

Solar Cell Surface Texturing Combined Wet Etching and Ultrasonic Vibration

Yan Chao^a, Yutao Wu^b, Jie Yu^c and Liquan Wu^d

School of Mechanical Engineering, Hangzhou Dianzi University, Hangzhou, Zhejiang Province
310018, P.R. China

^ay_nest@hotmail.com, ^bwuyu870518@126.com, ^cyujiett0607@163.com, ^dwuliquan@hdu.edu.cn

Keywords: Solar cell, Surface texturing, Wet etching, Ultrasonic vibration, Molecular motion controlling

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 is 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 effectiveness is still limited. 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

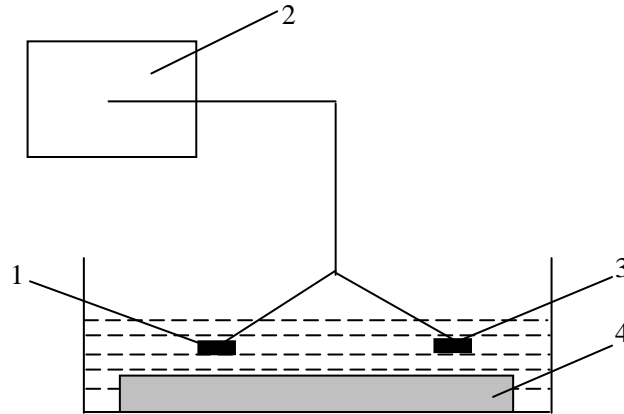


Fig. 1 The structure of ultrasonic vibration
1, 3-Vibration head; 2-ultrasonic source; 4-silicon

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.

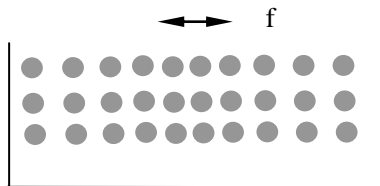


Fig. 2 Motion of molecular by single generator

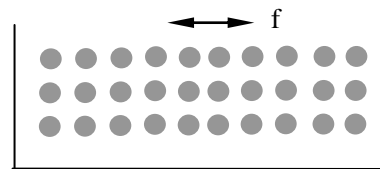


Fig. 3 Motion of molecular by two generators

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 Chemical Etching Process. 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 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.

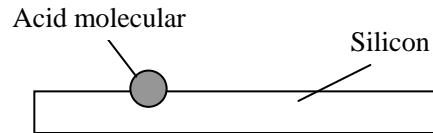


Fig. 4 Chemical etching process

The Collision Process Between Molecular Motion and Silicon Surface. 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_n , and damp ratio of system is ζ , then the frequency of acid molecular vibration can be calculated as follow:

$$\omega_d = \omega_n \circ (1 - \zeta^2)^{1/2} \quad (2)$$

Equation (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.

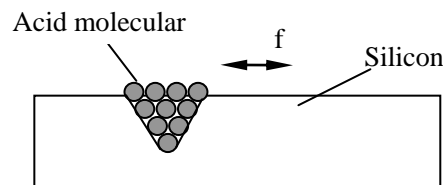


Fig. 5 Collision between molecular and silicon

Experiment

An experiment of HF combined with ultrasonic is developed to etch the multicrystalline texture, the size of sample is $24.5\text{mm} \times 24.5\text{mm}$, the frequency of vibration is 50K Hz and the density of HF is 45%. After 5 minutes machining, the width of pyramid is $4\mu\text{m}$ and the depth is $7\mu\text{m}$. 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 is limited. 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 conducted. The result shows that this approach is useful to improve the quality and efficiency in machining surface texture of silicon.

Acknowledgement

This study was supported by Public Project of Zhejiang Province (2010C31G2040106).

References

- [1] T. Yagi, Y. Uraoka and T. Fuyuki: Sol. Energy Mater. Sol. Cells, Vol. 90 (2006), pp. 2647-2656.
- [2] E. Fornies, C. Zaldo and J. M. Albella: Sol. Energy Mater. Sol. Cells, Vol. 87 (2005), pp. 583-593.
- [3] J.M. Rodriguez and I. Tobias: Sol. Energy Mater. Sol. Cells, Vol. 45 (1997), pp. 241-253.
- [4] Z. Xi, D. Yang and D. Que: Sol. Energy Mater. Sol. Cells, Vol. 77 (2003), pp. 255-263.
- [5] H. Shota, M. Takashi, T. Hideyuki and H. Yoshihiro: Solar Cells. Rare Met., Vol. 25 (2006), pp. 115.
- [6] S. Narayanan: *Study on Solar Cell Manufacturing* (Ph.D., University of New South Wales, Australia, 1989), pp. 45-47.
- [7] P. Path, G. Wileke, E. Bucher, J. Szlufcic and R.M. Murti: *Proc. 24th IEEE Photovoltaic Specialist Conf.* (USA, May 13-17, 1994), pp. 1347-1350.
- [8] J. Zhao and A. Wang: Appl. Phys. Lett., Vol. 73 (1998), pp. 1991-1997.
- [9] R.R. Bilyalov, L. Stalmans and L. Schirone: *IEEE Trans. Electron Devices*, Vol. 46 (1999), pp. 2035-2040.
- [10] H. Jansen and M.D. Boer: J. Micromech. Microeng., Vol. 5 (1995), pp. 115-120.
- [11] W.A. Nositschka, C. Beneking, O. Voigt and H. Kurz: Sol. Energy Mater. Sol. Cells, Vol. 76 (2003) No. 2, pp. 155-166.
- [12] J.P. Choi, B.H. Jeon and B.H. Kim: J. Mater. Process. Technol., Vol. 191 (2007), pp. 153-156.

Advances in Engineering Design and Optimization

10.4028/www.scientific.net/AMM.37-38

Solar Cell Surface Texturing Combined Wet Etching and Ultrasonic Vibration

10.4028/www.scientific.net/AMM.37-38.1210

DOI References

[3] J.M. Rodriguez and I. Tobias: Sol. Energy Mater.Sol.Cells, Vol. 45 (1997), pp. 241-253.

doi:10.1016/S0927-0248(96)00040-2

[4] Z. Xi, D. Yang and D. Que: Sol.Energy Mater.Sol.Cells, Vol. 77 (2003), pp. 255-263.

doi:10.1016/S0927-0248(02)00347-1

[9] R.R. Bilyalov, L. Stalmans and L. Schirone: IEEE Trans. Electron Devices, Vol. 46 (1999), pp. 035-2040.

doi:10.1109/16.791993

[11] W.A. Nositschka, C. Beneking, O. Voigt and H. Kurz: Sol. Energy Mater. Sol. Cells, Vol. 76 (2003) No. 2, pp. 155-166.

doi:10.1016/S0927-0248(02)00214-3

[9] R.R. Bilyalov, L. Stalmans and L. Schirone: IEEE Trans. Electron Devices, Vol. 46 (1999), pp. 2035-2040.

doi:10.1109/16.791993

[11] W.A. Nositschka, C. Beneking, O. Voigt and H. Kurz: Sol. Energy Mater. Sol. Cells, Vol. 76 (2003) No. 2, pp. 155-166.

doi:10.1016/S0927-0248(02)00214-3