Orissa Journal of Physics
ISSN 0974-8202

Vol. 22, No.1
February 2015
pp. 63-67

Effect of 120 MeV and 200 MeV Au ions on the Stress Profile of NiO thin Film

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Received : 10.11.2014 ; Accepted : 11.1.2015

Abstract. NiO thin films grown on Si substrate were irradiated by 120 and 200 MeV Au ions. The effect of different ion energy on the stress profile of NiO films was studied. Ion irradiation led to the development of compressive stress in both the ion energies with nearly equal stressed region. The present study thus indicates that the ions having electronic energy loss much higher than threshold value does not have much impact on stress profile of NiO matrix.

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

PACS: 61.80.Jh; 61.82.Rx; 61.85.+p; 61.82.Ms; 68.55.Ac

1. Introduction

Energetic ions penetrating through materials medium lose their energy in two nearly independent processes. These are (i) nuclear (elastic) energy loss and (ii) electronic (inelastic) energy loss. The former process dominates in keV range of ion energy and the later process dominates for Swift Heavy Ions (SHI) moving at velocities comparable to the Bohr velocity of the electrons [1]. When the electronic energy loss (S_e)exceeds certain material-dependent threshold value, S_{eth}, a permanent signature of the passage of the ions in the material is registered in the form of either amorphized latent tracks [2] or hollow track [3].The track radius is a few nanometers and length can be tens to hundreds of micrometers. The cylindrical ion tracks having variety of defects lead to interesting properties in the material [4].

In the present paper, the effect of 120 and 200 MeV Au ions on the stress profile of NiO matrix is reported.

2. Experimental

NiO films (thickness ~ 100 nm) were deposited on Si (100) substrate by e-beam evaporation technique as described elsewhere [Mallick 08]. The as-deposited films were sintered at 700 ^{0}C for half an hour. The sintered films were irradiated at room temperature (RT) with 120 and 200 MeV Au ions from the 16 MV tandemPelletron Accelerator at IUAC, New Delhi. 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.

3. Results and Discussion

Figure 1 shows the XRD pattern of NiO films irradiated with 120 MeV Au ions. NiO films irradiated with either 120 MeV or 200 MeV Au ions retain the crystalline nature up to the highest ion fluence (i.e. 3×10^{13} ions cm^{-2} for 120 MeV Au ion case and 1×10^{13} ions cm^{-2} for 200 MeV Au ion case) [5, 6]. However, the ion irradiation led to the development of stress, σ in the NiO matrix along different directions which can be explained by Trinkausmodel [7, 8]:

$$\sigma_{XX}(\theta) = -0.58\frac{E}{1-\nu}\alpha T(\cos^2\theta - \sin^2\theta) = \sigma(1-2\sin^2\theta) \tag{1a}$$

$$\sigma_{YY}(\theta) = -0.58\frac{E}{1-\nu}\alpha T\cos^2\theta = \sigma\cos^2\theta \tag{1b}$$

$$\sigma_{ZZ}(\theta) = 0 \tag{1c}$$

where E , ν , α , θ and T are the Young's modulus, Poisson's number, coefficient of linear thermal expansion, angle of incidence and freezing temperature respectively. In the present case, $\theta = 0^0$ therefore $\sigma_{xx} = \sigma_{yy} = \sigma$.

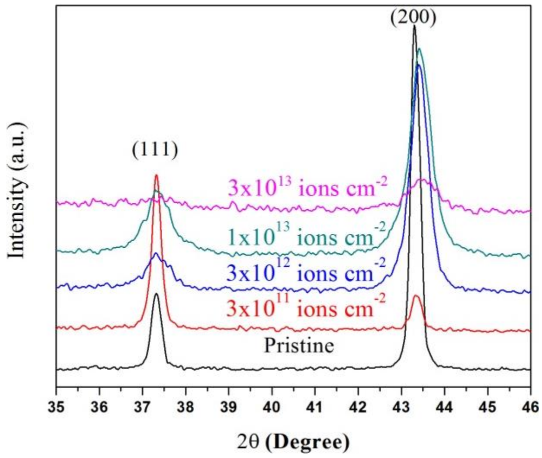

Fig. 1: XRD pattern of pristine and 120 MeV Au ion irradiated NiO films [5].

The magnitude of σ in the films due to ion irradiation was calculated from the XRD pattern by using the relation [9, 10]:

$$\sigma = \frac{-E(a_0 - a)}{2va} \tag{1}$$

where E is the Young's modulus, a_0 is the lattice parameter of pristine film, a is the lattice parameter of the irradiated film and v is the Poisson's ratio. The values of E and v for NiO are taken to be 200 GPa and 0.31 respectively [10]. The stress thus obtained at different ion fluencesfor 120 MeV Au ions is shown in Fig. 2. The magnitude of σ with negative sign indicating the stress is compressive in nature. Increasing ion fluence causes an exponential increase of the magnitude of the stress for both the ions. We estimated diameter of the stressed region around the ion path by fitting the variation of stress with ion fluence($\sigma(\Phi)$) to the following relation [12]:

$$\sigma(\Phi) = \sigma_0 + Ce^{-A\Phi} \tag{2}$$

where Φ is the irradiation fluence, A is the cross sectional area of the stressed region around ion path and, σ_0 and C are constants. The diameter of the stressed region was estimated by fitting data points of the stress vs ion fluence to Eq. (2) for both Au ion cases. The average diameter found for 120 MeV Au ion irradiation case is 12.1 nm. The same value for 200 MeV Au ion case is 11.6 nm [6].

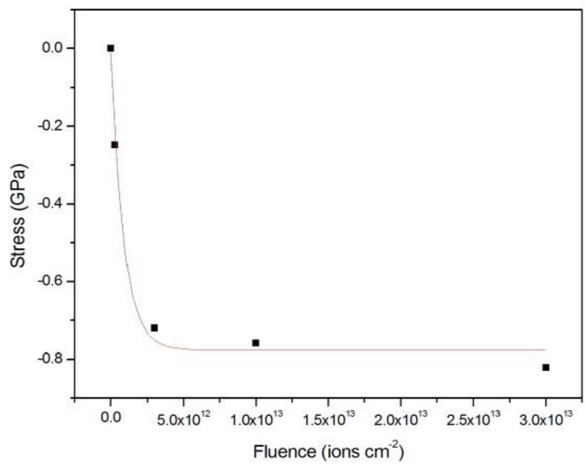

Fig. 2: Variation of stress with ion fluence is shown with solid squares. The line represents fit to the experimental data following Eq. (2).

Since the value of S_e for both the energies of Au ion is higher that the threshold value (S_{eth}) for track formation, it is therefore expected that these ions will create tracks along the ion path which is surrounded by the stressed region. The observations of nearly equal stressed region around the ion path for both energies of Au ion indicate that the value of $S_e$much higher than S_{eth}does not have much impact on stress profile of NiO matrix.

4. Conclusion

Effect 120 MeV and 200 MeV Au ions on the stress profile of NiO thin film grown by e-beam evaporation technique on Si (100) substrates and sintered at 700 ^{0}C is reported. Both the Au ions irradiation led to compressive stress generation in NiO medium with nearly equal stressed region. The present study thus indicates that the ions having $S_e$value much higher than S_{eth} does not have much impact on stress profile of NiO matrix.

Acknowledgements: Author thanks to Prof. N.C. Mishra, Utkal University for encouragement and Pelletron group of IUAC, New Delhi for providing good quality scanned beam for irradiation.

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