GROWTH AND CHARACTERIZATION OF ZrO_2 THIN FILMS GROWN BY UV-OZONE OXIDATION

Shriram Ramanathan

Dept. of Materials Science and Engineering, Stanford University

Pinkesh Sachdev and Krishna C. Saraswat

Dept. of Electrical Engineering, Stanford University

Carl J. Maggiore,

Ion Beam Materials Laboratory, Los Alamos National Lab

Paul C. McIntyre

Dept. of Materials Science and Engineering, Stanford University

NSF/SRC ERC for Environmentally Benign Semiconductor Manufacturing

MOTIVATION

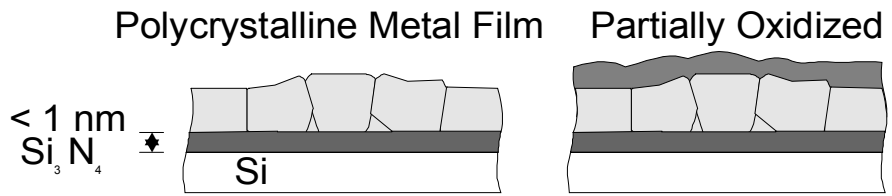
- New materials with high dielectric constant are presently being explored to replace SiO_2 as gate oxide
- Metal oxides such as ZrO_2 are considered to be key candidates to replace SiO_2
- Need to develop techniques for growing ultra thin oxide films with good structural and electrical properties
- Necessary to characterize interfaces at atomic resolution between Si and the dielectric films since they are expected to control the electrical properties

UV OZONE OXIDATION

Sequence of Reactions[1]

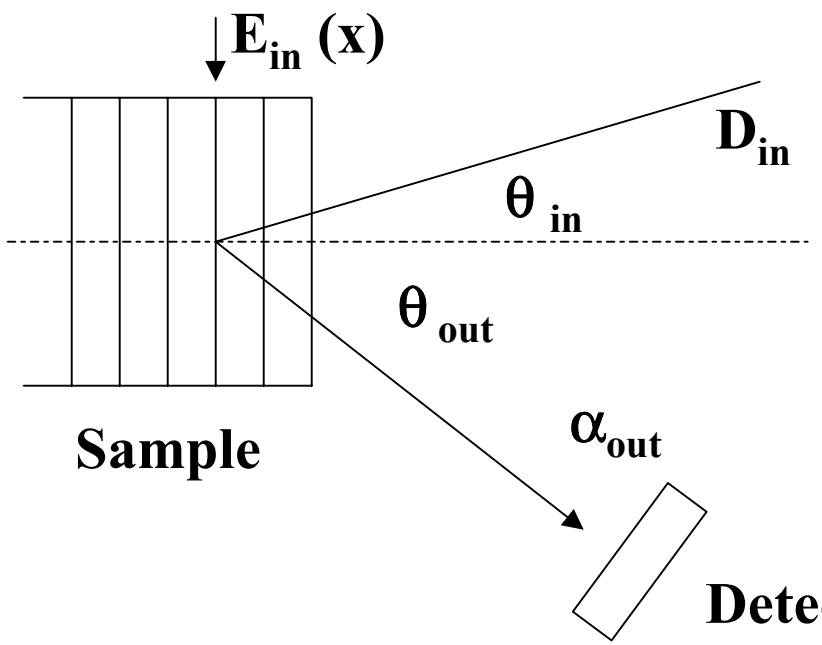
$O_2 + h\nu \rightarrow 2O$ (λ= 185 nm)
$O + O_2 \rightarrow O_3$
$O_3 + O \rightarrow 2O_2$
$O_3 + h\nu \rightarrow O_2 + O$ (λ=254 nm)

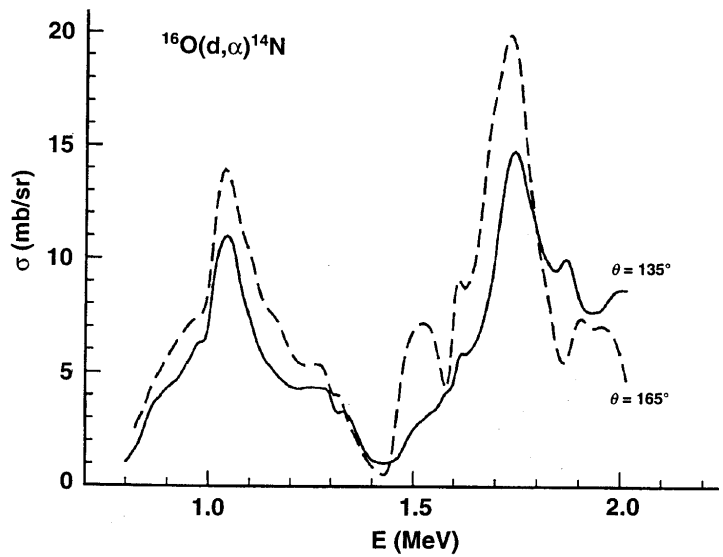
[1] H. Okabe, *Photochemistry of Small Molecules*



NUCLEAR REACTION ANALYSIS

- Use ^{16}O (d,α) ^{14}N nuclear reaction to investigate oxygen concentration in the sample
- Highly sensitive to oxygen, can calculate oxide thickness with high accuracy[1]



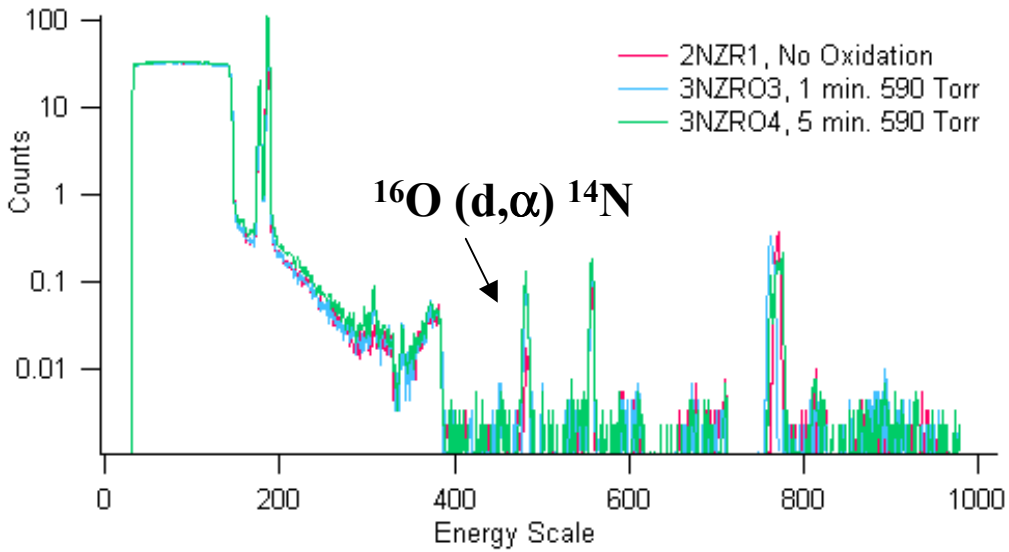


1. Turos *et al., NRIM B*, **111** (1973), 605

EXPERIMENTS

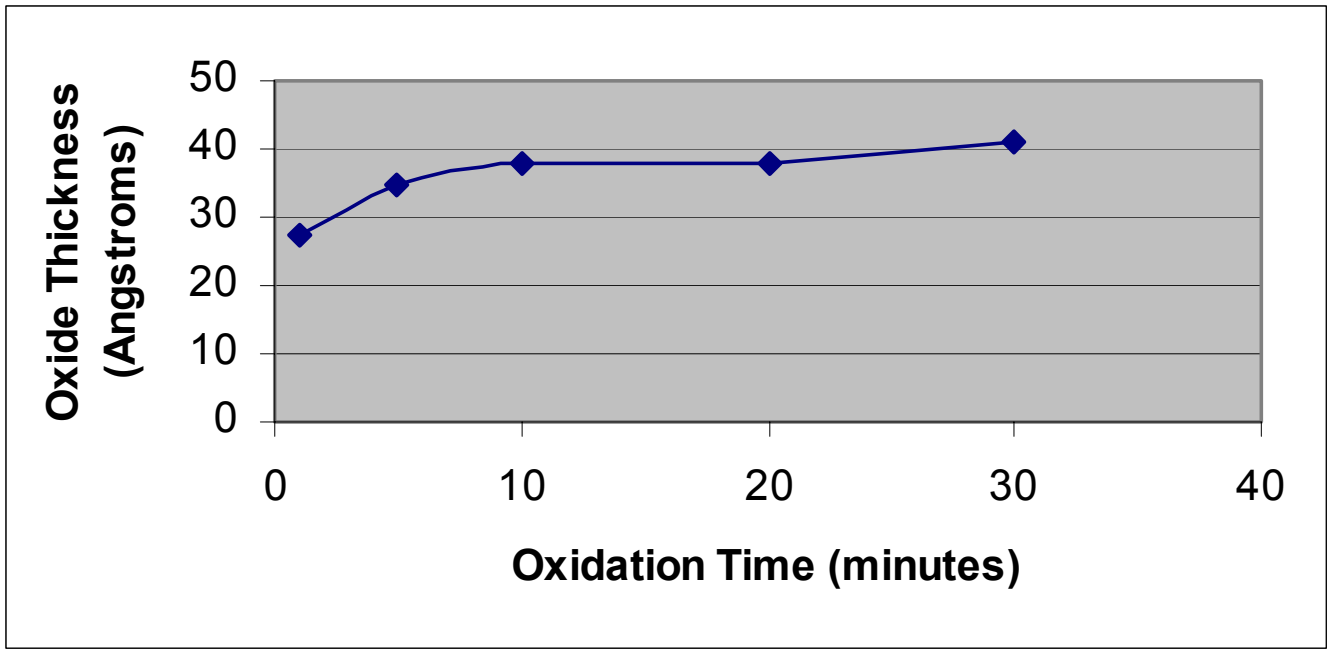
- Deposit ultra thin Si_3N_4 on Si(100) wafer by rapid thermal nitridation
- Deposit Zr film by sputtering in an ultra high vacuum chamber and oxidize *in-situ* (at 300 K) by UV-Ozone technique
- Study oxidation kinetics of the Zr film using an accelerator based Ion Beam Analysis

OXIDE THICKNESS CALCULATION



- Using a sapphire standard calibrate the spectrum
- Calculate the oxygen concentration in *at/cm*^{2} from the oxygen peak integrated area
- Calculate the oxide thickness from known density value of ZrO_2

Zr OXIDATION KINETICS



- Oxidation process appears to be self-limiting at high oxygen pressure

FUTURE WORK

- Perform electrical characterization (e.g. C-V and I-V) of the oxide - nitride stack
- Investigate effect of oxygen pressure on the oxidation kinetics of Zr to understand the mechanism of oxidation
- Investigate the structural and chemical nature of the nitride - oxide interfaces by High Resolution Electron Microscopy, Analytical Electron Microscopy, and XPS