Channeling parameters of protons along planar directions of Si

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Abstract
In this work, the channeling parameters, the ratio of channeling to random stopping power, and the mean channeling distance, of protons along the {100} and {110} directions of Si were studied. The channeling parameters were deduced using the simulation of the channeling Rutherford back-scattering spectra based on the exponential dechanneling function. The best simulation parameters were set using the Levenberg- Marquardt algorithm. The RBS/C spectra were taken in energy interval 1800-2200 keV, using a Si wafer.
Keywords: Channeling Rutherford Backscattering Spectrometry; Proton ions; Channeling stopping power; Mean channeling distance;

Introduction
The channeling phenomenon has been discovered by observing the strange behavior of an ion beam when it enters a crystal in a direction parallel to the major axial and planar crystallographic directions since the early 1960s [1]. For better understanding ion- solid interaction, the stopping power of channeled ions in crystalline samples has been extensively investigated so far. For this purpose, different treatments were employed [2, 3]. The computer simulation of RBS/C spectra with the exponential or the Gompertz type dechanneling function [4-6] lead to determining not only the channeling stopping power but also parameters that provide information about dechanneling phenomena which explain the ion-lattice interaction. The ratio of the energy loss of the channeled ions to the random ions, α, and mean channeling distance, λ, of proton in the energy region of 1800-2400 keV along Si <100>, Si <111> and Si <110> were measured [4-6]. Despite researches done on the channeling parameters of proton ions along the axial channels of Si, there is a lack of λ value along the planar directions.
In this paper, the channeling parameters as well as the ratio of the channel to the random stopping power of p ions along the {100} and the {110} plans were calculated using a Si wafer.

Experimental
The Si crystal wafer cut in the direction of the plane (100) was used as a target. The sample was cleaned and etched by 10% HF just before the RBS measurements. Ion beams were produced by using a 3 MeV Van de Graaff accelerator. The divergence angle of the beam was less than 0.06°. The Si surface barrier detector was employed at an angle θ=165° to the incident beam. The energy resolution of the detection system was 15 keV. The planar directions were determined by an angular scan of the target. The spectra of each direction were taken in the energy interval 1800-2200 keV in the tilt angle, at which the back-scattered particles count was the minimum.
The method used for simulating of channeling back-scattering Rutherford spectra has been described in detail by Aslanoglou et al. [5]. A set of parameters in which the least-squares achieved was picked as the best by using Levenberg-Marquardt Method.

Results and discussion
The experimental random and channeling spectra along the{100} and the {110} channels with simulations at energy 1800 keV for instance are presented in Fig. 1 and Fig. 2, respectively.

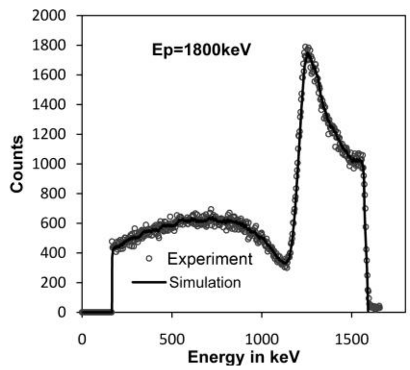

Figure 1. Experimental and simulation of RBS spectrum.

The simulation is in good agreement with experimental results. The values of α and λ along the {100} and {110} directions are illustrated in table 1. The results show that the values of α and λ do not change with the ion beam energy.

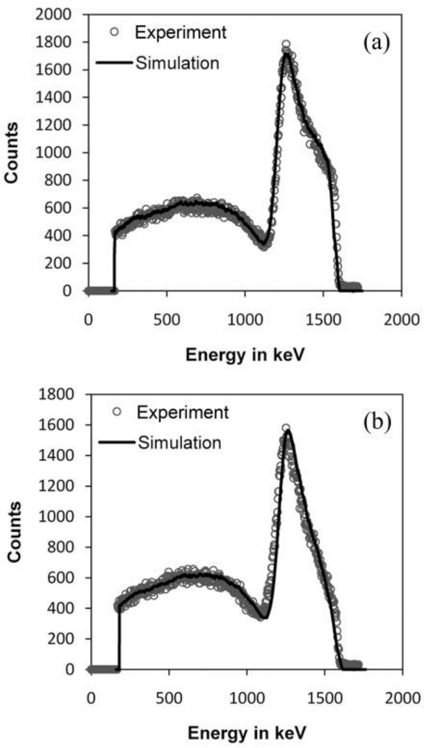

Figure 2. Experimental and simulation of RBS/C spectra along the (a){100} and (b){110} directions.

Table 1. Values of α and λ along the {100} and {110} planar directions.

		α		λ(μm)	
		{100}	{110}	{100}	{110}
Energy (keV)	1800	0.93±0.02	0.81±0.03	0.49±0.06	2.23±0.04
	2000	0.9±0.02	0.79±0.01	0.43±0.02	2.26±0.13
	2200	0.92±0.02	0.81±0.01	0.47±0.1	2.52±0.07
average		0.92±0.01	0.8±0.01	0.45±0.02	2.3±0.03
Ref [3]		0.88±0.04	0.82±0.04		

By considering the uncertainty, the calculated average values of α in this paper along the planar channels of Si are all in notable agreement with the values obtained in the literature. This confirms the validity of our simulation and subsequently the validity of the calculated values of λ. When ions enter along the channel of a lattice, they lose their energies due to inelastic scattering from the atomic electrons. They also obtain adequate transverse energy to surmount the potential barrier of the channel and escape the channel by multiple scattering from target nuclei and electrons. So the values of α and λ depend on the electron density or the fractional area of a channel blocked by atoms, which is the channel characteristic. The fractional area of the planar channels blocked by atoms inversely depends on the interplanar spacing. Since the {100} channel has smaller interplanar spacing than the {110} channel, it had less open area in comparison with the {110} channel. As a result, ion along the {100} channel get enough transvers energy to overcome the atomic potential of the channel by travel a very short distance along the channel. They also lose more of the energy during travel such a short distance along the channel.

Conclusions

In summary, this paper has studied the channeling parameters, λ, and the stopping power of the proton ions in the energy range of 1800-2200 keV along the {100}, and {110} channels of Si by simulating of the RBS/C spectra. Since the most area of the {100} channel blocked by atoms, the stopping power of the ions along this channel is near the random stopping power. Moreover, ions will be dechanneled after travelling a very short distance along this channel. The open area of the {110} channel is about 1.4 times the open area of the {100}. This cause ions along the {110} channel to pass a longer distance before being dechanneled. They also lose a bit less energy in comparison with the ions enter along the {100} channel of Si.

References

مراجع

1. Robinson, M.T. and O. Oen, *The channeling of energetic atoms in crystal lattices.* Applied Physics Letters, 1963. **2**(2): p. 30-32.
2. Cembali, F. and F. Zignani, *Determination of random and aligned stopping powers for 80–300 keV protons in silicon by back-scattering measurements.* Radiation Effects, 1977. **31**(3): p. 169-173.
3. Gehrmann, P., K. Lenkeit, and R. Stolle, *Measurements of proton channeling energy losses in silicon in the intermediate energy region.* physica status solidi, 1985. **131**(2): p. 519-526.
4. Aslanoglou, X., et al., *Simulations of channeling spectra in the system p+ 28Si.* Nuclear Instruments Methods in Physics Research Section B, 1998. **140**(3-4): p. 294-302.
5. Aslanoglou, X., et al., *Simulations and comparisons of channeling spectra in the p+ 28Si system in the backscattering geometry.* Nuclear Instruments Methods in Physics Research Section B, 2000. **161**: p. 524-527.
6. Kokkoris, M., et al., *On the dechanneling of protons in Si [110].* The European Physical Journal B, 2003. **34**(3): p. 257-263.