GROWTH AND CHARACTERIZATION OF ZrO$_2$ THIN FILMS GROWN BY UV-OZONE OXIDATION

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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
Sequence of Reactions

1. \( O_2 + h\nu \rightarrow 2O \) (\( \lambda = 185 \) nm)
2. \( O + O_2 \rightarrow O_3 \)
3. \( O_3 + O \rightarrow 2O_2 \)
4. \( O_3 + h\nu \rightarrow O_2 + O \) (\( \lambda = 254 \) nm)

\(^1\) H. Okabe, *Photochemistry of Small Molecules*
NUCLEAR REACTION ANALYSIS

• Use $^{16}\text{O} \ (d,\alpha) \ ^{14}\text{N}$ nuclear reaction to investigate oxygen concentration in the sample

• Highly sensitive to oxygen, can calculate oxide thickness with high accuracy$^1$

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

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EXPERIMENTS

- Deposit ultra thin Si$_3$N$_4$ 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