Development of antireflective silicon nanostructures for multicrystalline silicon solar cells

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Abstract: The textured multicrystalline silicon with nano-sized structures was carried out using chemical wet etching followed by reactive ion etching (RIE). Compared to standard industrial alkaline etching or RIE process, the combined wet etching/RIE technique could result in lower reflectance on silicon surface.

Keywords: multicrystalline silicon, surface texture, reactive ion etching, wet etching

1. Introduction
In order to reduce the production costs, multicrystalline silicon solar cells is obtained much attention in academia and Industry. Reducing the surface reflection of silicon wafer is one of important development technology in silicon solar cells research that is called antireflection technology. Currently, antireflection technology of silicon solar cells is mainly divided into two parts, one of the method is fabricated an anti-reflection coating (ARC) on silicon surface [1], the other method is processed texture treatment. Single-crystal silicon solar cells are generally textured with random pyramids, which are produced by etching in an isotropic alkaline solution such as KOH [2] or NaOH [3]. The random nature of the crystal orientation of multicrystalline silicon wafers makes such techniques much less effective for this material because only a minority of grains are properly orientated. For the reason, RIE which is belonged to anisotropic etching is more suitable to produce nano-sized structures as anti-reflection for multicrystalline solar cells [5]. In this work, we combine chemical wet etching and dry etching for texturing the front surface of multicrystalline Si.

2. Experimental
The surface saw damage of the as-cut multicrystalline silicon wafer will conduct surface treatment in saw damage removal (SDR) method by two different ratios that is mixed nitric acid-hydrofluoric acid (HF/HNO₃) solution in 1:18 and 1:4, respectively [5]. The surface nano-sized texturing structure is produced by RIE which reactive gas is mixed SF₆/O₂ at 400 w, 300 mTorr. Besides, the standard industrial alkaline etching will be the reference sample that is processed in 80 °C KOH. The scanning electron microscope (SEM) and UV-Vis spectrum analyse the surface profile of multicrystalline silicon and reflectance, respectively.

3. Results and discussion
Figure 1 shows SEM images of multicrystalline silicon wafers with various surfaces. In the as-cut wafer (Fig. 1a), the heavy surface damage is evident as deep fissures and cracks, resulting in reasonable reflection control but high recombination. After HF: HNO₃=1:18 SDR process, multicrystalline silicon surface appear the bowl-like features surface such as Figure 1(b). When increase HF ratio of SDR solution to HF: HNO₃=1:4, multicrystalline silicon surface becomes smooth and flat along showed in Figure 1 (c). Figure 1 (d) is standard industrial alkaline-etched wafer. It appears to have some micro-sized, grain-dependent texturing.

![Fig. 1  SEM images of multicrystalline silicon wafers with various surfaces. (a) Raw wafer, (b) HF: HNO₃=1:18, (c) HF: HNO₃=1:4, (d) standard industrial alkaline etching.](image-url)
reflectance greatly. And the reflectance is lower when contained

Fig. 2 SEM images of reactive ion etching process after (a) HF: HNO₃=1:18 and (b) HF: HNO₃=1:4 SDR treatment.

higher HF ratio condition. Consequently, by controlled the process parameters, we obtained optimize nano-sized structure which is provide with high etching rate and low reflection.

4. Conclusion
We combined chemical wet etching method by HF: HNO₃ mixtures solution and dry etching by reactive ion etching to produce nano-sized structures on silicon surface that is applied as anti-reflection of multicrystalline solar cells. The reflectance of such techniques is lower than standard industrial alkaline etching. There is lower reflectance when SDR solution contained higher HF ratio.

5. References

Fig. 3 The reflectance of reactive ion etching process after HF: HNO₃ = (a) 1:18, (b) 1:4 SDR treatment. (c) standard industrial alkaline etching.