Mimization of Incubation Layer in Nanocrystalline Silicon Films Prepared by Catalytic CVD at 100°C

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Nanocrystalline silicon (nc-Si) films have been studied extensively for an active layer of thin film transistors (TFTs), owing to its superior stability and field effect mobility to those of amorphous films. Recently, as flexible display devices are of utmost interest in next-generation mobile applications, efforts have been directed to lower the deposition temperature of the nc-Si films to accommodate plastic substrates. However, an amorphous incubation layer which is formed during the first few nanometers of growth deteriorates performance of the transistors because bottom-gate TFTs channel is formed in the lower part of active layers. In this study, we used catalytic chemical vapor deposition (Cat-CVD) technique to prepare nc-Si films at a substrate temperature of 100 ˚C. In order to minimize the incubation layer thickness at 100 ˚C, a hydrogen dilution technique was used. The hydrogen dilution ratio of the source gas, $R_H=[H_2]/[SiH_4]$, was varied from 14 to 64.

[Fig. 1] shows the variation of the crystalline volume fraction (X_C) as a function of hydrogen dilution ratio at two different values of the chamber pressure, 50 mTorr and 60 mTorr. Crystallites appeared when R_H was higher than 34, and X_C increased monotonically with R_H. The pressure inside the reaction chamber did not affect X_C, but the films deposited at 50 mTorr showed better adhesion and deposition rate than those at 60 mTorr. On the other hand, the substrate temperature exceeded 100 ˚C during the 50 mTorr process, while it was controlled below 100 ˚C successfully during the 60 mTorr process.

For TFT construction, a thin layer of nc-Si is topped with a relatively thick amorphous layer for a reduced process time and a smooth surface profile. We attempted modulation of the pressure and hydrogen dilution ratio to accomplish a minimal incubation layer, good adhesion, and suppression of the self-heating at the same time. [Fig. 2] compares the Raman spectrum of an nc-Si single layer with that of an nc-Si/a-Si hybrid film prepared by modulation of the pressure and hydrogen dilution ratio. During the modulation process, the initial pressure inside the reactor was set to 50 mTorr with a hydrogen dilution ratio of 64, and then increased to 60 mTorr with hydrogen dilution ratio of 14. X_C of the corresponding nc-Si single layer was calculated to be 64 %. This nc-Si/a-Si film showed an incubation layer that was thinner than 4 nm, a crystalline volume fraction of 60% in the channel region, and good adhesion. This nc-Si/a-Si film is believed to be applicable to TFTs.

[Fig. 3] shows a cross-sectional high-resolution TEM image of the nc-Si single layer discussed in Fig. 2. The incubation layer thickness was estimated to be 4 nm by taking an average distance between the crystallites and the substrate. However, it can be clearly seen that some crystallites even start to nucleate directly on the substrate.

In summary, we prepared nc-Si layers having a X_C of 64% and an incubation layer thickness of 4 nm successfully at 100 ˚C. A hybrid structure of nc-Si/a-Si was fabricated by modulation of the pressure and hydrogen dilution ratio. This film showed enhanced adhesion, while preserving the minimal incubation layer thickness and suppressing the self-heating.

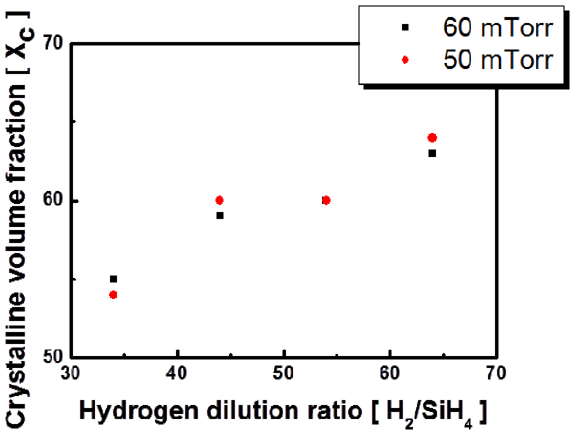

Fig 1 Change in crystalline volume fraction as a function of hydrogen dilution ratio at two different values of process pressure

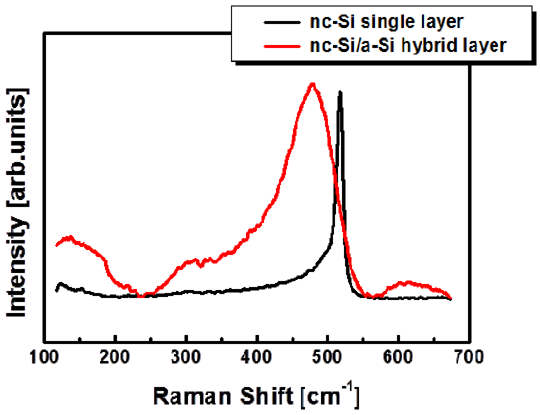

Fig 2 Raman spectra of nc-Si single layer and nc-Si/a-Si hybrid layer prepared by modulation of pressure and hydrogen dilution raio

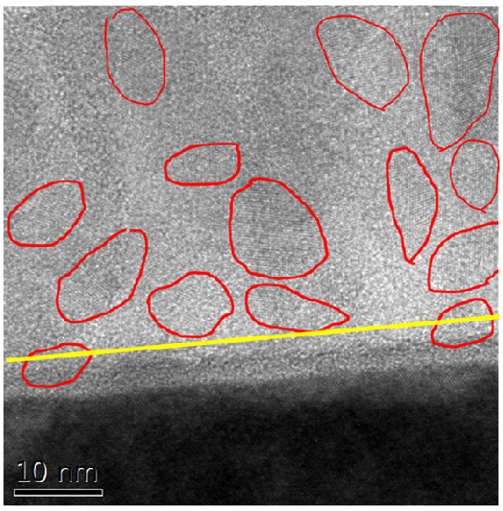

Fig 3 Cross-sectional TEM image of an nc-Si film having a crystalline volume fraction of 64 %

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