Study effect of incidence angle on ion implantation in ZnO matrix

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The ion implantation method is one of the techniques used to dope the materials. The TRIM software (Transport and Range of Ions in Mater) created by Ziegler and colleagues [1] can simulate it. In this work, we studied the effect of incidence angles for different energies on the distribution of implant ions in the target by using the TRIM software, and several processes resulting from the interaction between Potassium ions and the target atoms are examined. Simulated physical effects are intriguing.

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1. Introduction

Doping is a technique used in the science of semiconductors to change a pure substance's conductivity by adding a small number of impurities. The number of charge carriers that a semiconductor possesses accounts for a substantial portion of its properties. These carriers can be electrons or holes. There are numerous ways to modify a material, including ion implantation, laser doping, and nuclear transmutation doping [2]. Ion implantation was initially employed for surface cleaning, but as the physical qualities beneath the battered surface changed, it was also utilized to dope semiconductors. When using ion implantation, the amount of doping that can be introduced is not constrained by how soluble it is in the target material. The efficiency of doping by ion implantation is characterized by controlling the distribution of doping, damaging the target material after ion implantation, healing it by thermal annealing, and, most importantly, electrical characteristics of the semiconductor after implantation and post-implantation annealing [3]. Zinc Oxide has very interesting electronic, electrical and optical properties which make it a candidate for various applications in optoelectronics. In particular for the production of LED devices and in the photovoltaic field [4]. We propose in this work a numerical simulation study of the Potassium implantation effect for different angles and energies on ZnO by using the Stopping and Range of Ions in Matter (TRIM) software, in order to investigate the defect profile, ionization phenomena; distribution process, and phonon production.

2. TRIM software simulation

The Stopping and Ranges of Ions in Matter developed by James F. Ziegler is a group of computer programs that calculate the interaction of ions in the matter; use a Monte Carlo method to simulate ion-target interactions [5,6]. A program forms the foundation of SRIM. TRIM is a series of programs that uses a quantum mechanical treatment of ion-atom collisions to determine the stopping and range of ions (10 eV - 2 GeV/Uma) into the matter. The interaction of the ions beam with the sample is formed of two distinct mechanisms, the first of which is the interaction of the ions with the target atoms' nucleus, and the second of which is the interaction with their

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electrons. In this work, we used the TRIM (Transport and Rang of Ion in Matter) which is a collection of software packages developed by Ziegler and Biersack that calculate the stopping and range of ions in matter It is based on a Monte Carlo simulation and is a reference program that is very well-liked by the radiation effects field [3].

3. Results and discussion

To investigate the impact of bombarding a $0.5\,\mu m$ ZnO target with Potassium ions, 10000 ions were shot for different incidences angles to the plane of the material's surface, with implantation energies ranging from 10 keV to 70 keV.

3.1. Ion distribution

In Fig.1 we presented the distribution of the ion in the ZnO layer, with the target depth for different incidences angles. The distribution consists of beam particles of the Gaussian type. When we bombard the ZnO target with 50 KeV Potassium ions for different angles, the ion range decrease we can see this variation for different incidence angles when we change the energy ionization. Fig.2 illustrates the ion range depth of Potassium for incidence angles. With increasing incidence angle the ion range is decreasing. The penetration is deeper for high energies and normal incidence.

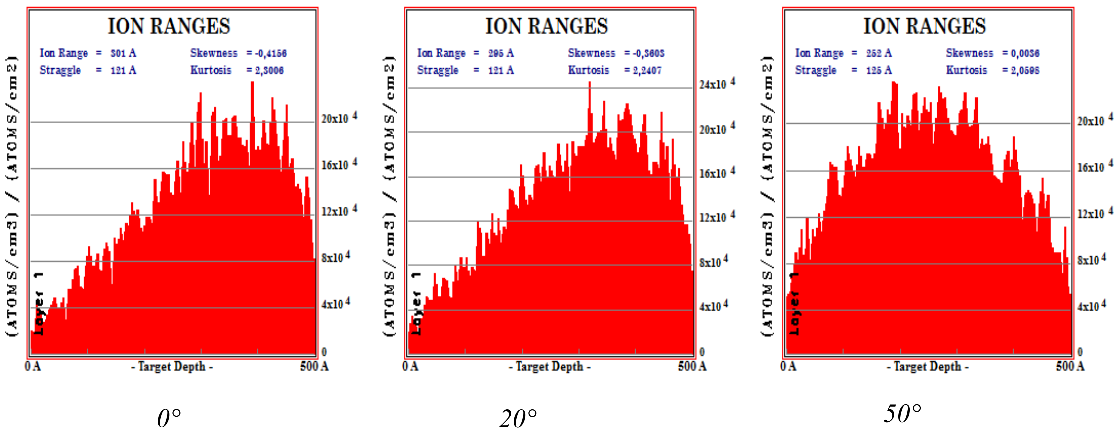


Fig. 1. Probability of the presence of each implanted K ion (E =50 keV) in ZnO.

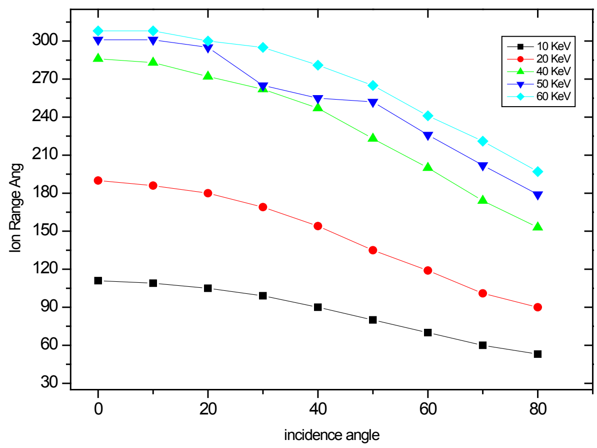
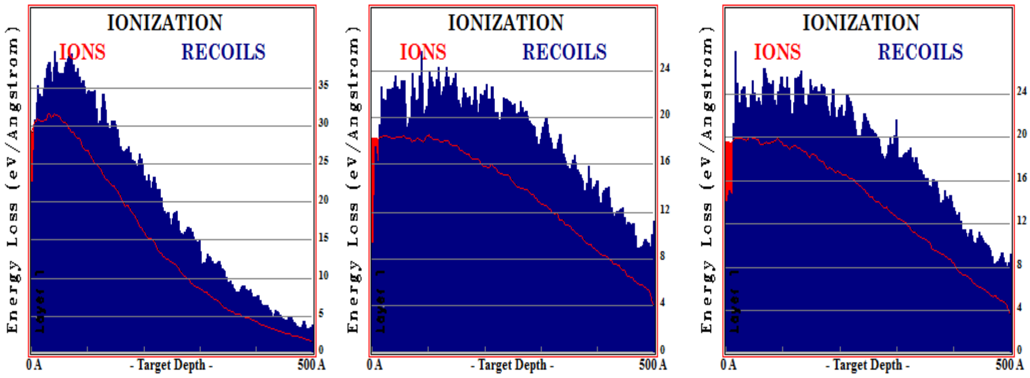


Fig. 2. Ion range depth as a function of incidence angle.

3.2. Ionization process

The ionization process is the major result of the entrance of Potassium ions that have been accelerated and the recoiled ions into the surface. The process of ionization involves the loss of energy to the target electrons. If the target is a metal, the energy is released as heat, whereas if the target is an insulator, it is released as phonons. The electrons of the target take energy from the quickly traveling ions and recoil atoms [7]. Fig.03 represents the ionization from the incident ions Potassium and recoiling target atoms; for example the acceleration energy 50 keV and different angles. We notice that in the case of Potassium implantation, the energy transferred by the Potassium ions is greater than the energy transferred by the target atoms. The energy loss decreases when the incidence angles change from normal.

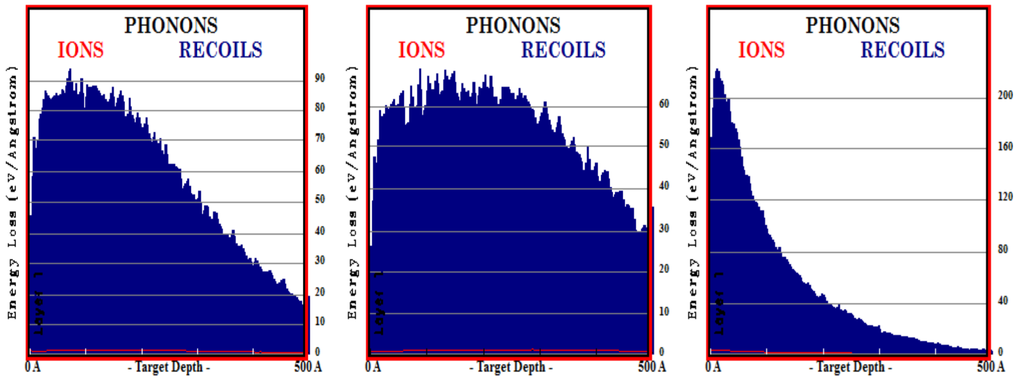


0° 20° 50°

Fig. 3. Probability of the presence of each implanted K ion (E = 50KeV) in ZnO.

3.3. Phonon production

Phonons are atomic vibrations that store energy in a crystal. Because all of the atoms in a crystal are linked, when one of them vibrates, many of the other atoms begin to vibrate as well. Because it is quantized, this mass vibration is referred to as a phonon [7]. Fig.4 illustrates the produced phonons; the red line (at the bottom) shows the ion loss energy transferred to the phonon.



0° 40° 70°

Fig. 4. The distribution of target phonons produced for different incidence angles (E = 50 KeV).

Fig. 5 presents the energy loss for ions and recoils for different values of incidence angles, in the case of 10 keV the ions losing from its energy 2.50 % to phonons and the recoils are depending 68.05 % of energy into phonons where the incidence angle is $\theta = 0°$ for energy 40 keV the energy loss for the same incidence angles, with increasing incidence angle and energy ionization the energy loss for ions and recoils are decreasing. The energy loss is greater for the normal incidence.

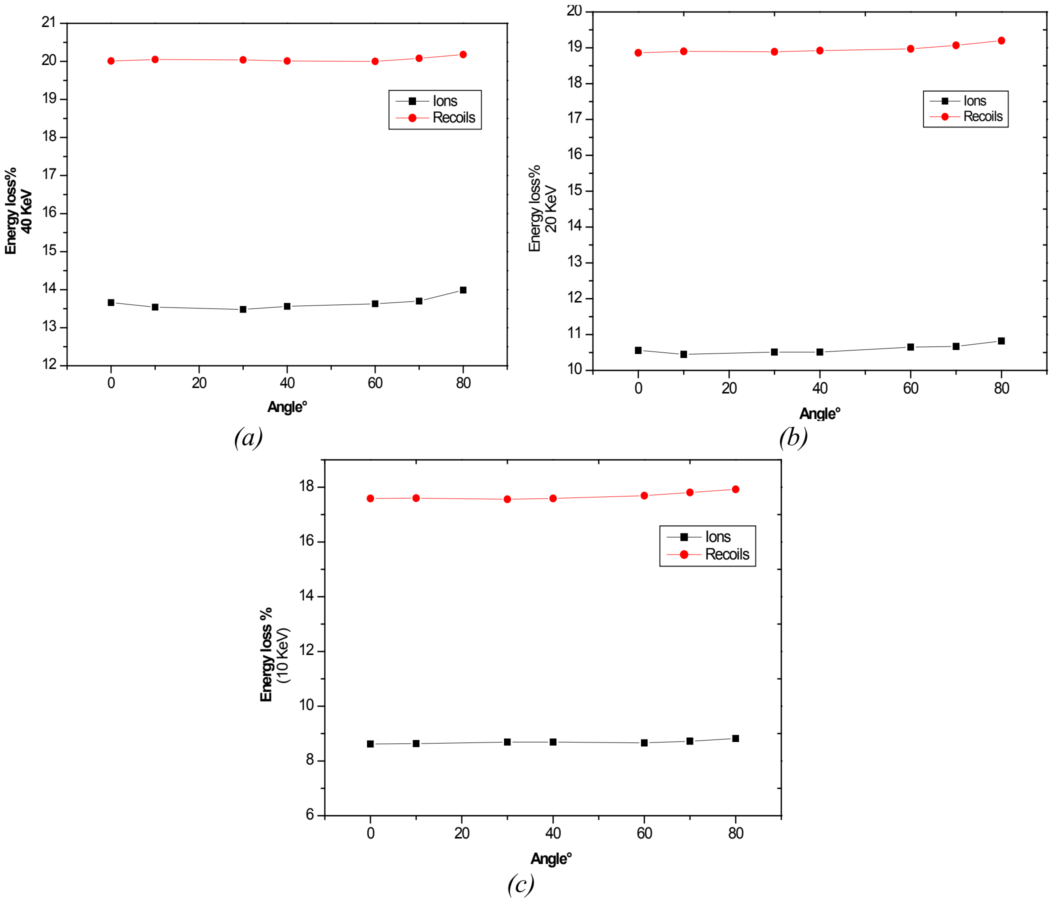


Fig. 5. The energy loss for ions and recoils produced for different incidences of angle
a =10KeV ; b = 20 KeV ; c = 40 KeV.

4. Conclusion

Ion implantation simulation of Potassium ions in ZnO material shows that most of the energy loss is due to ionization and phonon production. The variation of incidence angle for ionization energy has a big effect at ions distribution; phonon production and ionization process for ions and recoils The change in incidence angle explained to us how the implantation is damage profile will behave and also led us to understand how ion radiation affects for this layer

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