETs, because mechanical stress creates channel profile variation due to the transient enhanced diffusion (TED) variation of channel impurities[1,2]. Micro-Raman spectroscopy is popular for measuring mechanical stress in small device areas[3], but the spatial resolution of micro-Raman spectroscopy is at most about 1μm, which is not sufficient to evaluate deep submicron devices. In order to improve the spatial resolution, we studied micro-Raman spectroscopy after substrate fabrication for a LOCOS structure coated Al film with small windows.

2. Micro-Raman spectroscopy with an Al-mask

First, we determined the thickness of Al films necessary to exclude a Raman beam reaching the Si substrate. The Raman spectra were measured using a 488 nm wavelength of argon ion laser with 5 mW of power. Fig. 1 shows the Raman intensity from an Si substrate through the Al-films. The Raman intensity was reduced exponentially as the Al film thickness increased, and when the thickness of Al was 40 nm, the intensity of Raman light was comparable to the background level. Hence, we decided on a thickness of 40 nm for the Al film. Next, we evaluated the Raman intensity of Si through the small Al windows. Fig. 2 shows the Raman spectrum of Si through a 200 nm window. The Raman intensity decreased as the size of the window decreased as shown in Fig. 3. Although the Raman intensity through a 200-nm window was about 1/300 compare to that of bare Si, we were able to obtain a sufficient intensity to evaluate the mechanical stress of Si substrate. If a lithography permits smaller pattern, we can evaluated it with a sub-100-nm spatial resolution.

3. Evaluation of LOCOS induced stress

We then evaluated the Raman spectrum in the LOCOS structures using an Al-mask with 200-nm square windows. Fig. 4 shows the process flow for making LOCOS structure. In this study, we compared two types of LOCOS structures: ON-LOCOS using an oxynitride pad and a conventional LOCOS using a SiO_2 pad[1]. We made 1 μm line and 5 μm space, and 3 μm line and 5 μm space the LOCOS patterns. The thickness of the LOCOSs oxides was 300 nm. After the formation of the LOCOS structure, an Al mask was made using the lift-off method without damaging the etching on the Si substrate. The 200 nm square resist patterns were made using electron-beam (EB) lithography. As shown in Fig. 5, the Al-windows position from LOCOS edge were varied to evaluate the spatial distribution of Raman shift in the active region. The Al-window pitch was shifted 0.1 μm (for 1 μm and 5 μm L/S pattern) or 0.2 μm (for 3 μm and 5 μm L/S pattern) from the LOCOS-pattern.

Fig. 6 shows peak shift profiles in the active region of a 3 μm width LOCOS pattern. The thickness of the LOCOS oxides was 300 nm. The Raman peak shift for ON-LOCOS was larger than that for the conventional LOCOS. The mechanical stress of Si (100) becomes -2.49 x 10^9 dyne/cm^2 corresponding to the Raman peak shift of 1 cm^{-1} [4]. Using this conversion, the mechanical stress for ON-LOCOS at the middle of the active area was about -7.7 x 10^8 dyne/cm^2 and the stress for the conventional LOCOS was -1.9 x 10^8 dyne/cm^2. The profile for ON-LOCOS is relatively uniform, and the profile for the conventional LOCOS is cone-shaped. The reason the compressive stress for ON-LOCOS is stronger seems to be the structural feature. Fig. 7 shows a cross-sectional SEM image of the ON-LOCOS structure. Because the field oxide grew under the nitride mask, the compressed stress appears to be induced farther from the LOCOS edge compare to the conventional one.

When the width of the active region narrowed to 1μm, the peak shifts in the middle of the active area increased as shown in Fig. 8. In the case of the conventional LOCOS, the cone-shaped profiles in the middle of the active area remain. The peak shift at the LOCOS edge is the same for ON-LOCOS and the conventional LOCOS. We found that the mechanical stress had distinctive differences depending on the type of LOCOS and the size of the active area.

4. Conclusion

We have demonstrated the new method of a Raman spectrum using an Al-mask with 0.2μm square windows. Using this method, mechanical stress distribution in sub-micron devices can be evaluated.

References

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[3] K.Kobayashi et al., J. Electrochem. Soc. **137**, 1987 (1990).
[4] Th. Englert et al., Solid-State Electronics **23**, 31 (1980).

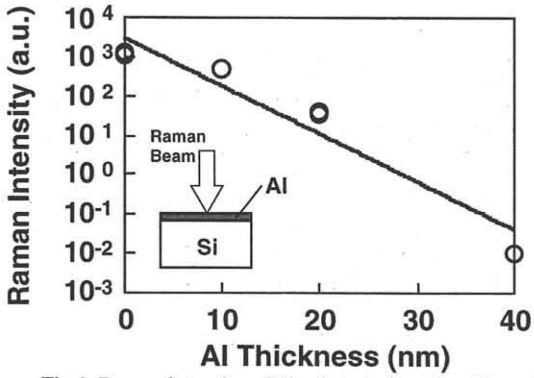


Fig.1. Raman intensity of Si substrate from the Al mask

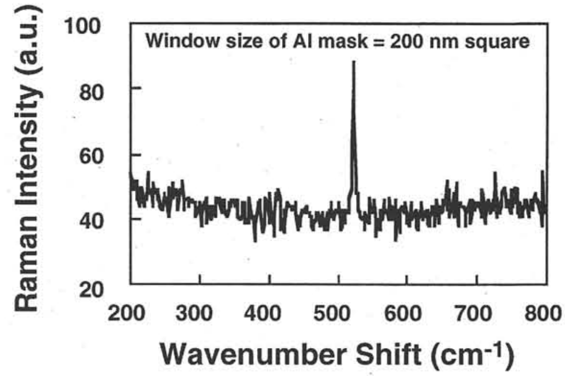


Fig.2. Raman spectrum of Si through the 200 nm square Al window

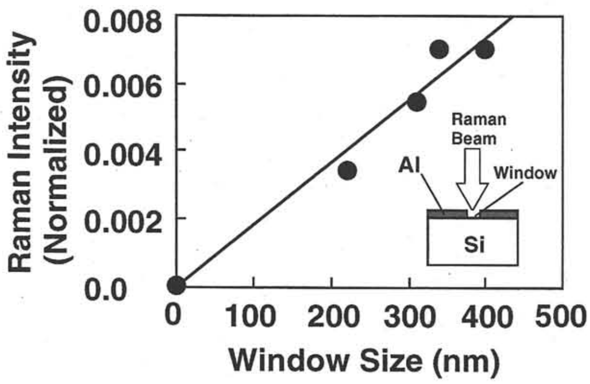


Fig.3. Raman intensity of Si substrate through the Al window

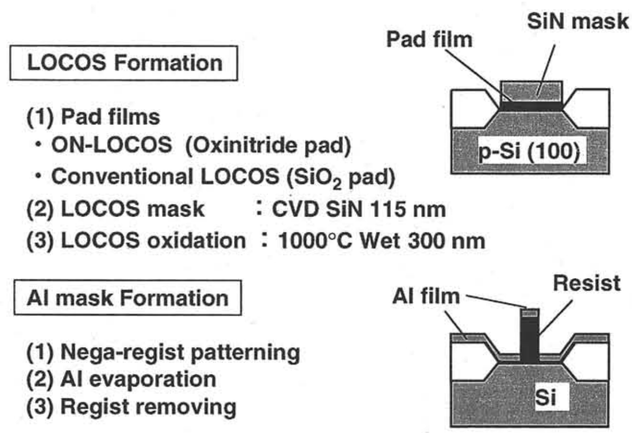
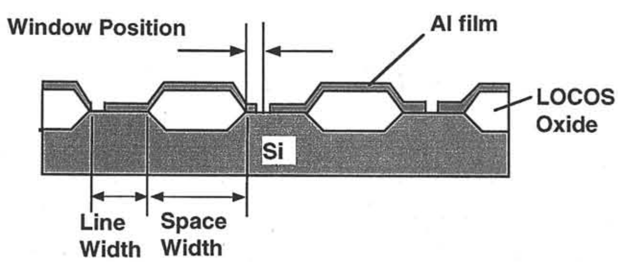


Fig.4. Process flow



Line Width	1	3
Space Width	5	5
The Shift of Window Pitch	0.1	0.2

(μm)

Fig.5. Pattern layout

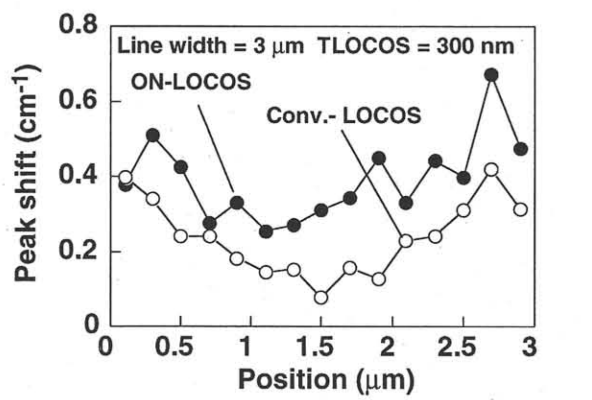


Fig.6. Raman peak shift in the active region in 3 μm line patterns

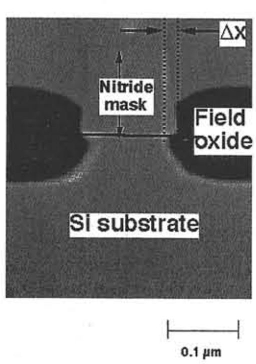


Fig. 7. Cross-sectional SEM image of ON-LOCOS

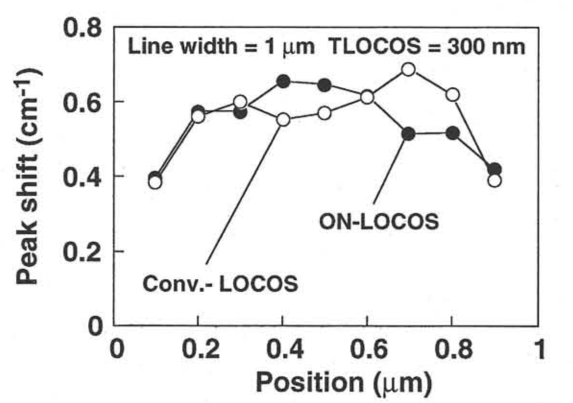


Fig. 8. Raman peak shift in the active region in 1 μm line patterns