The Effect of H-Treatment on Au-Induced Lateral Crystallization of Phosphorus-Doped a-Si:H Films

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We report and model the use of preannealing hydrogen treatment to improve the growth length in Au-induced lateral crystallization (MILC) of phosphorus-doped a-Si:H. Doped phosphorus atoms generate a large number of dangling bonds, which then capture metal atoms and interrupt the MILC processing, thus retarding the growth length. With the hydrogen treatment, the dangling bonds are passivated, and thus the MILC-grown polysilicon length can be increased from 18.6 to 53.9 μm after 6 h annealing.

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Results and Discussion

Figure 1 shows SIMS Au depth profiles of the Au-MILC phosphorus-doped poly-Si samples with and without H-treatment, respectively. The MILC annealing temperature and time were set at 450°C and 6 h, respectively. For comparison purpose the XRD spectrum of these samples is presented in the inset. In the phosphorus-doped samples, the SIMS profile without the H-treatment shows more Au atoms reside in the surface, which corresponds well to the highest intensity in peaks of Au (111) and Au (200). Additionally, the Au peaks in the undoped and without H-treatment film have the lowest intensity. We suspect the phenomena is due to the interruption of metal atoms by the doped phosphorus ions and their induced dislocations in Si, and thus in turn to the MILC growth length. As the phenomena were found previously, the mechanisms have not been described in detail.

Figure 2 shows the schematic model to illustrate the impediment of metal atom diffusion comprehensively. During the MILC annealing, the phosphorus atoms substitute parts of silicon atoms or reside in interstitial regions to create dangling bonds in Si lattice (Fig. 2a). Because the phosphorus atom has a strong tendency to getter metal element in Si, more Au atoms are trapped by these phosphorus atoms. The dangling bonds getter the Au atoms to form Au–P complex, and interrupts them to react with Si, forming MILC conditions. Finally, we characterized these MILC processed with and without phosphorus-doped LTPS samples by XRD, SEM, SIMS, and FTIR.

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Experimental

First, a 500 Å layer of phosphorus-doped a-Si:H film was deposited on undoped crystal silicon or glass substrates using plasma-enhanced chemical vapor deposition (PECVD). The radio frequency (rf) power, substrate temperature, and total pressure were kept at 50 W, 250°C, and 0.5 Torr, respectively. The flow rate of the reaction-gases SiH₄, PH₃, and H₂ are 10, 15, and 40 sccm, respectively. Then, the 30 min H-treatment was processed in the PECVD chamber with rf power and hydrogen flow rate at 60 W and 30 sccm, respectively. Sequentially, the Au layer with a thickness of 500 Å, through a spaced 500 μm finger metal mask, was evaporated on the top of samples. After that, the phosphorus-doped a-Si:H thin films were taken to the annealing chamber for 450°C, 6 h MILC annealing. Furthermore, for comparison purpose, some spilt samples without H-treatment were prepared with similar deposition and MILC conditions. Finally, we characterized these MILC processed with and without phosphorus-doped LTPS samples by XRD, SEM, SIMS, and FTIR.

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Au-silicide as illustrated in Fig. 2b. Because the eutectic temperature of Au–P complexes is 935°C, which is higher than 361°C for Au–Si, it is more difficult to release the Au atom from the Au–P complex to form Au–silicide with Si atoms under 450°C annealing. We used the plasma-excited hydrogen atoms, which have been successfully used to passivate dangling bonds, for improving phosphorus-induced retardation of MILC length. With the H-treatment, hydrogen atoms compensate the dangling bonds to generate P–H or Si–P–H complexes and result in permeating more Au atoms for forming Au–silicide during the MILC processing as illustrated in Fig. 2c. Besides, the H+ ions generated by the H-treatment can lead to the formation of nanocavities below the Si surface as trapping sites for metallic impurities to increase formation of Au–silicide. We used SEM micrographs and FTIR to support our model as shown in Fig. 3-5.

Figure 2. Bond structure model of phosphorus, Au and hydrogen atoms in a-Si film: (a) formation of dangling bond, where P is in this substitution or interstitial position, (b) without hydrogen treatment, the Au atoms are captured by dangling bonds and form Au–P complexes, and (c) with hydrogen treatment, the dangling bonds are passivated by hydrogen atoms.

Figure 3. SEM micrographs of the surface morphology of Au-MILC-proceeded phosphorus-doped a-Si:H films with H-treatment and (inset) without under 450°C and 6 h annealing.

Figure 4. SEM micrographs to show the MILC growth lengths of Au-MILC-proceeded phosphorus-doped a-Si:H films with H-treatment and (inset) without under 450°C and 6 h annealing.

Figure 5. FTIR spectrum of P–H bond in phosphorus-doped Au-MILC LTPS films without and with hydrogen plasma.

Conclusion

This study demonstrates the H-treatment is an efficient and attractive method to improve the Au-MILC growth length, which is degraded by the doped phosphorus ions and/or their induced dislocations. The improvement is attributed to the hydrogen passivation of these induced dangling bonds or dislocations, and results in the enhancement of Au silicide formation and the MILC length. We well the SIMS and X-ray analysis shown in Fig. 1. Additionally, the SEM micrographs in Fig. 4 indicate that the growth length is retarded to about 18.6 μm, which is about 1/5 of the reported 95 μm for an undoped one. However, with the H-treatment, the length becomes 53.9 μm, which is almost 2.9 times that without the H-treatment. The remarkable progress in the growth length evidences the effectiveness of the H-treatment.

Furthermore, in the FTIR spectrum shown in Fig. 5, the higher absorption peak of the P–H bond for the H-treatment sample implies that the larger phosphorus dangling bonds have been passivated by H-atoms. Besides, there exists an absorption peak at 2344 cm⁻¹ in FTIR spectrum for both with and without the H-treatment phosphorus-doped samples, and the former has a higher intensity. It is not clear for the time being, but we suspect this peak may come from Si–P–H complexes. Since The H-treatment sample has a larger hydrogen quantity than that of the film without H-treatment, and thus results in a higher intensity peak.
used a schematic model to illustrate the mechanisms comprehensively and evidenced the model with analyses of XRD, FTIR, SIMS, and SEM.

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