Study on SiGe Film Properties Fabricated Using a Reactive Thermal CVD Method

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1. Introduction

Polycrystalline Si (poly-Si) film has attracted considerable attention for use in devices such as solar cells and thin film transistors (TFTs). In order to fabricate these devices on a large substrate, a low temperature process is desirable, because low-cost conventional glass substrates are applicable. An excimer laser annealing technique has come into wide use for poly-Si film fabrication, especially for TFT applications. However, to improve productivity, it would be desirable to develop a direct poly-Si deposition technique. In most cases of poly-Si deposition, including plasma-enhanced chemical vapor deposition (CVD) and hot-wire CVD, the existence of an incubation layer with amorphous tissue degrades the crystallinity of the film [1-4]. In order to solve this problem, a reactive thermal CVD (RTCVD) technique has been proposed where an Si₂H₆ and GeF₄ gas mixture is used to deposit poly-SiGe films [5,6]. In the present paper, the structural and electrical properties of SiGe films deposited using RTCVD were studied to investigate the film growth mechanism and to examine its feasibility for TFT applications.

2. Experimental

The SiGe films were deposited on 6" ϕ p-type Si wafers with 100nm SiO₂ layers using RTCVD equipped with a lamp heating system. The schematic diagram of the deposition apparatus is shown in Fig. 1. The substrate temperatures (Ts) were 475-525°C. A gas mixture of GeF₄, Si₂H₆ and He was introduced into the chamber. The flow rates of the GeF_4 (F_G), Si_2H_6 (F_S) and He (F_H) were 0-0.1sccm, 0.3-3sccm and 500-1000sccm, respectively. The cross-sectional SEM images were observed for the deposited films including secco-etched samples. Electrical properties were measured for simple structure bottom gate TFTs fabricated using maskevaporation of Au Source/Drain electrodes on the samples. The W/L values of the TFTs were 10mm/0.5mm or 5mm/0.5mm.

3. Results and Discussion

In Fig. 2, cross-sectional SEM images are summarized for the samples deposited at F_G of 0-

0.1sccm. The values for F_S , F_H , total gas pressure and Ts were 3sccm, 500sccm, 665Pa and 475°C, respectively. The secco-etched samples are also shown for F_G of 0.03, 0.06 and 0.1sccm. The sample deposited at F_G of 0.1sccm shows a crystallline phase through the whole thickness region, while the sample deposited at the F_G of 0.03sccm shows no granular structure, which corresponds to the amorphous phase. The sample deposited at F_G of 0.06 shows a complex structure; the first 110nm shows the crystalline phase and the next 20nm layer shows the amorphous phase. These results indicate that the crystallinity of the film is basically improved with increasing F_G , and that the amorphous to crystalline transition takes place around an F_G of 0.06sccm.

The structure of the sample deposited at an F_{G} of 0.06sccm is different from the common results for poly-Si deposition using the CVD method where the first incubation layer of the amorphous phase changes to the crystalline phase in upper layer [1-4]. However, some previous papers revealed generation of the amorphous phase in poly-Si deposition [7] or of an sp2 phase in diamond deposition [8] at the crystalline nuclear coalescence region. In the crystal grain coalescence process, the amorphous phase is likely formed between the grains. In the present experiments, a similar mechanism should take place for the condition of $F_G=0.06$ sccm. The deposition apparatus is equipped with a lamp heating system where the source gases are easily heated in the gas phase. Therefore, not only at the substrate surface but also in the gas phase, Si_2H_6 should be decomposed to SiH₂ whose sticking coefficient is unity [9]. Then once the amorphous phase has been generated, sequential amorphous phase growth should take place.

The TFT transfer characteristics are shown in Fig. 4 for the crystalline samples. Because the films were too thin, less than 100nm, after HF etching prior to source drain electrode deposition, the S-values are relatively large. The p-type and n-type mobility values are 8.0 and $1.6 \text{ cm}^2/\text{Vs}$ for the F_G of 0.06sccm, and 1.4 and $0 \text{ cm}^2/\text{Vs}$ for 0.1sccm.

The structural results of the SEM observations and TFT mobility values are summarized in Fig. 4 for all the samples in the present study. In the figure, it is seen that the samples deposited near the amorphous to crystalline transition show relatively high mobility of $3-10 \text{cm}^2/\text{Vs}$. This result is in agreement with previous reports on direct CVD deposition of poly-Si films [10,11].

4. Conclusion

The SiGe films deposited using RTCVD with lamp heating system are investigated. With increaseing GeF₄ flow rate, the deposited film changes from amorphous to crystalline. In the amorphous to crystalline transition condition, some samples show the bi-layer structure of amorphous SiGe/poly-SiGe. This is considered to be caused by generation of the amorphous phase between the crystalline grains in their coalescence process. The TFT mobility of poly-SiGe with the deposition condition near amorphous to crystalline show relatively high p-type mobility of 3-10cm²/Vs.

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Fig. 1 Schematic diagram of the RTCVD deposition apparatus.



Fig. 2 Cross-sectional SEM images of SiGe films deposited using RTCVD.

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Fig. 3 Transfer characteristics of SiGe TFTs. SiGe films were deposited at F_G of 0.06 and 0.1sccm. Fs was 3sccm for both samples.



Fig. 4 Summary of structural and electrical properties of the SiGe films deposited using RTCVD. The notation of "n:0.01, p:4" denotes that n-type and p-type TFT mobilities are 0.01 and $4\text{cm}^2/\text{Vs}$, respectively.