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Very Low Temperature Deposition of Micro/Polycrystalline Si Films Made by Hydrogen Dilution with PE-CVD and ECR-CVD

K. C. Wang, Y. L. Jiang*, T. R. Yew**, and H. L. Hwang
Dept. of Elec. Eng., National Tsing-Hua University, Hsinchu, Taiwan 300, R.O.C.
*Dept. of Elec. Eng., National Chung-Hsing University, Taichung, Taiwan, R.O.C.
**Materials Science Center, National Tsing-Hua University, Hsinchu, Taiwan 300, R.O.C.

This paper presents the results of low temperature micro/polycrystalline silicon growth on SiO_2. The silicon films were deposited by hydrogen dilution method with plasma enhanced chemical deposition and electron cyclotron resonance chemical vapor deposition at 250°C and without any thermal annealing. The ratios of $H_2/(SiH_4+H_2)$ were from 90% to 99%. The micro/polycrystallinity of silicon films was identified by cross-section transmission electron microscopy and Raman spectroscopy. The maximum grain size is about 1 μm. The crystallinity ratio of the optimal polycrystalline silicon film is near 100%.

I. Introduction

Hydrogenated amorphous silicon (a-Si:H) were widely used in large area microelectronics devices such as thin film transistors (TFT's), solar cells, and image sensors. Lacking of long range order, the a-Si:H has a large amount of network defects and carrier trap states. The on-current and carrier mobility of a-Si:H TFT's are limited by the defects and carrier trap states. Efforts have been put in improving the a-Si:H network to promote the on-current and carrier mobility of a-Si:H TFT's. Methods have been developed to deposit crystalline silicon on SiO_2 by plasma enhanced chemical deposition (PECVD). Polycrystalline silicon (poly-Si) films which were deposited by hydrogen dilution, have grains with the largest grain size of 2000Å.[1] This is the largest grain size ever reported. The electron cyclotron resonance (ECR) plasma source is electrodeless, and can be developed for producing reactive plasmas. Such as a reliable and long-lived plasma source is expected to create clean plasma, free of undesired impurities.[2] With its capability of creating dense plasmas efficiently and uniformly over large area, this source is an attractive candidate for low temperature poly-Si deposition. In this work, we investigate the poly-Si growth on SiO_2 at 250°C by PE-CVD and electron cyclotron resonance chemical vapor deposition (ECR-CVD).

II. Experimentals

The growth conditions of poly-Si films are described in Table I. The substrate temperature was

Table I. Growth conditions of poly-Si films

Parameters	Range 1 (PE-CVD	Range 2 (ECR-CVD
Substrate Temperature	250°C	250°C
Microwave Power	10 W	1200 W
$H_2/(SiH_4+H_2)$ Flow Ratios	90-99%	90-99%
Total Pressure	700 mTor	20 mTorr

250°C. The microwave power was 1200W for ECR-CVD and 10W for PE-CVD rf power. The deposition pressure was 700 mTorr for PE-CVD and 20 mTorr for ECR-CVD. The $H_2/(SiH_4+H_2)$ flow rate ratios of the samples deposited by ECR-CVD were described in Table II. The SiH_4 source was 5% diluted in argon gas.

Table II. Hydrogen dilution ratios of poly-Si films by ECR-CVD.

Sample	$H_2/(H_2+SiH_4)$ Flow Rati
A	90%
B	95%
C	98%
D	99%

III. Results and Discussion

The Si films deposited by PE-CVD were microcrystaiine phase. The grain size of these films have grain sizes distributing between 100-500 Å. The Si films deposited by ECR-CVD have gains with grain size exceeding thousands Å. These are much larger than those of the Si films deposited by PECVD, and the Si films could be called " polycrystalline silicon" (poly-Si). Growth rate and largest grain size of poly-Si v.s. hydrogen dilution ratio is shown in Fig. 1

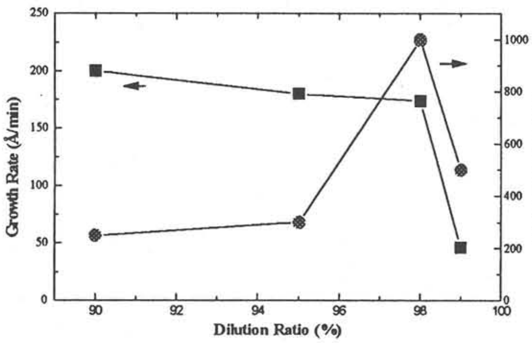

Fig. 1 Growth rate and largest grain size of poly-Si v.s. hydrogen dilution ratio.(by ECR-CVD).

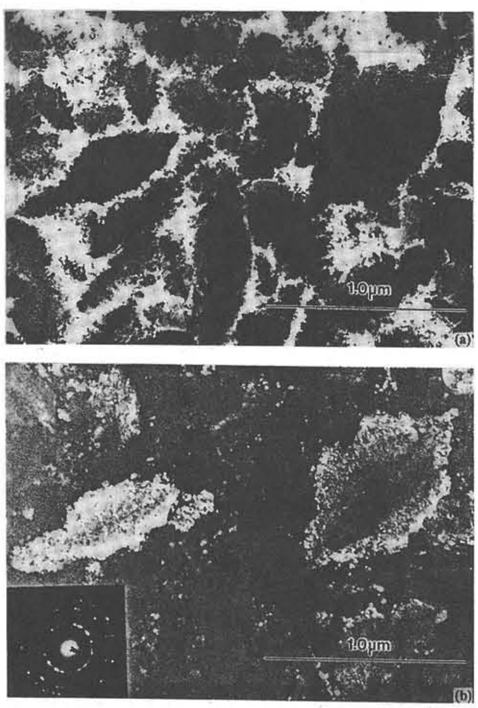

Fig. 2 XTEM images of sample C (a) bright field and (b) dark field (with diffraction pattern).

The result of plane-view TEM image of sample C is shown in Fig. 2 (a) and (b), in a bright field and dark field mode, respectively, with diffraction pattern. The grain shapes of the poly-Si are leaf-like. The maximum grain size is more than 1 μm. So far as we know, this is the largest grain size of poly-Si ever deposited at a temperature less than 300°C.

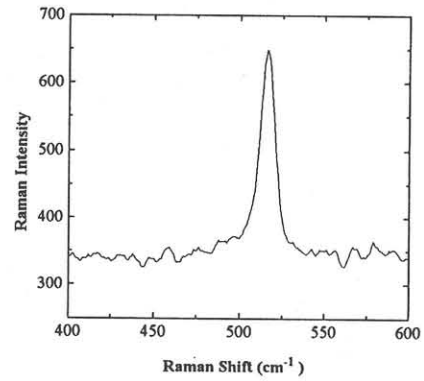

Fig. 3 Raman Spectrum of sample C.

Raman spectrum of sample C is shown in Fig. 3. In Raman spectrum, the peak centered at 516 cm^{-1} is contributed by crystalline silicon of the Si film, and the peak centered at 477 cm^{-1} by amophous silicon. If the peak is composed by two components which are centered at 477 and 516 cm^{-1}, the peak will be one with a shoulder shape. It is easy to see that a peak almost without a shoulder and centered at 516 cm^{-1} appears in Fig. 3. It could be possibly concluded that almost all the silicon film is crystalline. That is, the crystallinity ratio is near 100%.

IV. Conclusion

The hydrogen dilution is proved to be effective in ECRCVD now. According to the present result, the observed phenomena of hydrogen dilution in ECRCVD is much like that in PECVD. The most important is that the poly-Si film deposited by ECRCVD has grains with grain size : 1 μm. This is an achievement never being done. The crystallinity of the sample C is near 100%.

References:

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