SPECTROSCOPIC CORRELATIONS TO RESISTIVE SWITCHING OF ION BEAM IRRADIATED FILMS

K.N. Rathod†, P.S. Solanki, N.A. Shah, Department of Physics, Saurashtra University, India
J.P. Singh, Pohang Accelerator Laboratory, Pohang University of Science and Technology, South Korea
K.H. Chae, Advanced Analysis Center, Korea Institute of Science and Technology, Republic of Korea
K. Asokan, Inter University Accelerator Centre, India
†rkunalsinh@gmail.com

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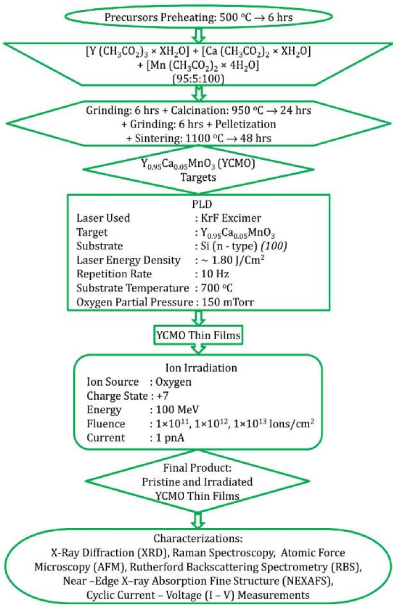
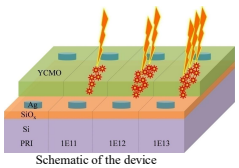
ABSTRACT

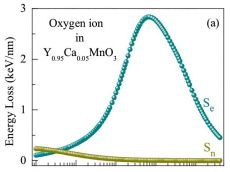
Researchers concentrated on resistive random access memories (RRAMs) due to excellent scalability, high integration density, quick switching, etc [1, 2]. Intrinsic physical phenomenon of RRAMs is resistive switching. In this work, ion beam irradiation was used as a tool to modify resistive switching of pulsed laser deposited (PLD) $Y_{0.95}Ca_{0.05}MnO_3$/Si films. Ion irradiation induced optimal resistive switching with spectroscopic correlations has been attributed to oxygen vacancy gradient. Resistive switching ratio is estimated to be increased for the film irradiated with fluence 1×10^{11} ions/cm^2 due to irradiation induced strain and oxygen vacancies verified by X–ray diffraction (XRD), Raman, atomic force microscopy (AFM), Rutherford backscattering spectrometry (RBS) and near–edge X–ray absorption fine structure (NEXAFS) measurements. Strain relaxation and oxygen vacancy annihilation have been realized for higher fluence (1×10^{12} and 1×10^{13} ions/cm^2) owing to local annealing effect. Present study suggests that the films understudy can be considered as emerging candidates for RRAMs.

EXPERIMENTAL & SIMULATION

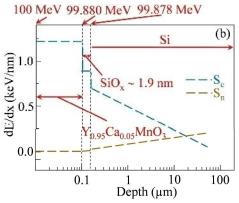




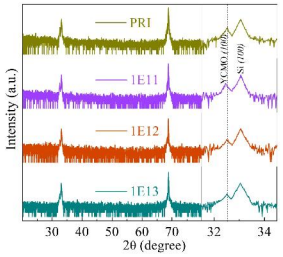
Schematic of the device



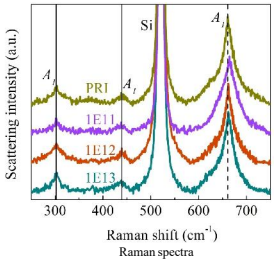
Ion energy and depth simulations



PHASE & STRAIN



X–ray diffraction patterns



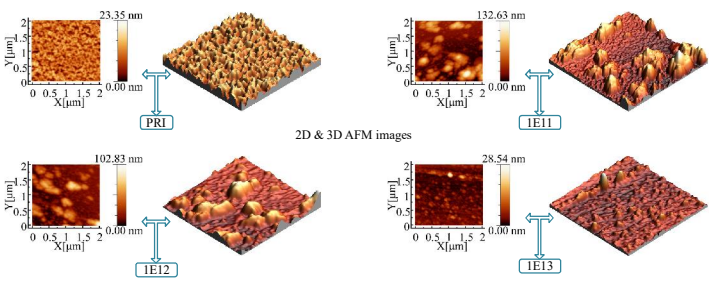
Raman spectra

- Hexagonal structure, films oriented in (*h00*) with Si substrate
- Peak separation indicates strain, compressive in nature
- Peak intensity (~ 32.5°) reduced with irradiation due to structural deformation
- A_1 Raman mode (~ 660 cm^{-1}) indicates O1 and O2 displacements
- Phonon hardening for 1E11 and softening for higher fluence of irradiation

Strain, RMS, Raman parameters

Sr. No.	Thin Film	Strain (%)	Intense mode (A_1) position (cm^{-1})	RMS roughness (nm)
1	PRI	−1.55	660.7	3.04
2	1E11	−1.80	662.5	22.18
3	1E12	−1.68	662.1	15.10
4	1E13	−1.62	661.1	2.30

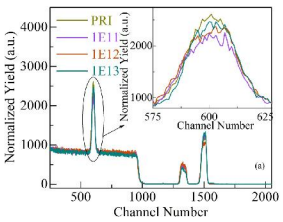
SURFACE



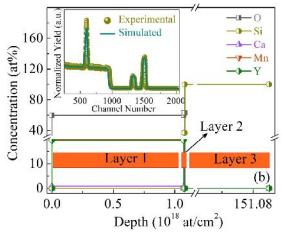
2D & 3D AFM images

- Maximum defect found in 1E11 film
- Reduced surface roughness for higher fluence attributed to filling of pores as a result of increased local temperature

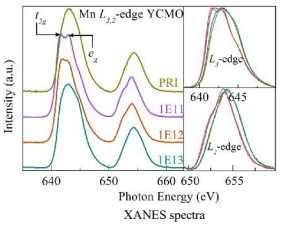
COMPOSITION & VALENCE STATE



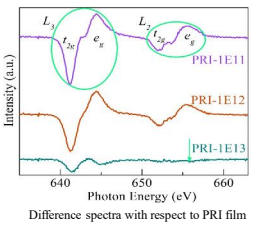
RBS spectra



Simulation and Elemental depth profile of PRI film



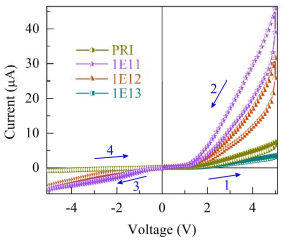
XANES spectra



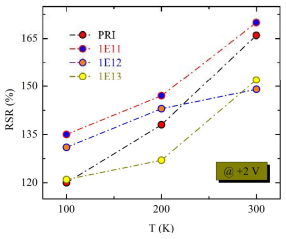
Difference spectra with respect to PRI film

- RBS spectra indicate minimum oxygen content in 1E11 film, simulation of RBS spectra used to calculate thickness of the film (~ 97.9 nm for PRI film)
- From PRI to 1E11, edge shift towards lower energy due to reduced oxidation state signifying increased oxygen vacancies

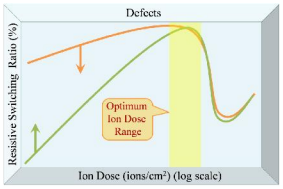
RESISTIVE SWITCHING



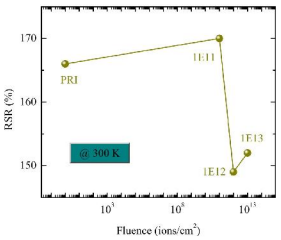
Hysteretic Current – Voltage measurements



Resistive switching ratio (RSR) with temperature



Model representation of RSR



RSR as a function of fluence

- Bipolar resistive switching observed , non-linear rectifying behavior with presence of leakage current due to oxygen vacancies
- Highest RSR at 300 K attributed to high mobile oxygen vacancies with small migration time
- Easy conduction path formed by oxygen vacancies is responsible for best RSR in 1E11 film

SUMMARY

- ✓ RSR is found to get modified by ion irradiation in all the YCMO films
- ✓ At room temperature, best RSR is observed for 1E11 film due to the presence of large number of oxygen vacancies in 1E11 film
- ✓ RSR results are correlated to spectroscopic results
- ✓ Retention performance and endurance measurements need to be studied
- ✓ Emerging candidate for RRAM device applications

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1) X.J. Zhu, J. Shang and R.W. Li, Resistive switching effects in oxide sandwiched structures, Front. Mater. Sci. 6 (2012) 183–206.
2) D.S. Jeong, R. Thomas, R.S. Katiyar, J.F. Scott, H. Kohlstedt, A. Petraru and C.S. Hwang, Emerging memories: resistive switching mechanisms and current status, Rep. Prog. Phys. 75 (2012) 076502:1–31.