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# Structural Investigations of Polycrystalline Silicon Films Prepared by Plasma Enhanced CVD

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## INTRODUCTION

Among several growth techniques of a polycrystalline silicon film, plasma enhanced chemical vapour deposition(PECVD) followed by solid phase growth is one of useful methods in applications for giant micro-electronics for industrial use, because of the low-temperature process below 600℃. From an electrical point of view, both the polycrystalline grain-size including its quality and the nature of grain boundaries including its density govern the characteristics of a thin film transistor. We investigated their dependence on deposition conditions and on subsequent processes in full detail. This is the first report on a fabricating condition and an analytical result of device-quality polycrystalline silicon films using PECVD process below 500℃.

This paper focuses on the basic characterization of a film grown by an above PECVD method under various conditions in terms of structural analysis by Raman scattering and TEM, showing the effective size of a grain and the stress in a film. Growth temperature dependence of defect density was also observed by an electron spin resonance(ESR).

## EXPERIMENTAL PROCEDURES

Specimens were prepared in plasma enhanced CVD reactor using silane. The flow rate of silane was 20sccm with its pressure of 0.1Torr. Plasma power was kept at 25W during deposition. Thin films of 100-200 nm thick were deposited on a cleaned quartz substrate with its temperatures ranging from 400-600℃, followed by solid phase growth (annealing at 580℃ for 72 hours under $N_2$ atmosphere). ESR and Raman measurements were made on an undoped film before and after hydrogenation, which was performed under hydrogen plasma power at 250W for 5 hours at 350℃. Electrical properties were monitored by self-aligned planer-structured device.

## RESULTS

Photograph 1 shows a TEM cross-sectional view of the film deposited at 500℃ and annealed at 580℃, showing the large size(~0.5$\mu$m) of crystallites consisting of coagulating twins. Detailed nature of a film was extracted from $\Gamma_{25}$ phonon spectra taken by Raman scattering. Upon increasing the deposition temperatures, both the shift and the FWHM of the Raman spectra decreased as shown in Fig.1. In Fig.2, the asymmetry parameters of the Raman spectra as defined in the figure are plotted against the deposition temperature and were found to show the deep minimum at 500℃. The paramagnetic spin densities in as-deposited and in as-annealed films are both plotted against the deposition temperatures as shown in Fig.3, indicating the minimum value at 500℃. In addition, the deposition temperature dependence of the line-width of an ESR absorption spectra in as-deposited films is shown in Fig.4. Employing the film deposited at 500℃ followed by solid phase growth of crystallite at 580℃, electronic mobility of 38cm$^2$/V·sec was achieved.

## CONCLUSION and DISCUSSION

By using present PECVD method which assists the dissociation of silane, it becomes apparent that even before annealing nucleation precursor for subsequent solid phase growth of polycrystalline silicon was found to appear at 400℃, which is by 100℃ lower than the reported one attained by an LPCVD method.

In addition to these potential characteristics of PECVD method, low temperature deposition at 500℃ was found to be reasonable through an investigation of the asymmetry parameter of the Raman spectrum as well as an apparent FWHM, because spectral asymmetry strongly reflects and very sensitive to the relative ratio of amorphous or disordered portion of polycrystals to well-defined crystalline one, clearly providing us with more detailed structural information. From these experimental results, it became clear that the PECVD method preparing polycrystalline silicon film showed the significant low temperature effect rather than previous techniques, such as LPCVD.

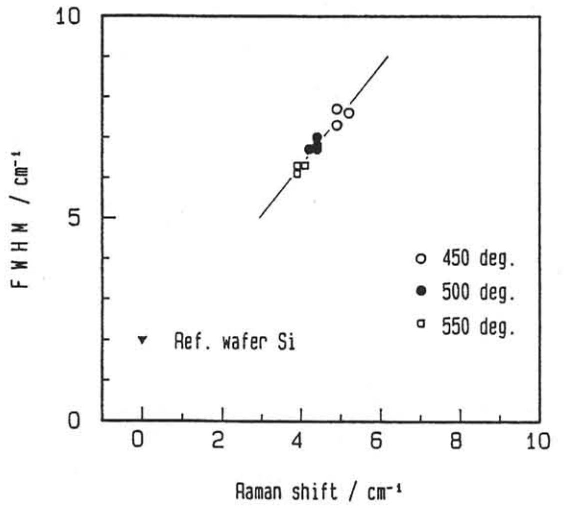


Fig.1 Correlation between the shifts and the FWHM of the Raman spectra under various deposition conditions.

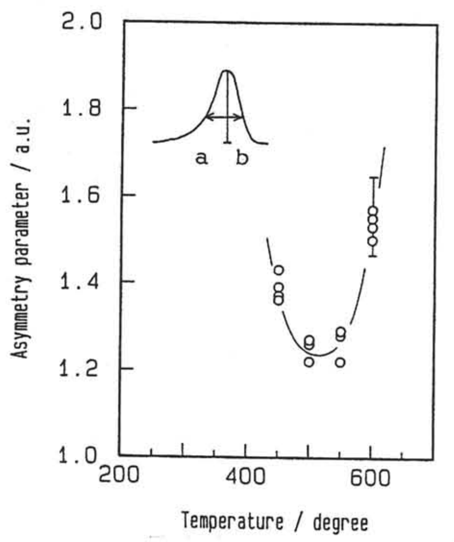


Fig.2 Temperature dependence of the asymmetry parameter of the Raman spectra. Asymmetry parameter is defined as a/b.

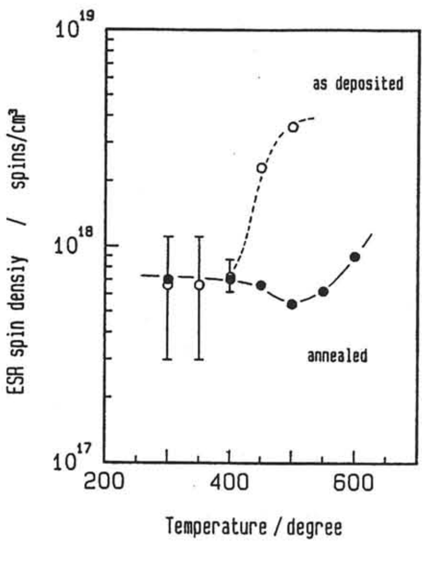


Fig.3 Temperature dependence of the ESR spin density in as-deposited and in as-annealed film.

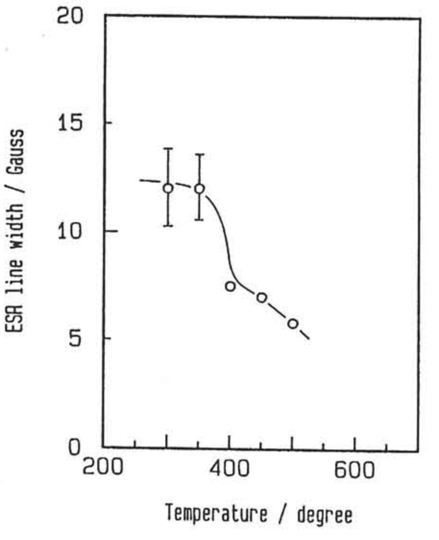


Fig.4 Temperature dependence of the ESR line-width in as-deposited film.

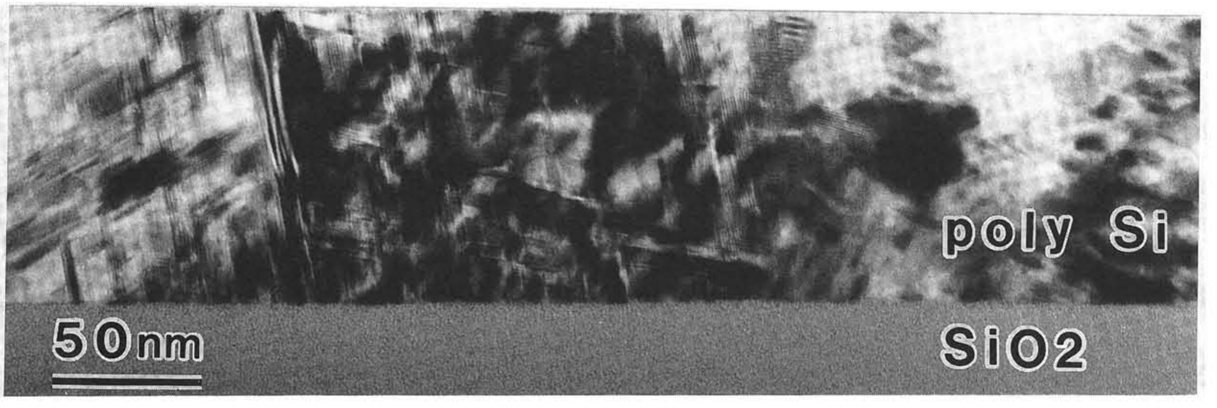


Photo.1 TEM cross-sectional view of the polycrystalline silicon film deposited on SiO2 under conditions in the text. Grains of the order of ~0.5μm with coagulating twins are clearly visible.