Use of HCl gas gettering in the epitaxial wafer equivalent concept

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Purpose of the work: The concept of the epitaxial wafer equivalent (EpiWE) is pursued to reduce the cost of silicon solar cells. High costs of standard wafers are mainly due to the time and resource consuming purification steps of the silicon feedstock to obtain semiconductor quality wafers. Within the EpiWE concept, only a small amount of the expensive high purity silicon is needed for the epitaxial deposition on a low-cost silicon substrate. The term "wafer equivalent" hints at the similarity to a standard wafer and implicates that it can be further processed in a standard wafer cell production [1]. The epitaxial thin film represents the active layer of the solar cell and therefore requires a good light confinement which could for example be achieved by an intermediate reflecting layer. Another challenging task is the control of the impurity contents in the low-grade silicon substrate. Especially transition metals like Fe, Mn, and Cr act as recombination centres and degrade the minority carrier lifetime once they diffuse into the active layer. An effective and fast gettering method prior to the epitaxy of the high purity silicon is considered to be an easy way of reducing the metal impurities in the substrate to an appropriate level.

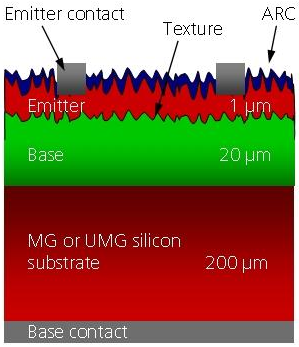

Figure 1. Scheme of the EpiWE cell.

Approach

Gettering of metal impurities by HCl gas shows great potential for the purification of metallurgical grade or upgraded metallurgical grade (MG or UMG) silicon. By the treatment of the substrate by HCl gas at temperatures between 1000°C and 1300°C, the metals form volatile chloride compounds which are removed from the surface by the stream of gas. Interstitial metal atoms diffuse to the surface in consequence of the resulting impurity concentration gradient, where they are removed again. An advantage of gettering by HCl gas in comparison to other gettering methods is the fact that it can be performed in the same chemical vapour deposition (CVD) reactor which is used for the epitaxy. For the analysis of metallic impurities, we apply standard analysis techniques like Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma with Optical Emission Spectrometry (ICP-OES) and Instrumental Neutron Activation Analysis (INAA). The gettering efficiency is proven by using the above mentioned tools. Applying Fourier Transformed Infrared Spectroscopy (FT-IR), we are able to investigate the exhaust gas and its components during the gettering process to optimize the method. EpiWE solar cells with and without gettering step are processed to evaluate the improvement of the electrical properties by HCl gas gettering.

Scientific innovation and relevance

Gettering of surfaces by HCl gas is a method which is known from microelectronics. But it has to be adjusted to solar cell applications since not only the surface but also the bulk of the wafer have to be gettered. It enables in-situ processes and by combining HCl gas gettering with HCl texturing and emitter epitaxy it seems to be possible to establish a fully dry in-line process for the wafer equivalents. ICP-OES and INAA show to be suitable trace element analysis tools, which will be investigated for higher throughput.

Results

Gettering of low-cost substrates was investigated on MG and UMG silicon wafers applying different analytical tools. On UMG-Si, starting with a concentration of about 1.2 ppmw Fe (ca. $3*10^{16}$at/cm^3) in the untreated wafer, a gettering efficiency of more than 45 was obtained by applying a 30 minutes gettering step. This signifies a reduction of Fe of more than 98%. Other transition metal impurities showed a gettering efficiency of 4 to 5. Also main group elements such as Ca and Al showed a certain gettering effect. In MG-Si higher metal concentrations in the expected order of magnitude were found [2]. Starting with a concentration of about 73.3 ppmw Fe, a gettering efficiency of more than 12, regarding Mn a gettering efficiency of 27 could be achieved. Using a simplified cell process, 5x5 cm^2 sized EpiWE cells on UMG substrate were fabricated with a solar cell efficiency of 7.1% (average of 11 cells). Applying HCl gas gettering to wafers of the same EpiWE cell batch a cell efficiency of 9.4% (average of 9 cells) could be achieved.

Conclusions

Recent experiments with HCl gas gettering show satisfactory results on UMG and MG silicon by decreasing the amount of metallic impurities dramatically. The improvement of EpiWE solar cells by HCl gas gettering is demonstrated. This new gettering method represents an important step within the promising EpiWE cell concept.

References

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