INVESTIGATION ON SURFACE PASSIVATION QUALITY OF NANOTEXTURED SILICON WAFER BY SPUTTERED AND ALD GROWN ALUMINUM OXIDE FILMS

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We have investigated the difference in surface passivation quality of nanotextured silicon (NT-Si) wafer by sputtered and atomic layer deposited (ALD) aluminum oxide (AlOₓ) thin films. We first prepared the NT-Si surface using Silver-Assisted Wet Chemical Etching (SAWCE), which resulted in the lower reflectance than the standard textured silicon (T-Si) as shown in Figure 1a. Arrays of NT-Si with ~370 nm average height and varying pitch (Fig. 1b) led to the strong incident light randomization in the forward direction in entire polychromatic spectral region. But, the large surface area of NT-Si leads to the enhancement in surface recombination with more density of surface defect states. Here, we adopted two different thin film deposition techniques to passivate the NT-Si surface; the study motivation is to find out the merits and demerits of the both techniques using various characterization techniques. For the NT-Si surface passivation; (1) by sputtering technique the AlOₓ film deposited in the oxygen reactive environment at working pressure of ~7 x 10⁻¹ mbar with RF power of 75 W, and (2) by ALD technique the AlOₓ film deposition carried out at substrate temperature of 300 °C and working pressure of ~1.7 mbar. Effective minority carrier lifetimes (τ_eff) of the NT-Si wafer without and with sputtered AlOₓ thin film are ~3 μs and ~45 μs, respectively, which quantified using Sinton WCT-120 lifetime tester. The carrier lifetimes of NT-Si surface passivation by the ALD films are still under investigation; the conclusive and final results will be presented during the meeting. For both cases, the post-deposition annealing step is very important to passivate effectively the silicon surface. The carrier lifetime values further used for estimating effective surface recombination velocity (S_eff) of the passivated NT-Si wafers. Preliminary results demonstrated the difference in S_eff values from two techniques, which is primarily due to the better conformal deposition of the AlOₓ thin film by ALD technique. Further, the elemental depth profile measurements carried out by Time of Flight-Elastic Recoil Detection Analysis (ToF-ERDA), from this analysis we inferred that the AlOₓ films by ALD are oxygen rich in comparison to the sputtered films. The oxygen dangling bonds of oxygen-rich AlOₓ film form charge states below the valence band of Si, which can lead to large negative fixed charges at the interface. The fixed charge states can provide field effect passivation with an enhancement in charge carrier collection efficiency. The sputtered Al₂O₃/NT-Si interface quantified by the density of interface trap states (D_it), and total fixed charge (Q_f) after the electrical measurements. The estimated values of D_it and Q_f are ~4 x 10¹¹ eV⁻¹cm⁻² and ~7 x 10¹² cm⁻², respectively; which led to the S_eff of ~35 cm/s for the sputtered AlOₓ films annealed at 500 °C in a mixture of N₂ and O₂ (1:1). Electrical measurements of the ALD grown AlOₓ/NT-Si interface and their correlation with the S_eff are going on, these results and more details will be presented in the meeting.

Figure 1: (a) Reflectance spectra of the bare silicon, conventional textured silicon, and nanotextured silicon wafers, and (b) 3D AFM micrograph of nanotextured silicon surface.