Selective Etchant to Remove Metal Gate Electrodes and Protect High-k Dielectrics

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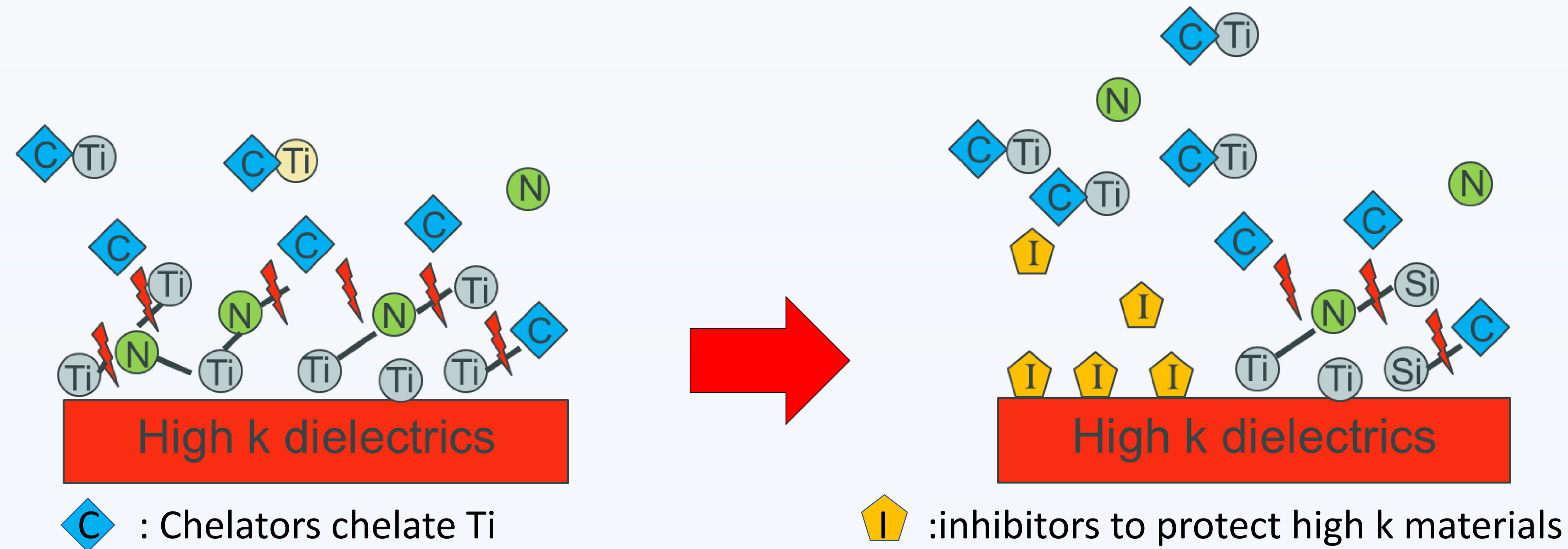
Introduction

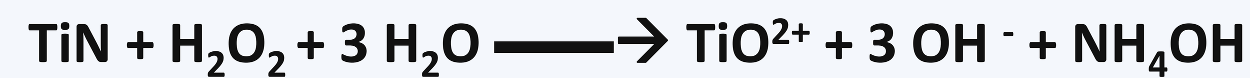
High-k metal gate (HKMG) technology has enabled improved device performance in next-generation CMOS devices, by reducing gate leakage and threshold voltages. As the critical dimension of transistor is scaling down to 7nm and below, multiple WFMs (Work Function Metals) are used to tune threshold voltages with no channel doping in a replacement metal gate (RMG) integration scheme. In order to form different NMOS WFM and PMOS WFM stacks, it is necessary to deposit, pattern and etch one WFM followed by deposition of another WFM. One such process step involves the removal of TiN WFM with good compatibility to high-k dielectrics such as lanthanum oxide, zirconium dioxide, hafnium oxide, hafnium silicon oxynitride, and aluminum oxide. The objective of this study is to develop a formulation with high TiN to high-k dielectric selectivity.

Results and Discussion

Hydrogen Peroxide and Chelators to remove TiN

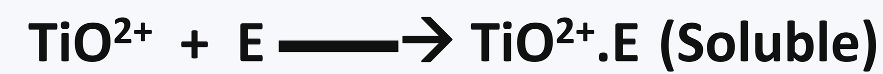


- H_2O_2 oxidize TiN to TiO^{2+},and the TiN etch rate increases with increasing H_2O_2



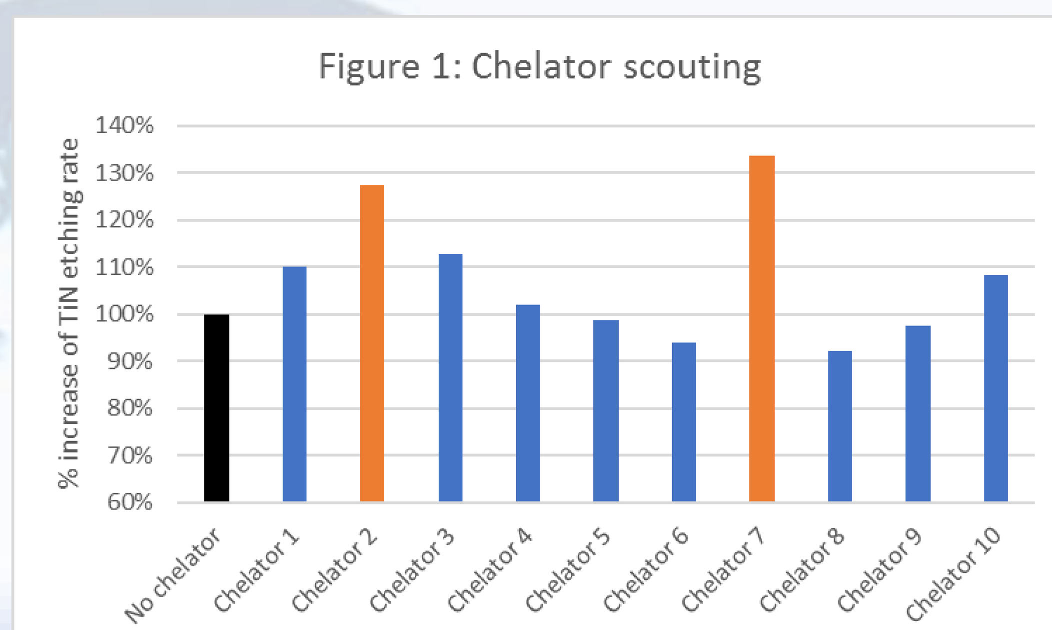
$$TiN + H_2O_2 + 3\,H_2O \longrightarrow TiO^{2+} + 3\,OH^- + NH_4OH$$

- TiN etch Enhancer to accelerate TiN etch by forming complex with TiO^{2+}



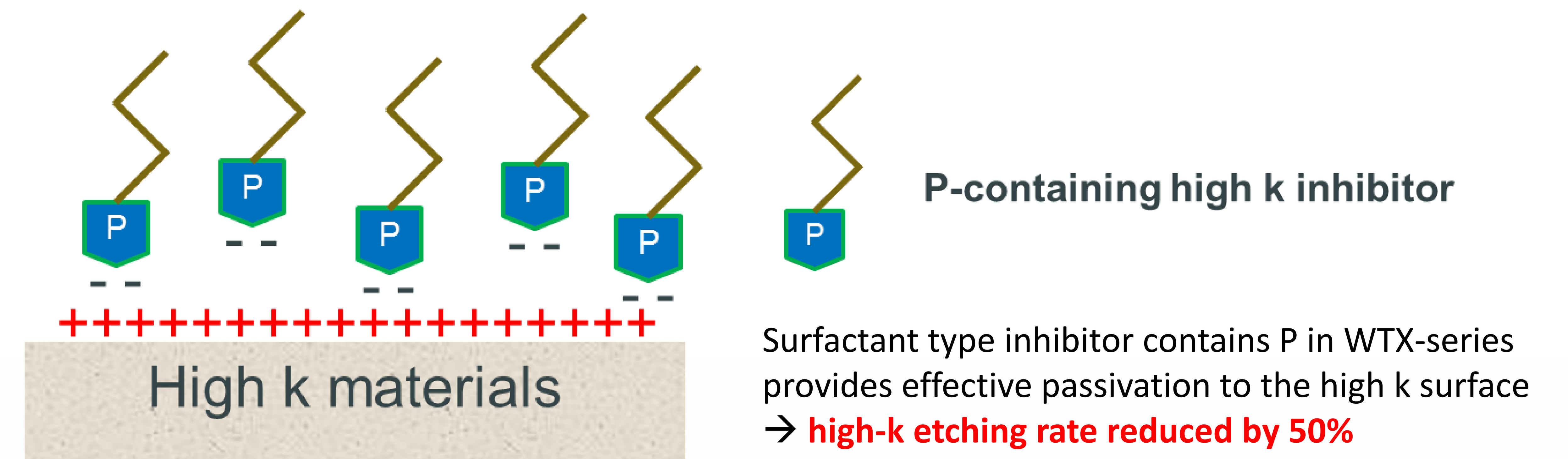
$$TiO^{2+} + E \longrightarrow TiO^{2+}.E \text{ (Soluble)}$$

[1] Mat. Res.Soc.Symp.Proc.Vol. 477, 1997



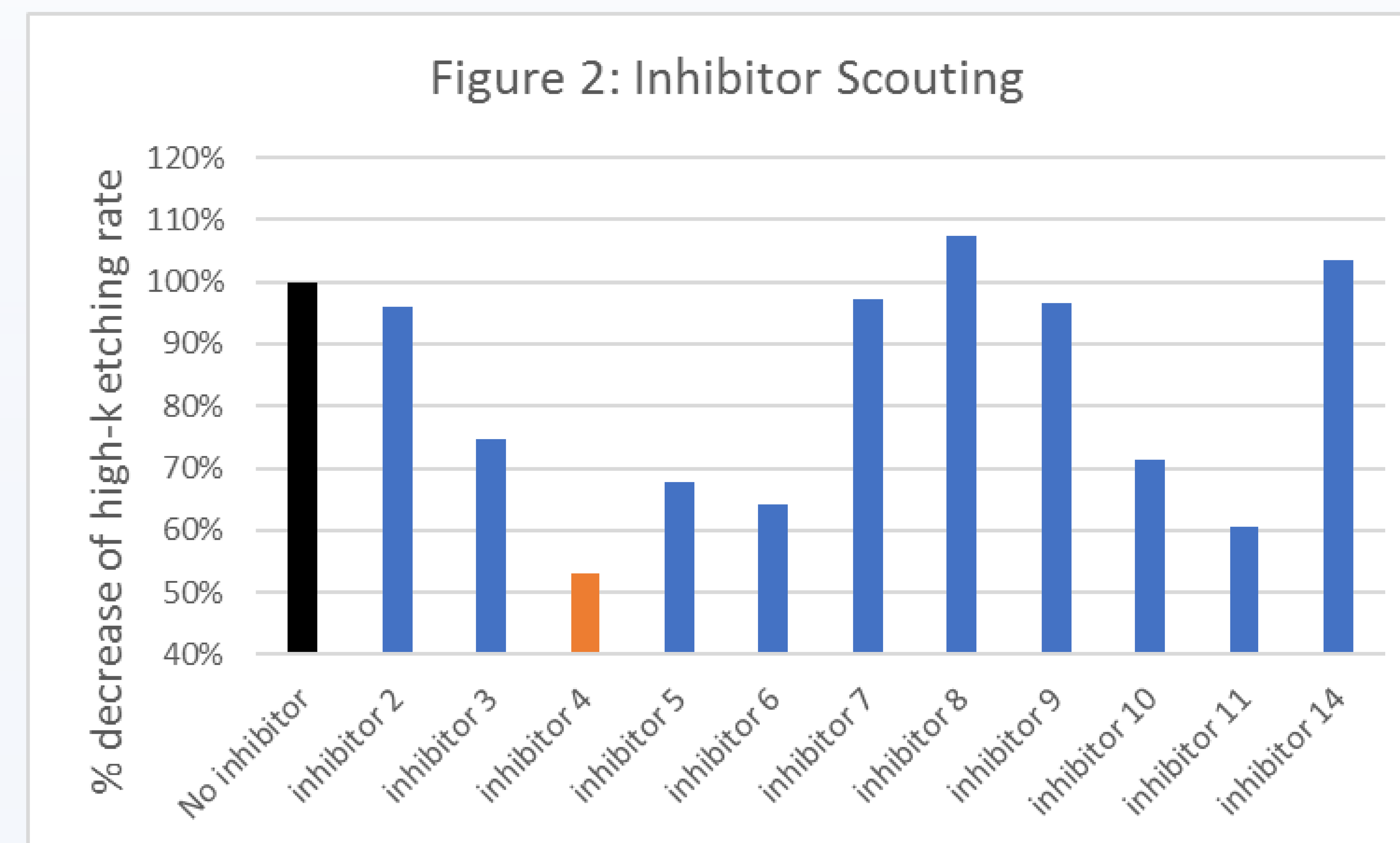
- Chelator 2 and chelator 7 show significant increase of TiN removal rate.

Effective Inhibitor to passivate high-k materials



Surfactant type inhibitor contains P in WTX-series provides effective passivation to the high k surface
→ **high-k etching rate reduced by 50%**

Inhibitor Scouting



- Couple of inhibitors show effective protection for high-k materials.
- Inhibitor 4 shows outstanding performance regarding to lowering the high-k etching rate.

Conclusions

In this study, we report series of novel selective etchant to remove metal gate electrodes and compatible to high-k insulators. Our formulation can achieve high selectivity (metal gate etching rate/high-k etching rate > 10) to remove gate electrodes. Effective chelators and inhibitors were found to achieve the selectivity between the metal electrode materials and high-k dielectrics.

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