Energetic ions when penetrate inside the material lose their energies by two nearly independent processes: (i) electronic energy loss (inelastic collisions with electrons: S_e) and (ii) nuclear energy loss (elastic collisions with atomic nuclei: S_n).[1,2] Generally, major contribution of the energy transfer comes from S_e when the velocities of the impinging ions are much greater than the orbital velocity of the K shell electrons bound to the target atoms.[2] As the ions move deeper inside the target, their velocities get reduced and then they suffer elastic collisions (S_n) with the target atomic nuclei. However, relative contributions of S_e and S_n depend on the projectile mass, velocity, charge state and also on the target itself. The energy losses of 800 keV Ar^{4+} ions (both S_e and S_n) have been estimated by using stopping power and ranges of ions in matter simulation (SRIM) technique[3] and presented in Figure 1. In SRIM calculation, the density of ZnO was taken as 4 g/cm^3 and the displacement threshold energies were taken as 18.5 eV and 41.4 eV for Zn and O atom respectively in ZnO lattice.[4] Figure 1 represents the variation of S_e and S_n against the penetration depth of Ar^{4+} ions inside the target film. It clearly indicates that the penetration depth is greater than the thickness of the films (~550 nm). The electronic energy loss (S_e) largely predominates over nuclear energy loss (S_n) as shown in Fig. 1. The energy transfer through S_n can only knock out the target atoms from their lattice positions and creates stable vacancies or vacancy clusters.[1,5,6] However, S_e is mostly responsible for the excitation and ionization of the target atoms. Above a certain critical value of S_e (~keV/nm), point defects or correlated defect clusters may also be produced in insulators.[2] But S_e for the Ar^{4+} ions is far less than the critical value responsible for the generation of such defects or defect clusters. SRIM calculation also reveals that Ar^{4+} ions create more damages at the Zn sites than O sites. However, SRIM can only predict the generated displacements. Majority of these defects immediately gets compensated (dynamic recovery) inside the target and this is the origin of the radiation hardness of ZnO.[1,7]

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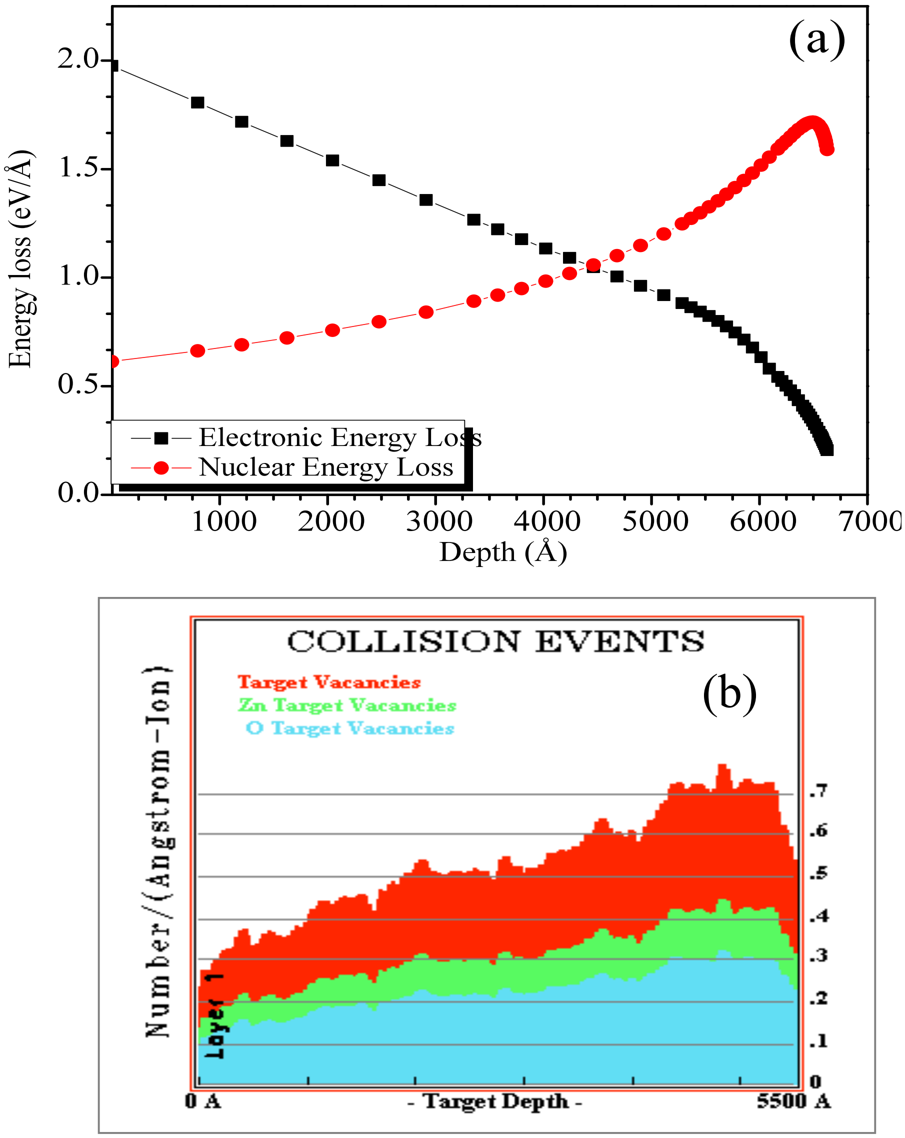

Fig. 1: (Color online) (a) Electronic and Nuclear energy losses with penetration depth of 800 *keV* Ar ions in $Zn_{0.95}Mn_{0.05}O$ films, calculated from SRIM. (b) Vacancy created by ion beam throughout the depth of the films, calculated from SRIM.