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Material Research on High Quality Passivation Layers with Controlled Fixed Charge for Crystalline Silicon Solar Cells

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1. Introduction

In the crystalline silicon (c-Si) solar cells, it is well known the grain boundaries and unfavorable impurities are major carrier recombination centers. In addition, the surfaces should also act as the minority carrier recombination centers. Therefore, many researches have been investigated for passivation layers, including hydrogenated amorphous silicon, silicon dioxide, and silicon nitride [1, 2]. The passivation efficiency is influenced by the fixed charge in the layers as well as the interface states. For the purpose, aluminum oxide (Al_2O_3) with negative fixed charge deposited by plasma-enhanced chemical vapor deposition (PECVD) is examined for the p-type c-Si passivation and showed an excellent result [2].

In this study, we evaluated and controlled positive and negative fixed charge in the binary composition oxide thin layers fabricated by the combinatorial pulsed laser deposition (PLD) [3].

2. Experiment

In order to evaluate the fixed charge effect on the passivation independently on the interface states, we prepared the surface oxidized p-type c-Si substrate. The 4nm surface SiO_2 film was fabricated by LSI grade oxidation and various dielectric films were deposited on the substrates. The dielectric films were deposited by using combinatorial PLD technique, in which the composition spread method with a moving mask is utilized to fabricate a film with continuously varying binary composition. The mask motion and speed are controlled to deposit the passivation layer from one edge to the other edge in each deposition cycle. From the target exchange and mask motion, the values of x in A_xB_{1-x} are exchanged continuously from 0 to 1 while the same thickness is maintained everywhere on the substrate. After passivation layer deposition, the platinum (Pt) gate electrodes were fabricated to measure the C-V characteristics. Schematic diagram of the sample is shown in Fig. 1. Target A and B was exchanged for Al_2O_3, HfO_2, and Y_2O_3, respectively. Therefore, we fabricated three kinds of sample, *i.e.*, Al_2O_3-HfO_2, HfO_2-Y_2O_3, and Al_2O_3-Y_2O_3 systems.

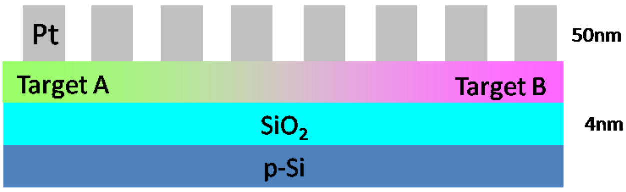

Fig. 1 Schematic illustration of sample

After the sample fabrication, the fixed charges in the passivation films were estimated by the flat band voltage (V_{fb}) in the C-V characteristics. The frequency for the C-V measurement was 100 kHz. Microwave photoconductive decay (μ-PCD) mapping was also carried out to evaluate the effect of the passivation on the minority carrier life time.

3. Results and Discussion

The C-V characteristics for Al_2O_3-HfO_2 systems are shown in Fig. 2. V_{fb} shows positive value with pure Al_2O_3 film due to the negative fixed charge. However it is clearly observed V_{fb} shifted toward negative direction with increasing HfO_2 incorporation in the passivation layers. Finally, V_{fb} showed slightly negative or neutral. Although it is difficult to decide the fixed charge only by the V_{fb} shift in the C-V characteristics, we verify the Y_2O_3-HfO_2 systems to achieve the clear evidence of the positive fixed charge. Y_2O_3 is expected to have the negative fixed charge base on the experience of the LSI gate stack formation [4]. The C-V characteristics of HfO_2-Y_2O_3 system are shown in Fig. 3. The negative V_{fb} can be clearly observed. One may note that the

Y_2O_3 with small amount of HfO_3 showed more negative V_{fb} shift than pure Y_2O_3 film. Finally, the C-V characteristics of the Al_2O_3-Y_2O_3 system are shown in Fig. 4. It can be clearly recognized the V_{fb} shifted widely from positive to negative. It can be considered that the origin of the fixed charge in the dielectric layers is some kind of defects, probably point defects such as oxygen vacancies or interstitials. Thus it may reasonable the amount of the fixed charge and sign can be controlled by the impurity incorporation, and the more charges can be induced by small amount of impurities than pure stoichiometric film.

Figure 5 shows μ-PCD mapping image taken from HfO_2 -Y_2O_3 systems. Clear contrast can be observed. The non-uniform image even with the homogeneous interface phenomena reflects the difference of the fixed charge effect on the passivation. The region indicated high minority carrier life time should be induced by the superior passivation with more negative fixed charges for p-type Si.

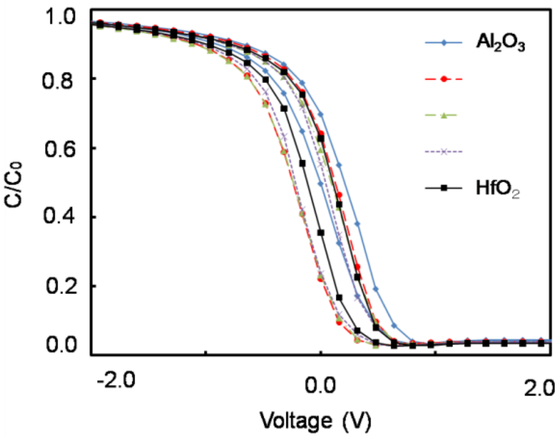

Fig. 2 C-V characteristics of Al_2O_3-HfO_2

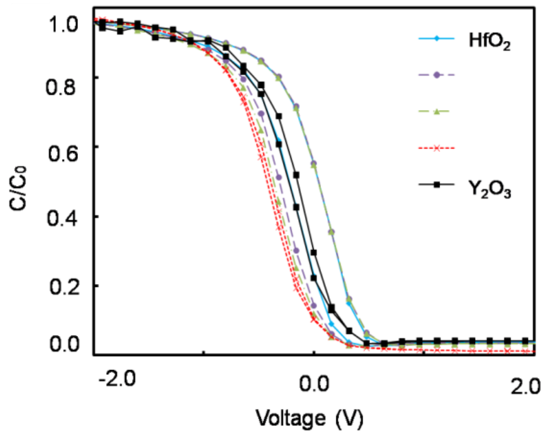

Fig. 3 C-V characteristics of HfO_2-Y_2O_3

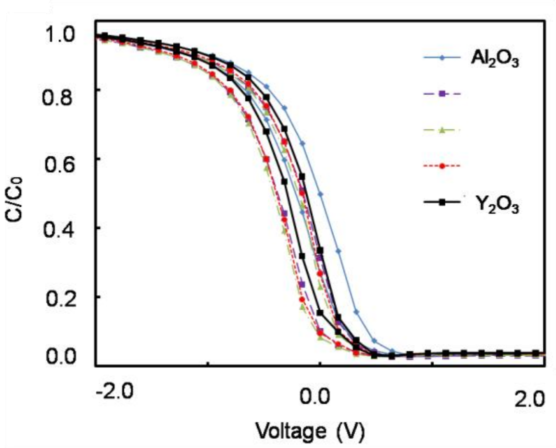

Fig. 4 C-V characteristics of Al_2O_3-Y_2O_3

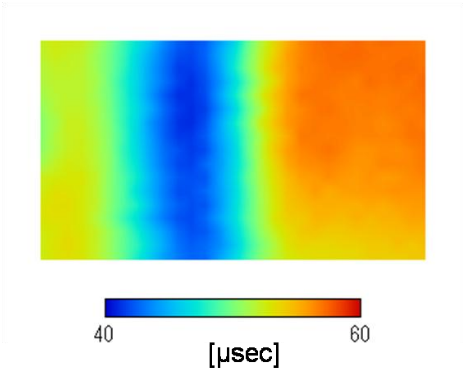

Fig. 5 μ-PCD mapping image from HfO_2-Y_2O_3 system

4. Conclusion

A combinatorial technique was employed to fabricate the new passivation layers with controlled fixed charge for c-Si solar cells. We examined Al_2O_3-HfO_2, HfO_2-Y_2O_3, and Al_2O_3-Y_2O_3 binary composition systems and evaluated their fixed charges using C-V characteristics. From these results, the amounts of fixed charge with both negative and positive sign can be controlled. The evidence in the minority carrier life time control was presented with μ-PCD mapping image.

References

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