

Measurements of Ti-Containing Barrier Materials and Low-K Dielectric Films Using Backside Polishing SIMS

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INTRODUCTION

- During SIMS analysis, titanium is typically monitored as a positive secondary ion because its positive ion yield with oxygen bombardment is significantly higher than its negative ion yield with Cs bombardment.
- However, for low-K dielectric materials, the high-energy (9keV) electrons used for charge neutralization can damage low-K materials during SIMS measurements when positive secondary species are monitored, using a Cameca IMS 4f instrument. [1]
- In the present work, the electron energy was lowered to ~10 eV by switching the secondary ion monitored from positive to negative so that the damage to the low-K material was greatly reduced.
- The Ti distribution was analyzed using a Cs primary ion beam and Ti-containing negative ions were monitored as secondary ions to improve the ion yield.
- In addition, advanced backside sample polishing was employed to reduce the ion mixing effect that occurs when samples are profiled from the front side from a layer of high concentration to low concentration. The results for various samples under different analytical conditions and preparation methods are presented.

SAMPLE PREPARATION

- One micron thick dielectric films with a CVD TiN barrier on top were used for this study. TEOS oxide was deposited by PECVD, while the porous dielectric was deposited using a PECVD method followed by a cure process.
- A 5 nm TiN barrier was deposited over the different dielectric substrates by CVD.
- The samples were then diced to small pieces suitable for SIMS analyses. Some of the small pieces were bonded to a silicon chip using low temperature epoxy and were polished from the backside. The remaining silicon thickness was approximately 1µm.
- Samples used for the front side SIMS were coated with a thin Au layer to reduce charging effects during SIMS analyses.

RESULTS & DISCUSSION

SIMS Craters Obtained in Low-K Materials While Exposed to 9keV and 10eV Electron Bombardments

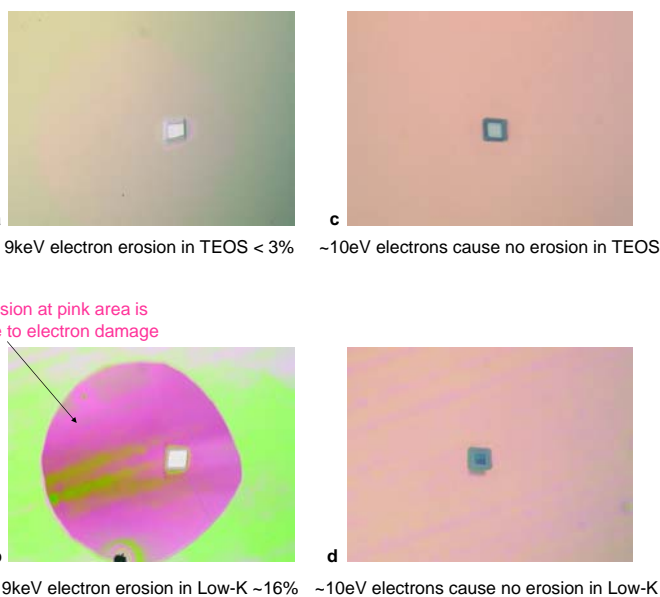


Fig. 1 Images of 125µm x 125µm, 1µm deep SIMS craters: (a), (b) 3keV O₂ primary beam and positive secondary; (c), (d) 14.5keV Cs primary beam and negative secondary.

RESULTS & DISCUSSION

Ti Quantification in Low-K is Approximated Using SiO₂ Implant Standards

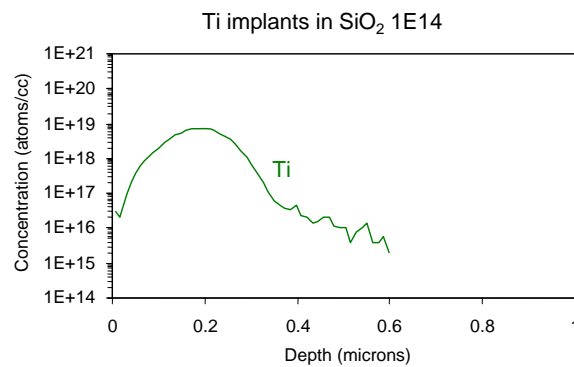


Fig. 2 Ti implant depth profile in SiO₂ acquired using 14.5keV Cs with negative secondary species.

Front Side SIMS Example: Porous Low-K Poor depth Resolution is Present Due to Ion-Mixing Effects

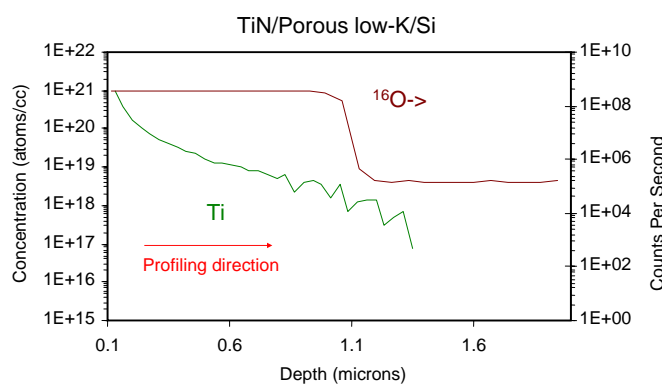


Fig.3 Ti profile acquired using Cs beam on a TiN/low-K/Si sample shows a slow decay tail due to ion-mixing effects, which prevents accurate measurements of the actual Ti distribution.

Backside SIMS

Fig. 4-6 Backside SIMS profiling allows the measurements from low Ti concentration to high Ti concentration with greatly reduced ion-mixing effects. The rapid rise in the leading edge in Ti profile provides excellent depth resolution for the measurements of Ti diffusion. Examples of Backside SIMS profiles acquired from various samples are shown.

Backside SIMS Example 1: Fully Dense Oxide

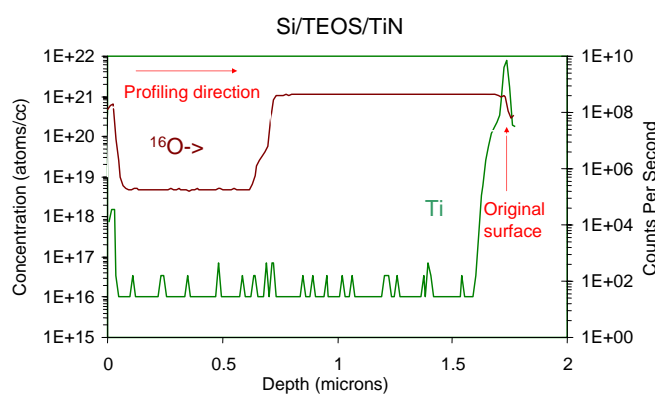


Fig. 4

RESULTS & DISCUSSION

Backside SIMS Example 2: Dense Low-K

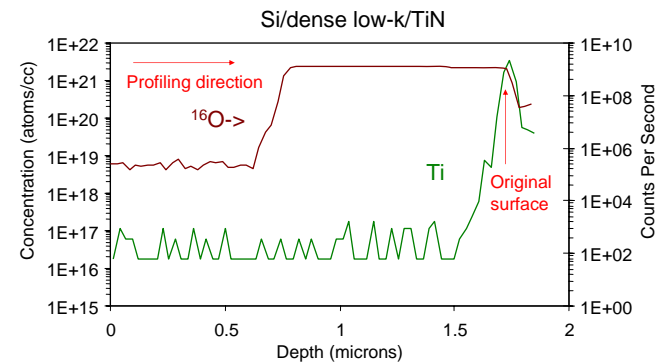


Fig. 5

Backside SIMS Example 3: Porous Low-K

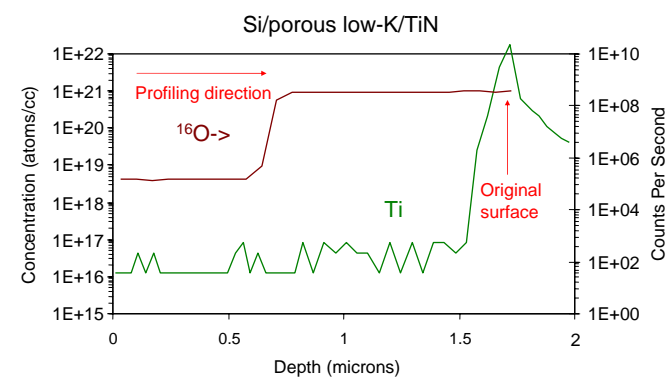


Fig. 6

Detection Limits (atoms/cm³)* for Selected Metals in Low-K Materials

Al	1E15-1E16
Ti	1E15-1E16
Fe	1E15-1E16
Cu	1E15-1E16

* Detection limits for metals are 1-2 orders of magnitude lower when positive secondary ions are monitored. However, e-gun damage is often present as shown in Fig. 1.

SUMMARY

- In this paper we have shown metal impurities can be measured in low-K materials using a Cs⁺ primary beam with negative secondaries on a Cameca 4f instrument.
- Metal impurities can be detected with reasonably good detection limits.
- Using Backside SIMS, profiling layer by layer from low to high concentration, Ti diffusion can also be measured in low-K with excellent depth resolution when TiN is used as a diffusion barrier.
- This method can be applied to different types of metal impurity measurements in either low-K or high-K materials.

References

[1] I.A. Mowat, X. Lin, T. Fister, M. Kendall, K. Chao, J. Lan, M.H. Yang, Oral Presentation, SIMS XV (2005)