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Effect of Swift Heavy Ion Irradiation on the Lattice Parameter of NiO Thin Film

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Abstract

NiO thin films grown on Si(100) substrate and annealed at 500^{0}C were irradiated with 120 and 200 MeV Au ions. The effect of Au ion energy on lattice parameter and hence the stress profile of NiO films were studied. Though the lattice parameter of NiO decreases with increasing ion fluence for both the ion energy cases the same decreases slightly larger amount at higher fluences for the NiO film irradiated with 200 MeV Au ions. Stress calculated form the lattice parameter indicated the development of compressive stress in both the ion energies. Our study indicated that the higher value of stressed region for 200 MeV Au ion irradiation case and the same may be due to higher electronic energy loss of the ion in the NiO medium.

Keywords: Ion irradiation; nanoparticles; lattice parameter; stress; electronic excitation; NiO

Introduction

The energetic ion beam has been considered as one of the effective tools for post deposition modification techniques in control manner. In this technique, one allows the ion beams to penetrate thorough the materials medium and the modifications in the medium takes place due to consequence of the deposition of huge amount of energy through electron-phonon coupling. Depending upon ion energy the either electronic energy loss (S_e) or nuclear energy loss (S_n) will be dominant. The S_n induced processes dominate in the keV range of ion energy and lead to creation of atomic size point defects and clusters of defects. For swift heavy ions (SHI) moving at velocities comparable to the Bohr velocity of the electrons, the S_e induced process is the dominant mechanism for energy transfer and materials modification [1]. The signature of the passage of the ion in the materials medium is registered in the form of latent track. The continuous amorphized latent tracks [2] or hollow track [3] is formed in the medium when S_e exceeds certain material-dependent threshold value, S_{eth}. Not only the cylindrical ion tracks having variety of defects but also the surrounding regions of the ion track which are affected due to de-excitation of the track regions lead to interesting properties in the material [4, 5].

In the present paper, we report the evolution of lattice parameter and relate them with stress profile developed due to the passage of 120 and 200 MeV Au ions in NiO film annealed at 500 ^{0}C. Our study indicated that the not only electronic energy loss but also initial microstructure of the pristine film takes the decisive role in the modification of the materials which in turn dictates the final properties of the materials.

Experimental

NiO films (thickness ~ 100 nm) were deposited on Si (100) substrate by e-beam evaporation technique following the procedure described elsewhere [6]. The as-deposited films were sintered at 500 ^{0}C for half an hour. The sintered films were subjected to 120 and 200 MeV Au ions generated from the 16 MV tandem Pelletron Accelerator at IUAC, New Delhi. Irradiation was performed at room temperature. The pristine and irradiated films were characterized by GAXRD at RT with CuK_α radiation using Bruker X-ray diffractometer (D8 Advance) under identical conditions.

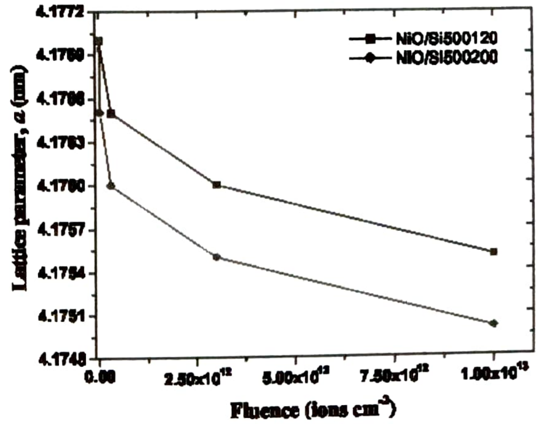


Figure 1: Variation of lattice parameter (a)with different ion fluence for NiO film irrdaited with 120 and 200 MeV Au ions.

Results and Discussion

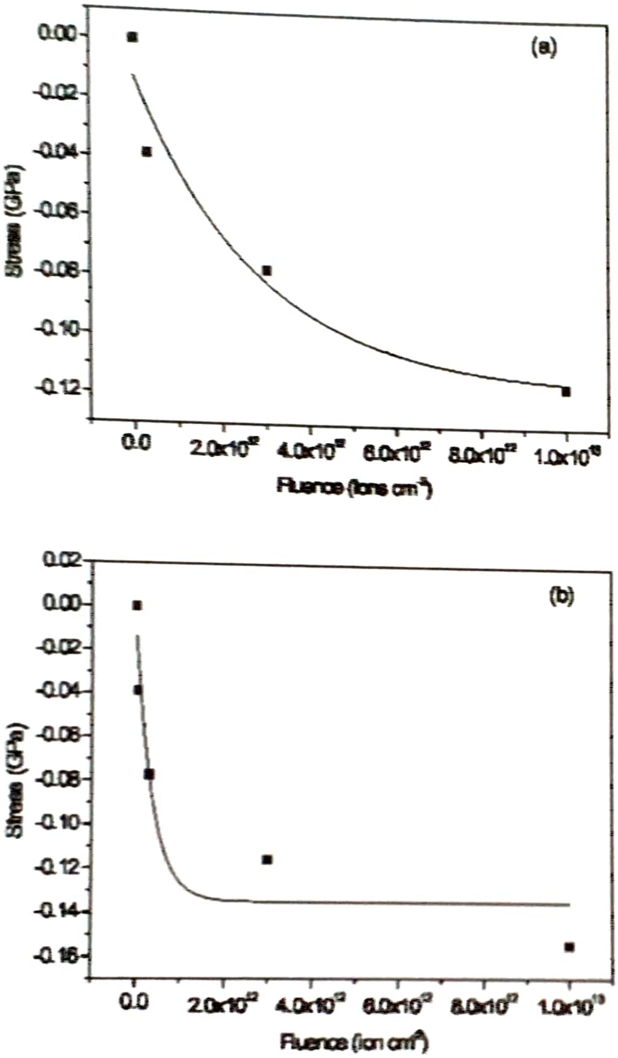
NiO film shows the fcc structure and the same is not affected under ion irradiation. However, the microstructure like lattice parameter, strain etc. are influenced considerably upon ion irradiation. Figure 1 shows the evolution of lattice parameter of NiO irradiated with 120 and 200 MeV Au ions at various ion fluences. Lattice parameter of NiO decreases with increasing ion fluence for both the ion energy cases. However, the lattice parameter decreases slightly larger amount at higher fluences for the NiO film irradiated with 200 MeV Au ions. This may be due to the effect of larger electronic energy loss of 200 MeV Au ions in NiO which in turn induces more compressive stress in the medium.

$$\sigma(\phi) = \sigma_0 + Ce^{-A.\phi}$$

Figure 2: Evolution of stress with ion fluence in NiO film irradiated with (a)120 MeV and (b) 200 MeV Au ions.

The magnitude of stress, in the films due to ion irradiation was calculated from the lattice parameter by using following the relation [7]

where is the Young's modulus, a_0 is the lattice parameter of pristine film, a is the lattice parameter of the irradiated film and is the Poisson's ratio. The values of



and ν for NiO are taken to be 200 GPa and 0.31 respectively. Figure 2 shows the evolution of stress with ion fluences in NiO medium when irradiated with 120 and 200 MeV Au ions. The magnitude of with negative sign indicating the stress is compressive in nature. Increasing ion fluence causes an exponential increase of the magnitude of the stress. We extracted the diameter of stressed region around the ion path by fitting the variation of stress with ion fluence to the Poisson's relation [8, 9]: where is the stress at an ion fluence , is the cross sectional area of the stressed region around ion path. The σ_0 and are constants. The diameter of the stressed region is ~ 6.77 nm and 14.26 $\pm$ 4 nm for NiO film irradiated with 120 and 200 MeV Au ions respectively. The higher value of stressed region for 200 MeV Au ion irradiation case may be due to higher electronic energy loss of the ion in the NiO medium. However, when the NiO film annealed at 700 °C and irradiated with both these Au ions, the stress diameter is not affected much [7, 10]. This further confirms that the initial microstructure of the pristine film is one of the crucial parameter which detects the modification of material under ion irradiation as was seen earlier [6].

Conclusion

The effect Au ions with different energy on the microstructural properties of NiO film annealed at 500°C was studied. Our study indicated that (i) different ion energy has different effect on modifying the microstructure of the NiO film, (ii) the present study confirms the role of initial microstructure in the modification of material under ion irradiation.

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