**C-3-7 LN**

# Minimization of Residual Stress in SOI Films

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The residual stress in Si on Insulator(SOI) affects the carrier mobility of MOS devices/1,2/. The enhancement of electron mobility by a high tensile stress impresses us, however, a residual stress in the active layer is not necessary for three dimensional(3D)-integrated circuits(IC) by taking account of material design. In some cases, the residual stress causes the film cracks. Recently, the device fabrication of 3D-SOI by laser recrystallization have been reported/3/ since the laser annealing technique can heat only the surface silicon layer. However, the temperature difference between the Si film and the substrate results in a residual stress, even if a surface oxidized Si substrate is utilized/4/. In the present work, the extensive characterization of residual stress in SOI structure which consists of various types of interlying insulator and substrate materials gave us a result. That is, an unworthy residual stress in the structure can be reduced by the performance of underlayers(substrates, insulators) with the slightly larger thermal expansion coefficients than that of Si.

In a preliminary study, it has been found that Raman frequency shift from unstressed bulk-Si(520.5 $cm^{-1}$) of Si films resolidified by an argon ion laser linearly increases with increasing thermal expansion coefficients of the substrate as shown in Fig.1. This measurement indicates the requirement of the substrate with larger thermal expansion coefficient($5.4 \times 10^{-6}$/°C) for a stress free Si film.

As previously shown, even if a Si substrate is used, a stress still remains. Furthermore, we found that the residual stress depends on the materials of interlying insulator, too. Figure 2 shows Raman spectra obtained in the resolidified Si/3μm-thick insulator/Si substrate. Here, we used 1 or 3μm thick $SiO_2$,PSG, and AlN films as an insulator, and Si and sapphire as a substrate. Figure 3 shows a summary of the influence of insulating materials on the residual stress in the Si film. The stress in the Si film on 3μm-thick AlN/Si substrate is lower than that on $SiO_2$, and micro cracks were found in Si film only on $SiO_2$ layer. When the insulator thickness was 1μm, no significant difference was observed. Using Si substrates, the increase of AlN film thickness brings about no stress accumulation. Using sapphire substrates, a residual stress is compressive, contrary to using Si substrates, and decreases with increasing thermal expansion coefficients of insulating materials.

In conclusion, we have demonstrated that the residual stress in SOI film depends on both substrate and insulating materials. In order to obtain a stress free Si film of 3D-SOI, the underlayer(substrate and insulator) of which thermal expansion coefficient is larger than that of Si should be used.

This work was supported by the MITI's Project of Basic Technology for Future Industries.

References

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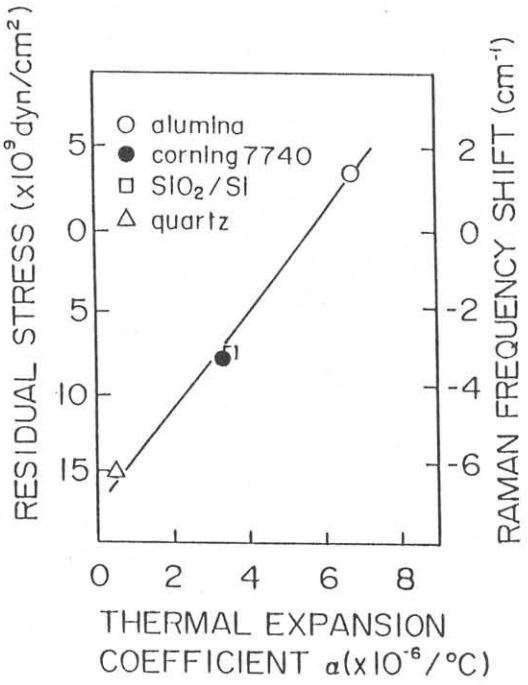


Fig.1

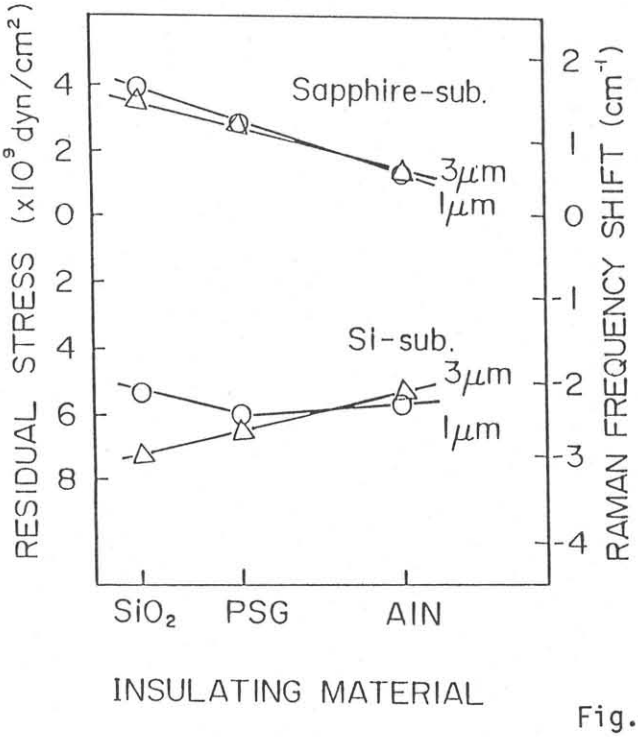


Fig.3

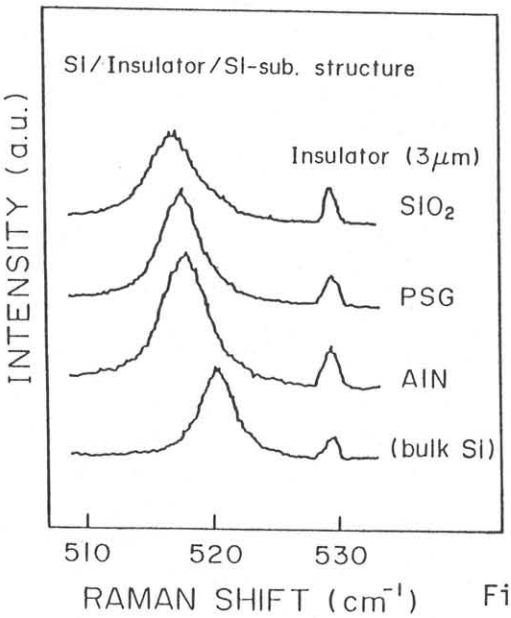


Fig.2

Fig.1 Frequency shift obtained in resolidified Si films versus substrate thermal expansion coefficient.

Fig.2 Raman spectra from resolidified Si film in SOI structure using Si substrate.

Fig.3 Summary of the influence of insulating material on residual stress in resolidified Si film.