

Solar Cell Fabrication by Wet Etching Combined with Ultrasonic Vibration for Multicrystalline Silicon

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Abstract. With the development of economy and society, more and more energy is needed to meet the requirement of industries and social life. It is necessary to find new types of energy that is clear, high effective and non-polluted. Although wet etching is widely used in industries to prepare the silicon surface texture, the etching process is stochastic and the influence light trapping. Many efforts have been made such as adjusting the proportion of different acids, to improve the quality of silicon surface by wet etching, the result does not meet the ideal requirement by now. In this paper, a new approach is presented to prepare the surface texturing. By combining wet etching and ultrasonic vibration, the sodium or acid molecular motion can be controlled, and the pyramid structure in silicon surface can be made regular.

Introduction

With the development of economy and society, more and more energy is needed to meet the requirement of industries and social life. It is necessary to find new types of energy that is clear, high effective and non-polluted. Solar energy is an available new energy, which can be translated from light energy into electric energy by crystalline silicon. Front surface texturing in crystalline silicon solar cells has a primary role for improving cell efficiency by means of its antireflection property and light trapping with antireflection [1–3]. In addition to increase light trapping by minimizing reflection of the incoming light, it increases the effective cell thickness through the double bounce effects, which is easy to achieve high efficiency by light trapping of long wavelength light. Conventionally, Single crystalline silicon wafer is used to produce crystallographic planes and pyramids texture [4,5], however the cost and complex processes in purifying limit its wide application. Nowadays, multicrystalline silicon is more used to substitute single crystalline silicon in industry to produce solar energy cell. Wet chemical processes etch and dry processes etch are two main methods in silicon surface texture preparation, wet chemical etch used sodium or acid to produce pyramids texture on oriented material, while the dry method such as laser-structuring [6], mechanical diamond saw cutting [7], photo-lithographically defined etching [8], porous-Si etching [9], mask less RIE etching [10,11] is recently present to prepare the theoretic texture. Although the precision of wet chemical processes method is lower than that of dry processes, the equipment cost of wet processes is also cheaper than that of the former, and widely used in solar energy cell industries. Sodium or acid etching is a stochastic process, and the pyramids structure can be not made regularly, which will affect light trapping. In this paper a new approach is presented by using ultrasonic wave to control the machining direction and velocity of liquid to improve the quality of surface of silicon for wet etching.

The Equipment of Etching Combined with Ultrasonic Vibration

In order to realize the regular motion of sodium or acid molecular, a structure of ultrasonic generator is designed in Fig. 1, 1 and 3 in Fig.1 are two ultrasonic vibration head to generate ultrasonic vibration. Then, in order to transfer ultrasonic vibration, the motion of sodium or acid molecular is forced to vibrate regularly according to the ultrasonic frequency. Fig. 2 illustrate the status of

molecular motion in several periods with single ultrasonic generator. Fig. 2 also shows that the transverse wave displacement is not the same at different moment, which will effect the arrangement of pyramid when sodium or acid reacts with the silicon. In order to overcome this problem, a new ultrasonic generator (Fig. 1)—No. 3 vibration head—is introduced, and the vibration frequency is the same as the No. 1 ultrasonic generator, the only difference is phase between No. 1 and No. 3 generator. After superposing two kinds of motion, a new status of molecular motion is presented in Fig. 3, and the displacement of molecular motion is controlled. After etching react with the silicon surface, it is possible to etching regular pyramid structure in silicon surface.

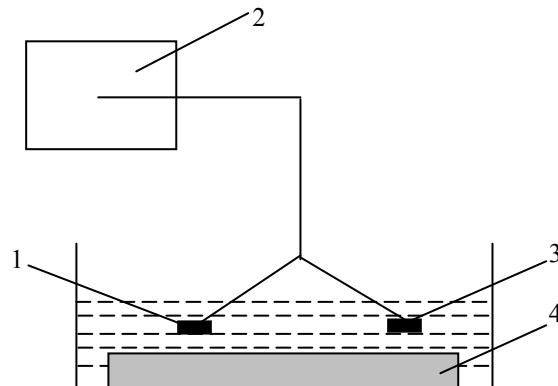


Fig. 1 The structure of ultrasonic vibration
1,3-Vibration head; 2-ulstrasonic source; 4-silicon



Fig. 2 Motion of molecular by single generator Fig. 3 Motion of molecular by two generators

The Process of Etching Combined with Ultrasonic Vibration

The process of wet etching combined with ultrasonic vibration is a very complex [12], including physical and chemical react. There are not clear conclusions to explain combined process by now. In generally, there are two main machining processes to prepare the silicon surface texture, one is chemical etching process and the other is collision process by molecular motion with silicon surface.

The surface texture prepared by wet etching is a chemical react process. As the react of HF acid with multicrystalline silicon for example, the chemical react function is as follow:



The react resultant SiF_4 is covered on the silicon surface. Traditionally with react process conducting, the resultant will accumulate and prohibit acid molecular from further reacting with silicon, which will influence the aspect ratio of pyramid structure. As chemical etching combined with ultrasonic vibration, Ultrasonic vibration will effectively improve this problem by transferring the vibration to acid molecular, and the motion of acid molecular will take away chemical react

resultant, which will be helpful for HF molecular to further react with silicon. Fig. 4 illustrates the chemical etching process. In Fig. 4, HF molecular has reacted with silicon, and a trough has been generated in the surface.

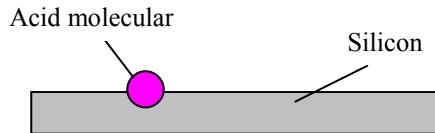


Fig. 4 Chemical etching process

The acid molecular motion is excited by ultrasonic vibration. Since the vibration of molecular is influenced by acid damp, friction between acid molecular and other factors, the motion is a two-stage vibration system. Supposed that the frequency of ultrasonic generator is ω_0 , and damp ratio of system is ζ , then the frequency of acid molecular vibration can be calculated as follow:

$$\omega_d = \omega_0 * (1 - \zeta^2)^{1/2} \quad (2)$$

Function (2) illustrate that the frequency of acid molecular vibration is less than that of ultrasonic generator. But because the frequency of ultrasonic is up to 50k Hz, the frequency of acid molecular vibration is also very high. When colliding with silicon, the acid molecular will damage the lattice structure of multicrystalline. The small lattice may be broken off along the grain boundary, which will be helpful to chemical etching. Fig. 5 illustrates the process of collision between excited HF molecular and silicon. Because the vibration amplitude of HF molecular reduce gradually, and the energy of vibration is directly related to vibration amplitude, if the energy of molecular is absorbed by the silicon in colliding, then the collision force received by silicon will reduce gradually with the increase of depth. So the upper layer of silicon is damaged the more seriously than lower layer, and a pyramid texture is made.

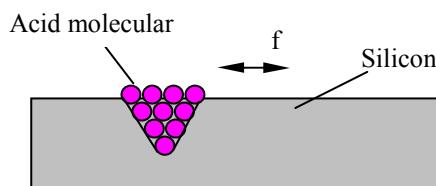


Fig. 5 Collision between molecular and silicon

In this paper a new method to texture the mc-Si solar cells is present by using ionized bubble, which is formed by ultrasonic wave combined with electrolysis in mixed acid solution. The movement of ionized bubble is observed. The process of texturing mc-Si solar cells by ionized bubble is analyzed, including chemical and physical etching, and can effectively improve etching quality. We have also used spectrophotometer to measure mc-Si surface reflectance to test the efficiency of two methods. The result express that light wavelength from 400nm to 1000nm is easy to be absorbed. The reflectance of mc-Si textured by ionized bubble is low, which means mc-Si solar cell textured by ionized bubble will absorb more light and generates more electric energy at the same light shining than that of traditional chemical mixed acid etching.

Experiment

An experiment of HF combined with ultrasonic is developed to etch the multicrystalline texture, the size of sample is 5mm×5mm, the frequency of vibration is 50K Hz and the density of HF is 45%. After 5 minutes etching, the width of pyramid is 4μm and the depth is 7μm. Compared with traditional wet etching, the manufacturing period is cut down and quality of surface texture is improved greatly. The further research is to measure light trapping by Spectrophotometer and process control in manufacturing.

Conclusion

Wet etching is often used in surface texturing to fabricate pyramid in industries at present, but the quality and efficiency of texturing influence it's widely promotion. In this paper, a new approach is present by combining ultrasonic vibration with wet etching to make the pyramid texture on silicon surface. The machining process is analyzed and an experiment is developed. The result shows that this approach is useful to improve the quality and efficiency in machining surface texture of silicon.

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