A new crystallization method using a patterned CeO_2 seed layer on the plastic substrate

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Abstract

We report crystallization of a-Si using XeCl excimer laser annealing [1] on the plastic substrate. We tried to obtain higher crystallinity as the effect of CeO_2 seed layer patterned. Also, we tried to control the direction of crystallization growth of silicon layer for lateral growth as the type of CeO_2 pattern. This crystallization method plays an important role in low temperature poly-Si (LTPS) [2] process and flexible display.

1. Introduction

Many researchers are focusing on crystallization of amorphous silicon (a-Si) for application of Thin Film Transistor Liquid Crystal Display (TFT-LCD) on the plastic substrate these days [3]. The advantages of plastic substrate over glass are the lightweight, flexibility and a reduced breakage during the process. Conventional crystallization methods that were commonly used are Excimer Laser Annealing (ELA) [1], Solid Phase Crystallization (SPC) [4], and Metal Induced Crystallization (MIC) [5]. We present our work on crystallization of amorphous silicon film using XeCl excimer laser annealing [1] on the polycarbonate (PC) substrate in this paper. And we are reporting CeO_2 seed layer patterned such as dot and line between silicon film and the substrate to obtain better crystallinity and lateral growth. The lattice constant and crystal structure of CeO_2 seed layer are similar to crystalline Si. Previous researches in this field have shown that laser of high energy density is required to crystallize a-Si films [6] without using seed layer. But, we have successfully obtained the

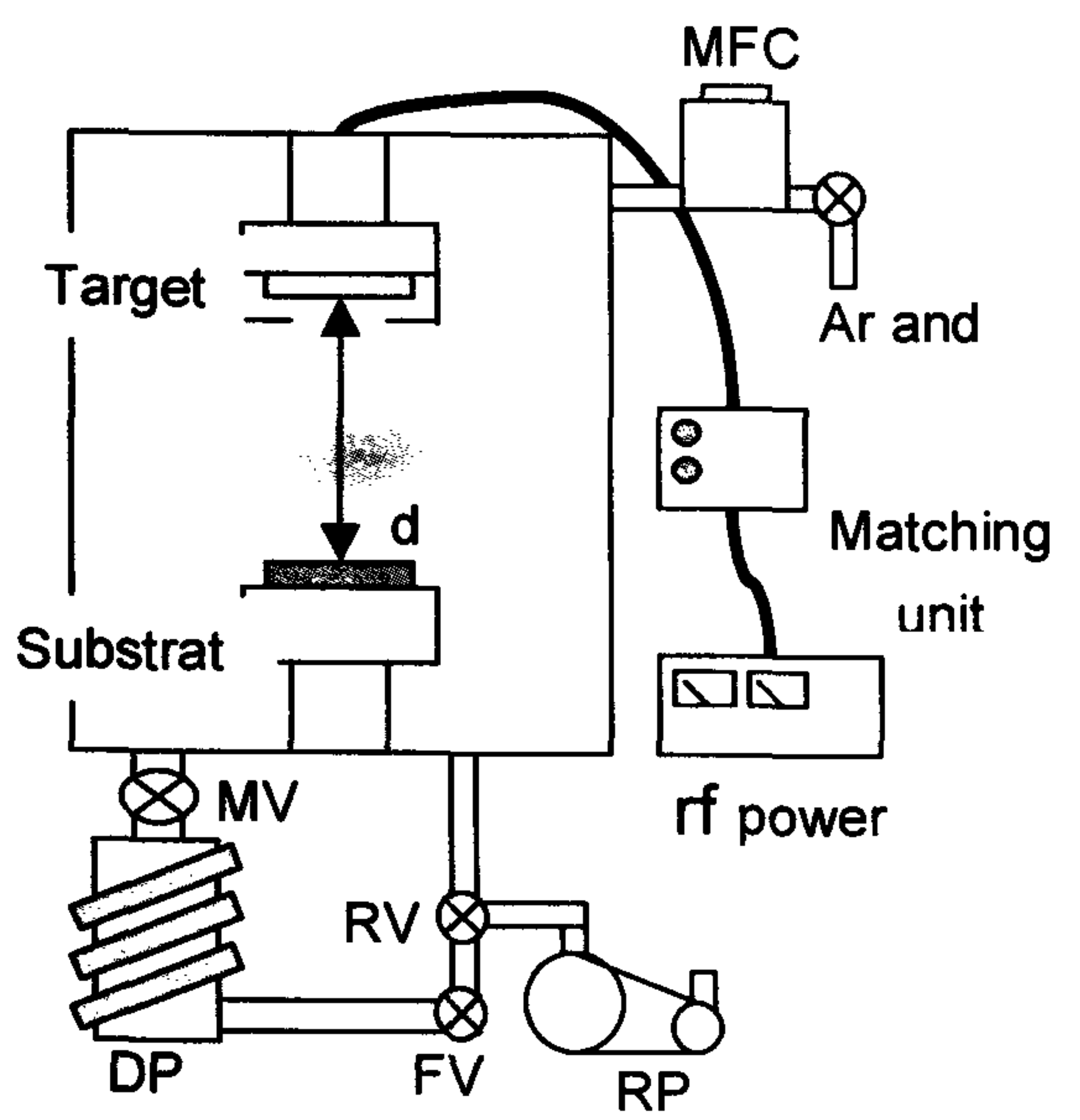

Figure 1 A schematic diagram of rf Sputter

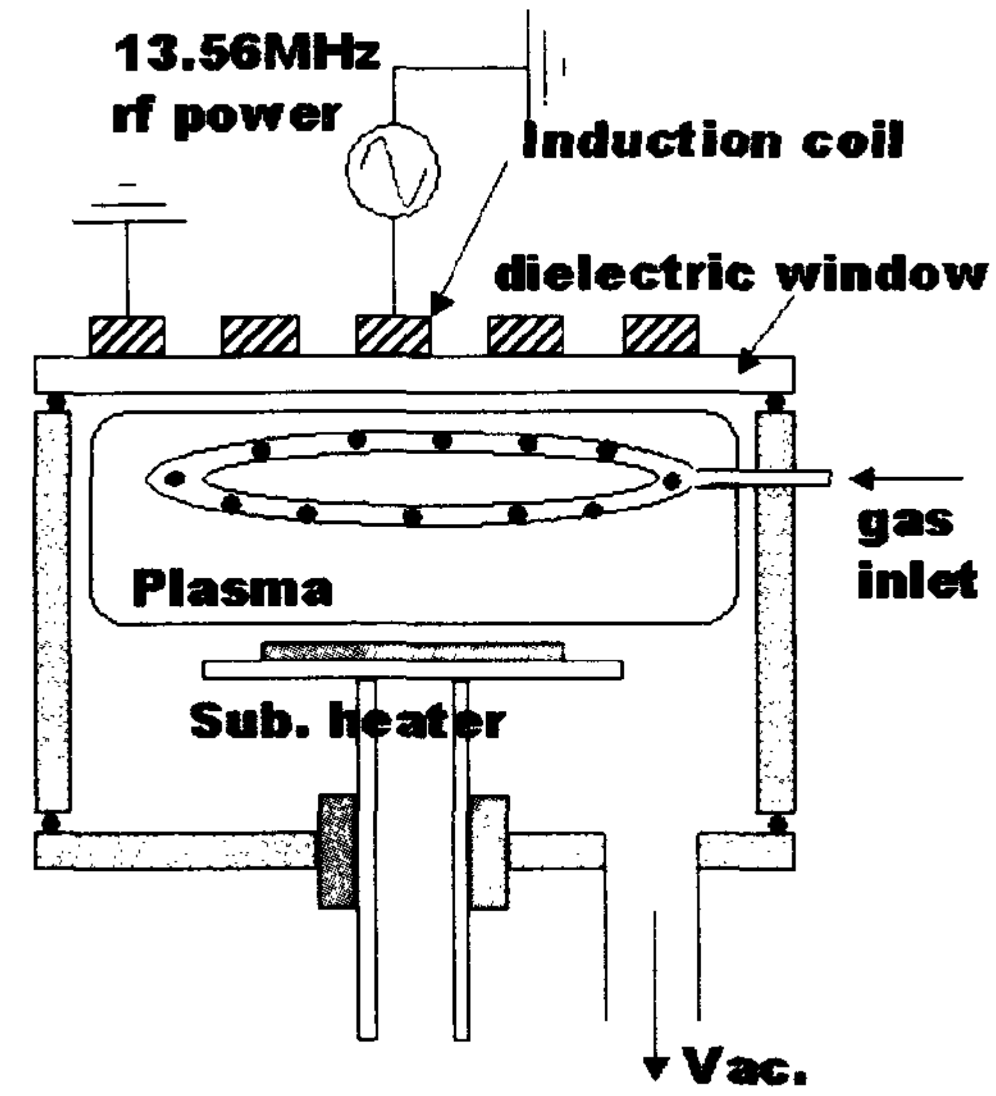

Figure 2 A schematic diagram of inductively coupled plasma reactor

crystallization condition using laser of low energy density and a seed layer of CeO_2. And CeO_2 film also plays an important role of passivation layer that prevents the movement of impurity, substrate bending, surface crack, and peeling off the film in ELA processing. This paper reports this achievement in details.

2. Experimental

The polycarbonate (PC) substrate possesses good chemical endurance to acid or alkali solutions and clear transmittance but they cannot withstand temperatures over 150 ℃. Therefore, all processes using a PC substrate must be carried out at room temperature. The required crystallization energy densities are too high in ELA processing. In order to overcome this problem, we propose a reliable method the application of seed layer between a-Si and the plastic substrate. We selected the deposition method of the CeO_2 film as the seed layer was grown by 13.56 MHz rf sputtering. The continuous deposition of the CeO_2 film for 30 minutes led to the bending of the PC substrate due to the rise in temperature by the impact of heavy ions. So we performed new method the plasma was repeatedly kept at the ON and OFF positions using a shutter at the room temperature. In this manner CeO_2 film was deposited over PC substrate at the room temperature. The a-Si film was grown by inductively coupled plasma chemical vapor deposition (ICP-CVD) method [7] at the room temperature. This a-Si film was irradiated by a 308 nm XeCl excimer laser to crystallize. The Raman Studies are carried out in the patterned region and the non-patterned regions to verify the lateral crystallization.

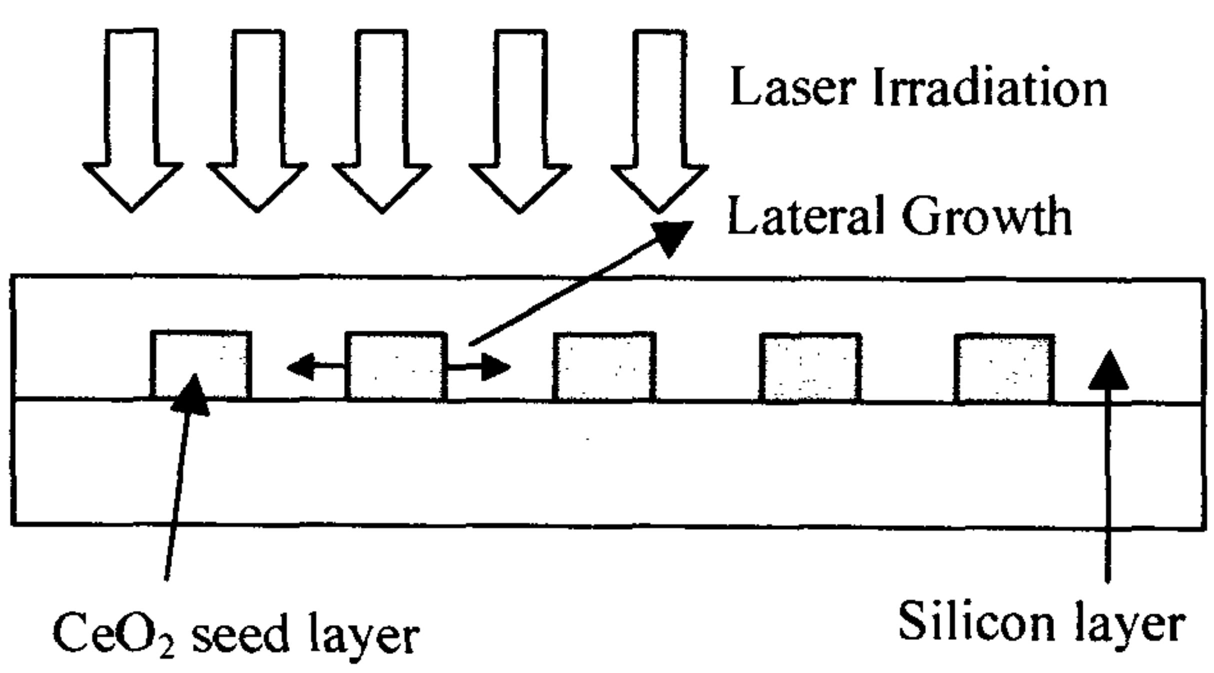

Figure 3 Schematic diagram for lateral growth using seed layer patterned

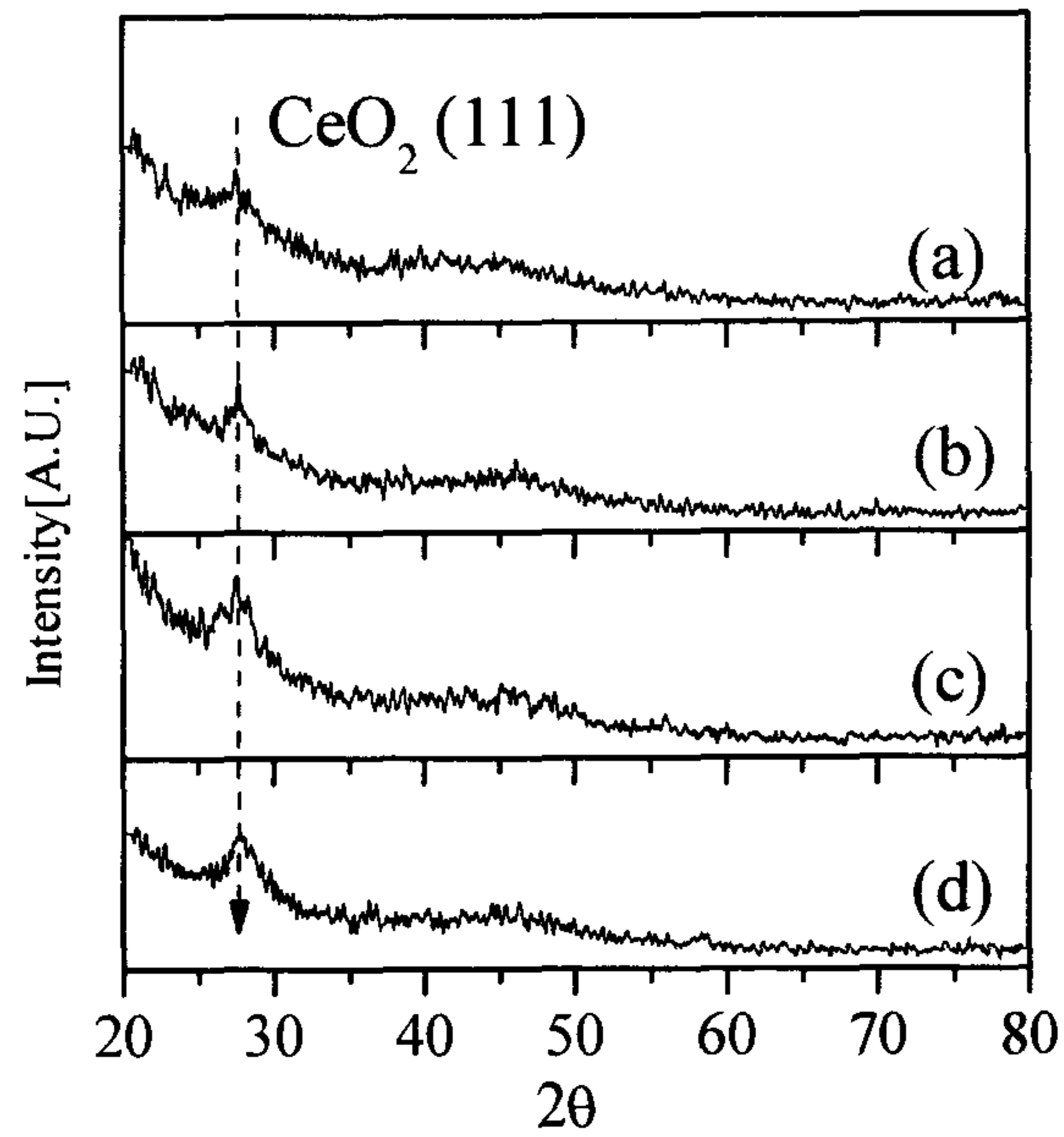

Figure 4 X-ray diffraction pattern of CeO_2 films deposited at room temperature on the PC substrate. Ce seed layer deposition time is (a) 10 min, (b) 20 min, (c) 30 min (15 times ON plasma for 2 min and with OFF plasma for 2 min), (d) 30 min (6 times ON plasma for 5 min and with OFF plasma for 5 min).

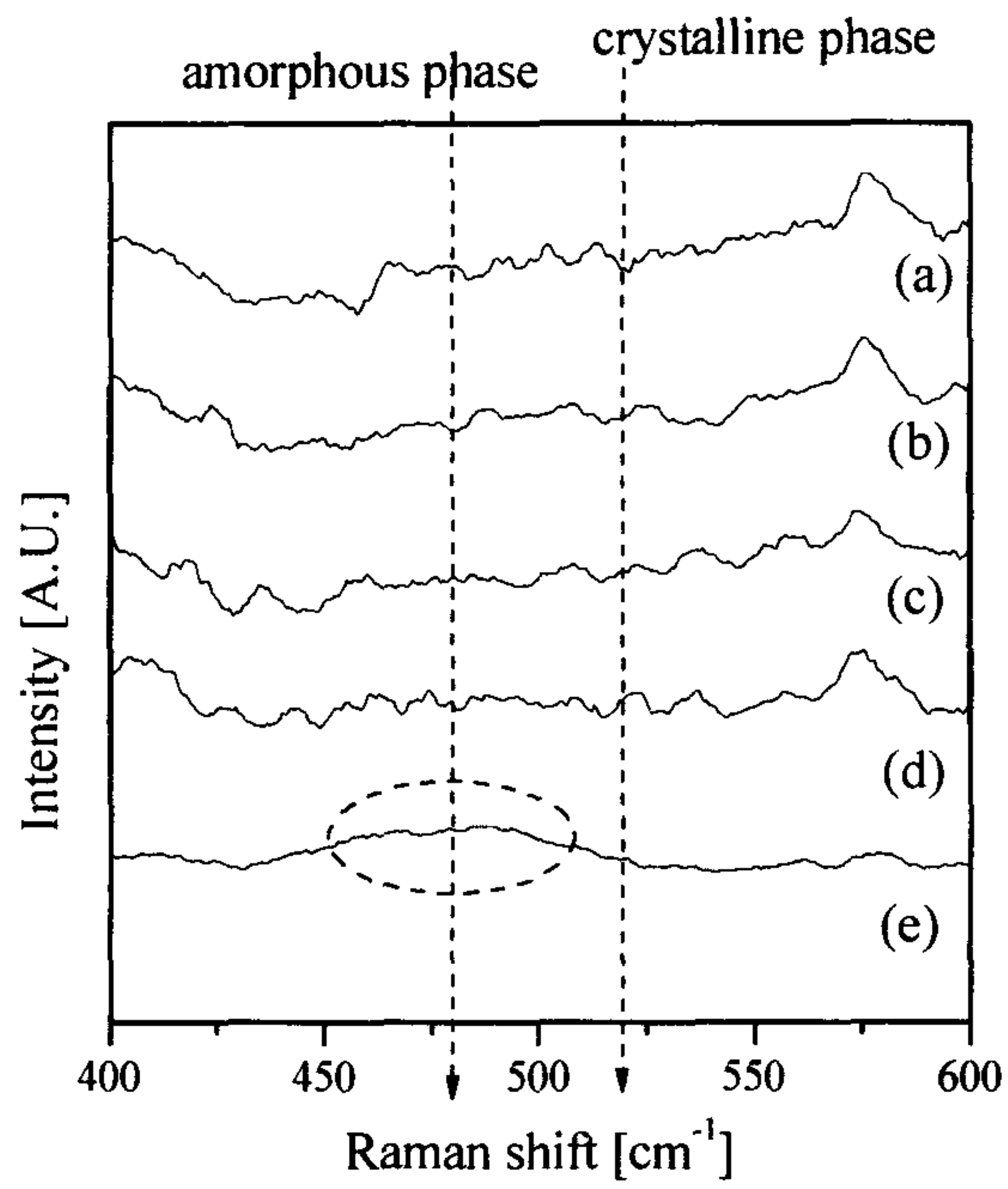

Figure 5 Raman spectroscopy without seed layer as a function of laser energy density (a) 50 mJ/cm^2, (b) 70 mJ/cm^2, (c) 85 mJ/cm^2, (d) 108 mJ/cm^2, (e) as deposited.

3. Results and discussion

The crystalline orientation of CeO_2 seed layer is shown in Figure 4. It is observed that the intensity of (111) orientation increases with the rise of the deposition time of the Ce metal seed layer. Especially the samples (c) and (d) have different plasma ON and OFF times. Figure 4 shows that the intensity of the crystalline peak of sample (c) is higher than others. These results demonstrate that the deposition time of less than 2 minutes in each run gives more uniform and good crystalline film. Therefore, we selected the sample (c) as the optimized seed layer.

Figure 5 exhibits Raman spectra of the deposited films as a function of low laser energy density and as deposited film. Raman spectra of the amorphous silicon phase show a broad TO-mode peak around 480 cm^{-1}, while those of the crystalline silicon phase show only the sharp Raman TO-mode peak at 520 cm^{-1} [8]. No Raman peak is observed in the case of the as-deposited sample. As a result of low energy crystallization, we knew that it is impossible to crystallize in the films without seed layer on the

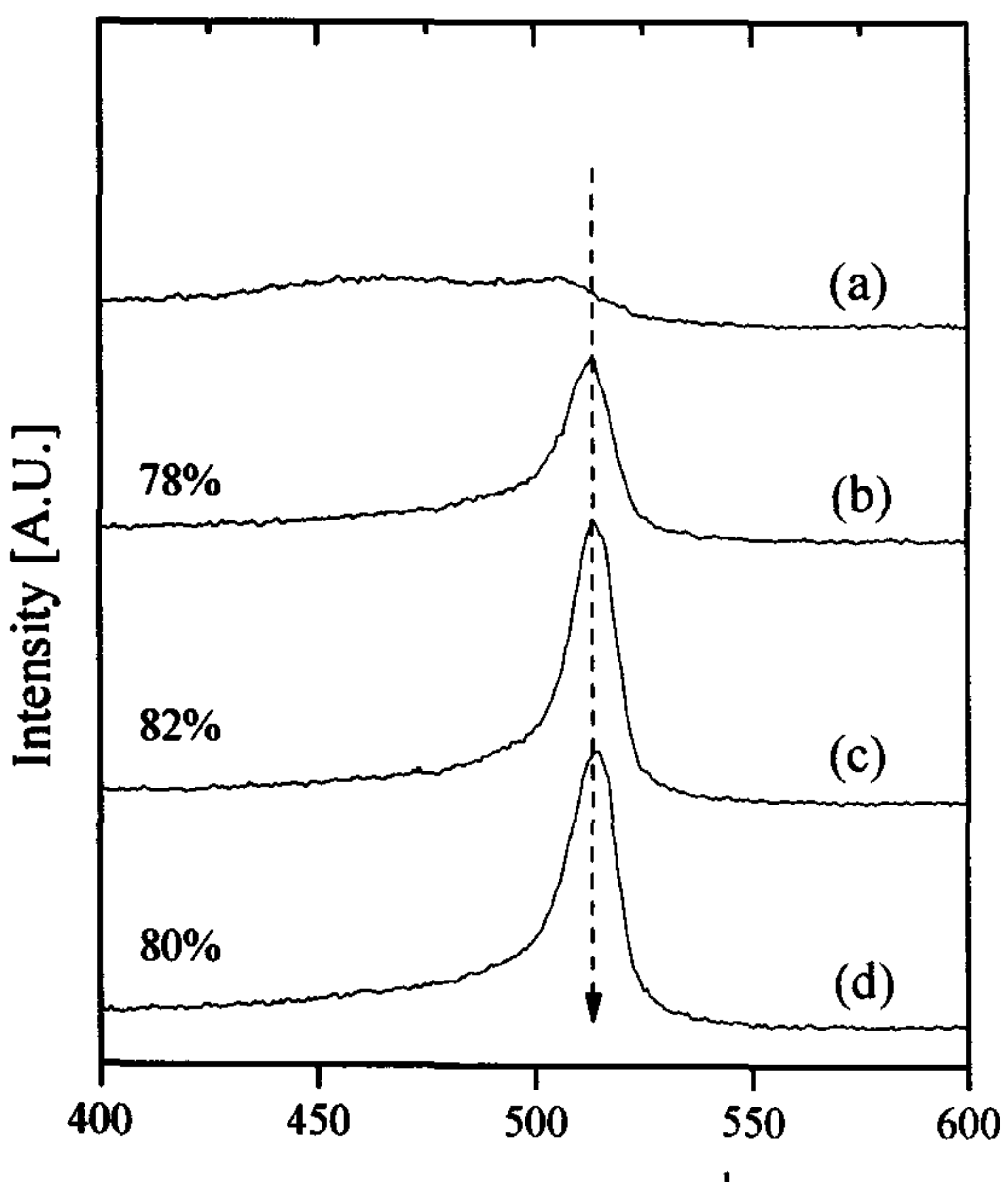

Figure 6 Raman spectroscopy with CeO_2 seed layer as a function of laser energy density (a) 50 mJ/cm^2, (b) 70 mJ/cm^2, (c) 85 mJ/cm^2, (d) 108 mJ/cm^2

plastic substrate.

We studied the laser crystallization of a-Si films having a seed layer on the PC substrate as a function of the laser energy density. Figure 6 illustrates the Raman Spectra of the samples as a function of laser energy. It is observed that the crystallization in these samples is possible. The ratio of crystalline volume fraction (X_C) is represented by equation $X_C = (I_{520}+I_{500}) / (I_{520}+I_{500}+ \sigma I_{480})$ [9]. We can take the correction factor as unity ($\sigma \fallingdotseq 1$) for a small grain size. Although the samples of (c) and (d) were irradiated with different laser energy densities, both of them were to have the same crystalline volume fraction of 78 %. Considering all these points it could be concluded that the laser energy of 85 mJ/cm^2 is the crystallization energy for a-Si with CeO_2 seed layer.

We also tried with two different types of patterns by using line and dot mask on the substrate and the laser beam was exposed to silicon layer. Then, the Raman studies were carried out in the patterned region and the non-patterned regions. And also the lateral crystallization was verified in the region 100 ㎛, far from the patterned portions. But it was found from the Raman results that lateral crystallization was missing in the regions away from the patterned portions. This was due to the peeling of Si layer from the non-patterned parts.

4. Conclusion

In this paper, we reported the laser crystallization of a-Si films deposited on the PC substrates with or without CeO_2 seed layer. Also, the deposition details of the CeO_2 seed layer at room temperature using sputtering method are elaborately discussed. Laser with energy density starting from 50 mJ/cm^2 has not been employed to bring crystallization in a-Si films deposited on the plastic substrates without seed layer. Films do not fully crystallize at energies less than 108 mJ/cm^2. The a-Si with seed layer could be crystallized at very low energy density of 85 mJ/cm^2 without laser energy induced large holes. Crystalline volume fraction is calculated as 78 % at the optimization condition of 85 mJ/cm^2. Thus, in this work, it has been successfully demonstrated the low energy crystallization of a-Si film deposited on the plastic substrate by using a CeO_2 seed layer and low laser energy treatment. And it is also revealed that the lateral crystallization is not found in this process.

5. Acknowledgements

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6. References

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