EVALUATION ON STRESS AND OPTICAL PROPERTY OF THIN FILMS USED IN OPTICAL MEMS DEVICE

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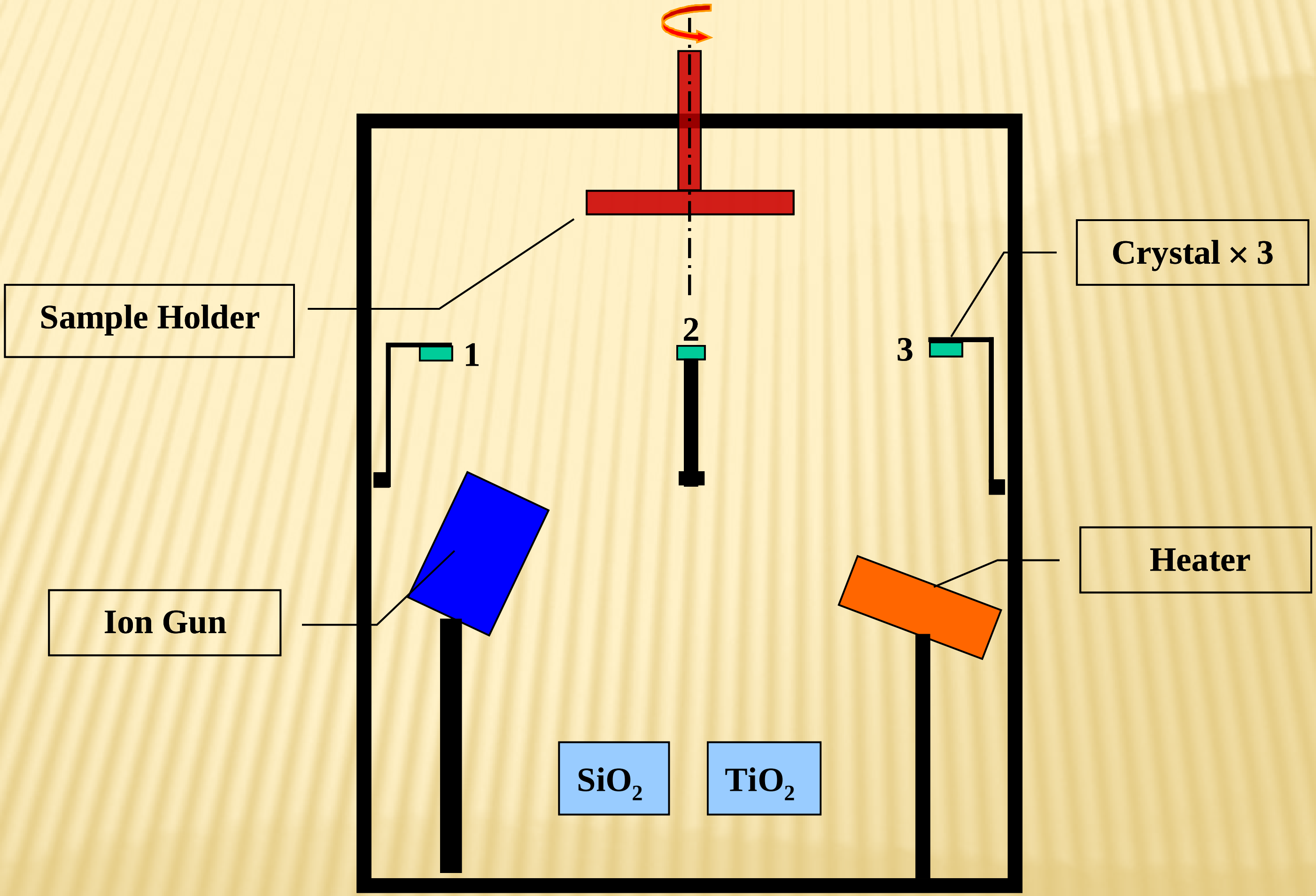
INTRODUCTION

Oxides such as Silicon dioxide, Titanium dioxide and Tantalum oxide have been widely used as interference coatings. In an optical MEMS structure, such as a tunable vertical surface emission laser, the wavelength is tuned through changing the cavity length between the top and bottom mirrors, which are using TiO_2 and SiO_2 multi-stacks typically. Due to the multi-structure nature of a MEMS device, the stress of thin film layers should be carefully controlled so that they can function properly as well as to be compatible to other adjacent configurations inside the device. In addition, the reliability of a MEMS devoice strongly depends on the stability of its substructures. Therefore, the evaluation of as-deposited films becomes very crucial. In this paper, the annealing effects at 150 °C and 250 °C to the TiO_2 and SiO_2 films on the film properties will be studied. In specific, film thickness, optical properties and film stress results will be reported here.

E-BEAM CHAMBER



EXPERIMENTAL DETAILS

1. Film Deposition

Technique: Ion-Assisted E-beam evaporation

Source Material: Pre-melted Solid Block from Ti_2O_3 Tablets for TiO_2 and SiO_2 disc for SiO_2

Deposition rate: 2Å/sec for TiO_2 and 3 Å/sec for SiO_2, controlled by quartz crystal

Total chamber pressure: 2.5×10^{-4} torr

Oxygen partial pressure: $0.6\text{-}1.0 \times 10^{-4}$ torr

Initial Chamber temperature: 150oC (monitored at near sample holder)

Substrate: 2” single side polished Silicon wafer rotated at a speed of 32 rpm during deposition

Annealing was conducted in an oven with temperature control precision ± 1o under atmospheric environment

2. Film Characterization

Ellipsometry Measurement

UV-Vis-NIR Variable Angles Spectroscopic Ellipsometer

Measured wavelength range: 210nm to 2000nm

Angle of incidence used: 65, 70 and 75 Degree

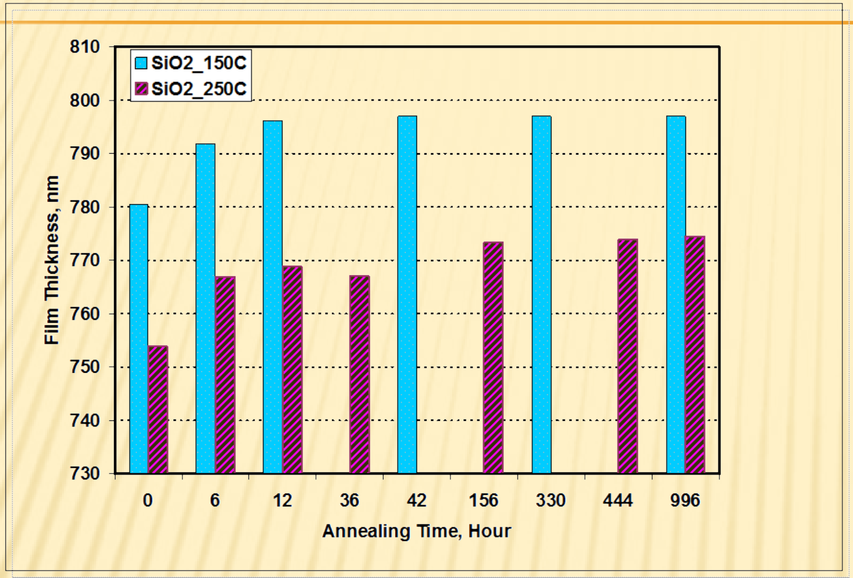
Measurement points: 120pts at each AOI

Stress

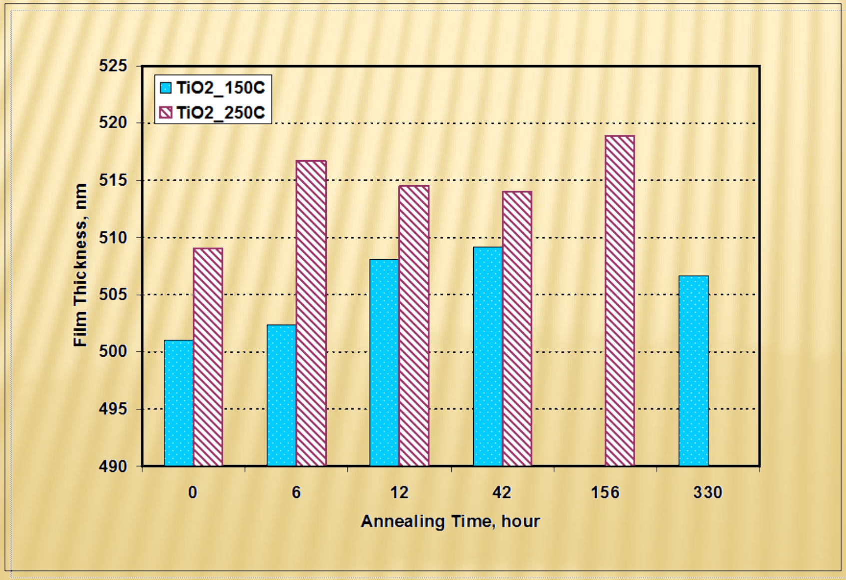
Curvature was measured with FSM 128 system and stress was calculated with Stoney’s Equation

THICKNESS CHANGES VS ANNEALING TIME

SiO_2

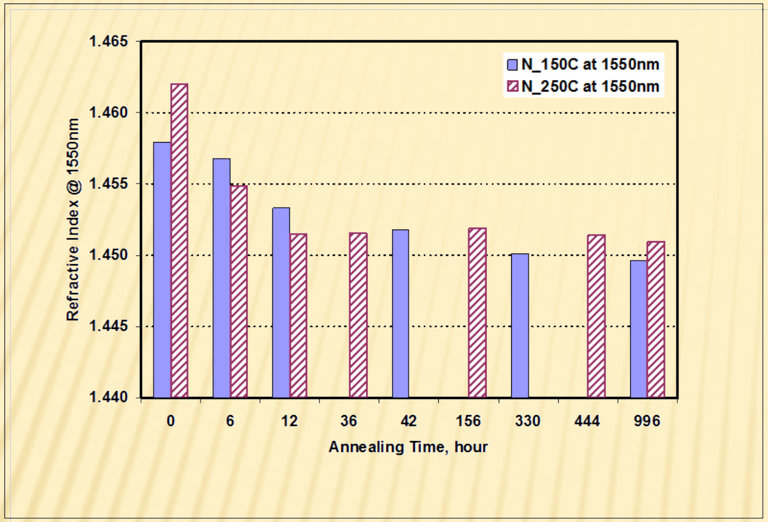


TiO2

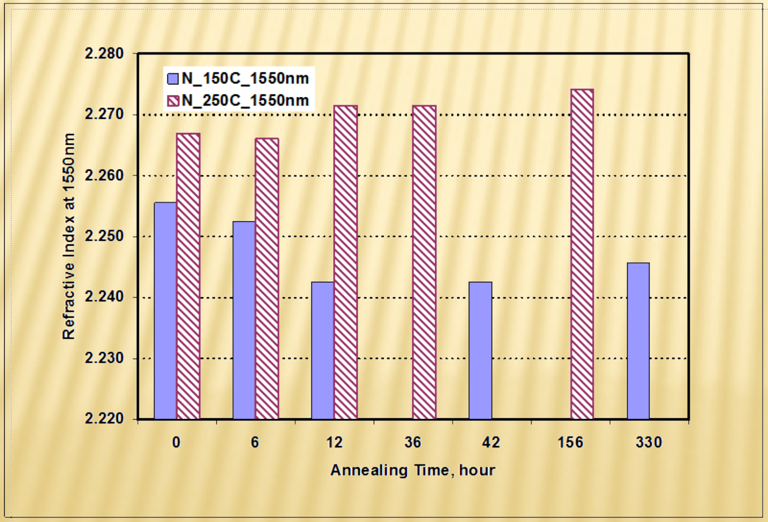


REFRACTIVE INDEX CHANGES (@1550NM) VS TIME

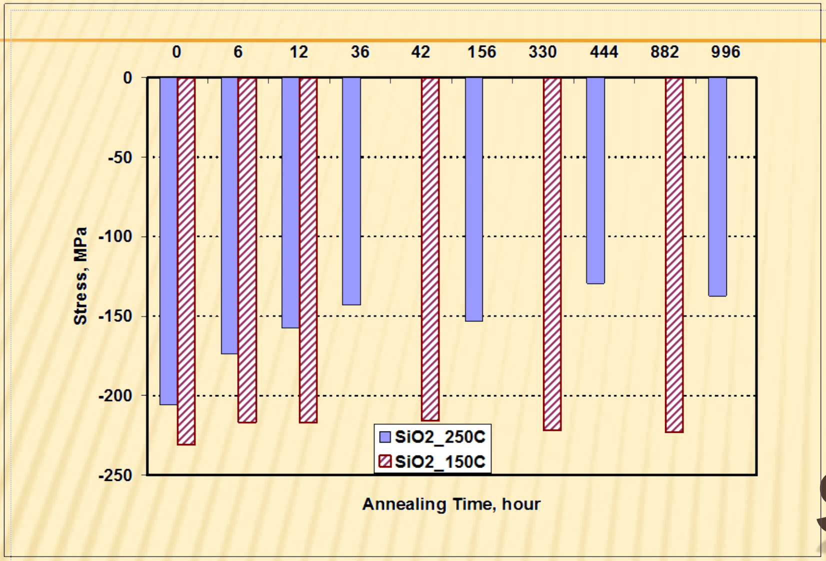
SiO_2



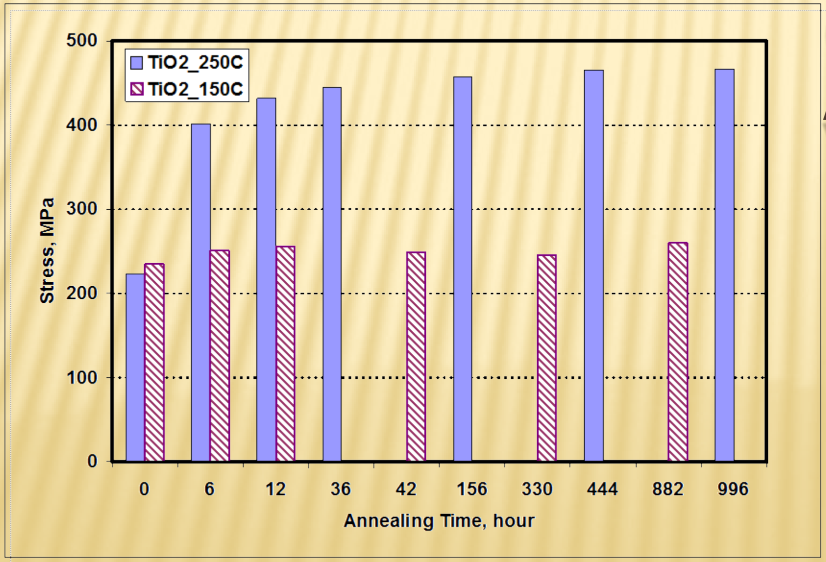
TiO2



SiO$_2$

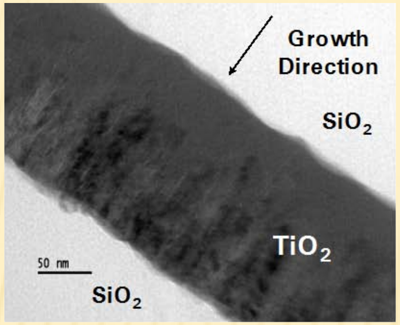


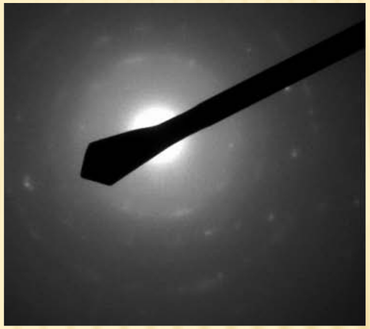
TiO2



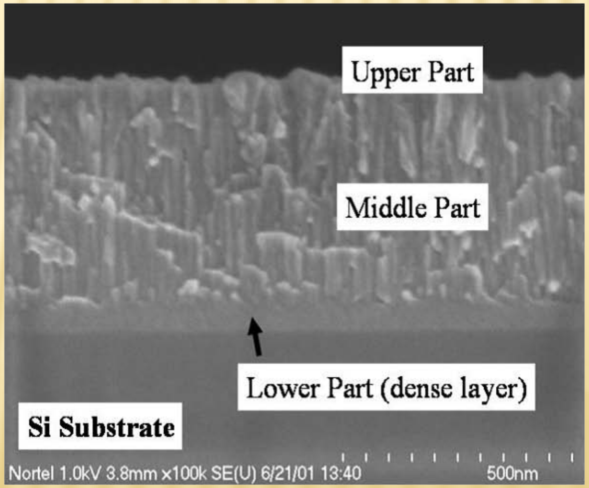
STRESS CHANGES VS ANNEALING TIME

STRUCTURE OF FILM



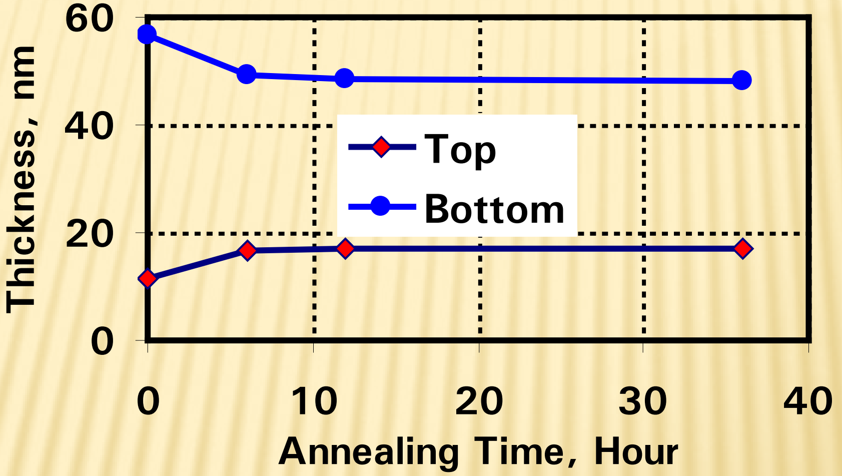


BF TEM Image shows TiO_2 sandwiched between SiO_2 in real mirror structure reveals both amorphous and crystalline features.



SEM cross section shows a typical growth structure for TiO_2 on Si substrate.

SUB LAYER ANALYSIS: EFFECT OF ANNEALING ON TiO_2 FILM



Detailed ellipsometry analysis reveals that sub layer thickness in TiO2 film changed after annealed at 250oC for different time.

SUMMARY

In this paper, the atmospheric evolution of TiO_2 and SiO_2 thin films for optical MEMS devices were studied. These films were prepared with ion-assisted e-beam evaporation. It is found that as-deposited SiO_2 films exhibit compressive stress; whereas, TiO_2 film is in tensile under present processing conditions. When annealed at 150 ^oC, both SiO_2 and TiO_2 films show little change of stress with annealing time. However, increasing the annealing temperature to 250 ^oC caused an obvious change of film stresses with time, in which SiO_2 film turns into less compressive and TiO_2 film appears to be more tensile. It is believed that the refractive index decrease for SiO_2 film is due to further oxidation. But, for the TiO_2 film, phase transformation which could cause film to densify at 250^oC may be a main reason to the increase in tensile stress after annealing. In addition, most significant changes in the film properties take place in the early stage of annealing, therefore, it could be beneficial from this finding that stability or reliability could be improved through applying such a short period annealing on the film.

FURTHER INFORMATION AVAILABLE

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