Atomic layer deposition of HfO_2 for gate dielectrics

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Background

SiO_2 gate dielectric film is more thin

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- Increase in leakage current by tunnel effect
- Reliability degradation of gate dielectrics

High dielectric constant insulator (HfO_2, ZrO_2, etc.)
is promising for a gate dielectric film

Purpose

We will investigate possibility of atomic layer deposition (ALD)
of HfO_2 for future gate dielectrics

- Merit of ALD
  - Excellent control of film thickness
  - Low thermal budget
  - Flat film surface

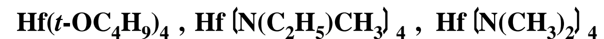
Source gases

Alternate supply of $Hf(HFAcAc)_4$ and H_2O

$Hf(HFAcAc)_4$ [Central Glass Company] — Tetrakis(hexafluoroacetylacetone hafnium

Feature
- High vapor pressure
- Small amount of impurities (Na, Mg, Al, K, Ca)
- No reports of ALD using the source gas

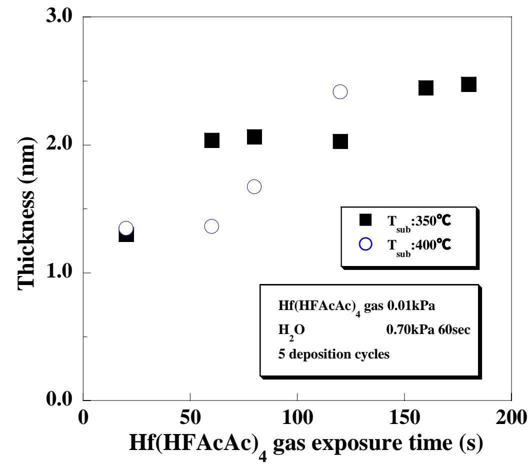
Example of Hf source gas used in other reports



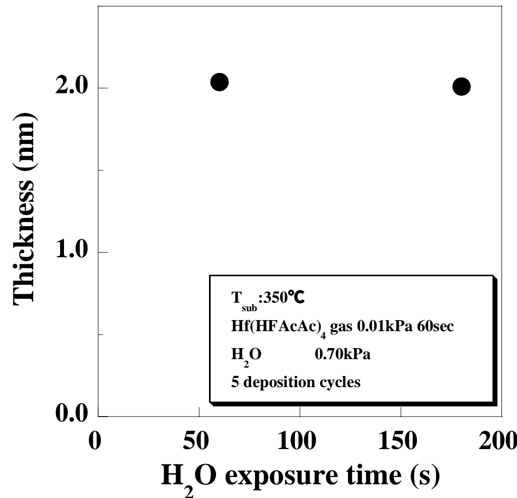
Experiments

- *p*-type Si (100) substrate treated with 0.5% HF
- Alternate supply of source gases
  one cycle (substrate temperature : 200 ~500 ℃)
  - $Hf(HFAcAc)_4$ exposure (0.01kPa)
  - Vacuum pumping
  - H_2O exposure (0.70kPa)
  - Vacuum pumping
- Thickness measurement by ellipsometry

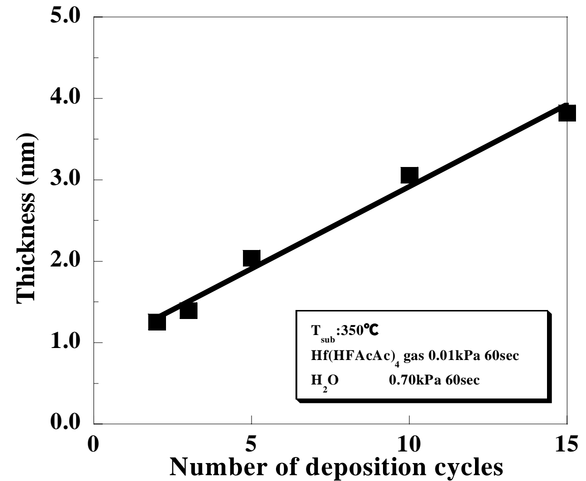
Dependence of deposited film thickness on $Hf(HFAcAc)_4$ gas exposure time



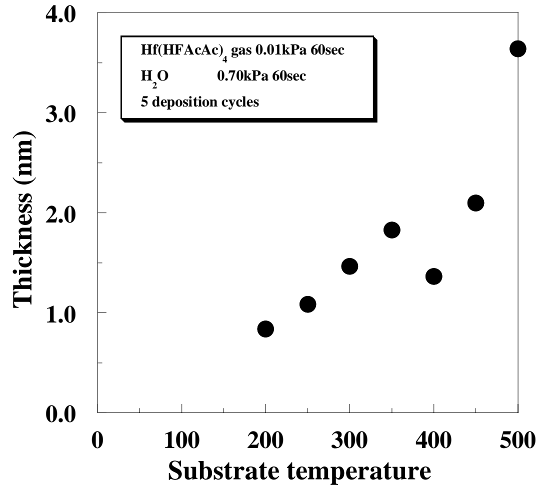
Dependence of deposited film thickness on H_2O gas exposure time



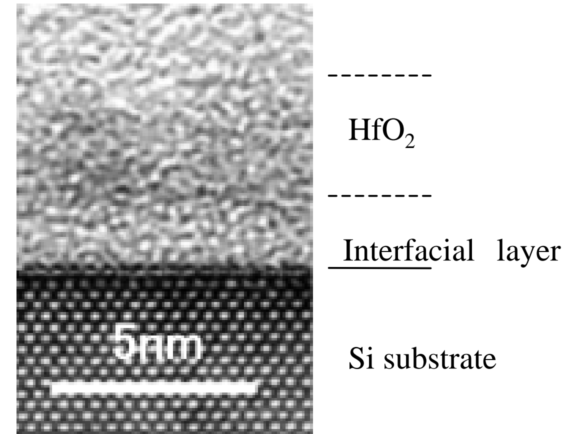
Dependence of film thickness on number of deposition cycles



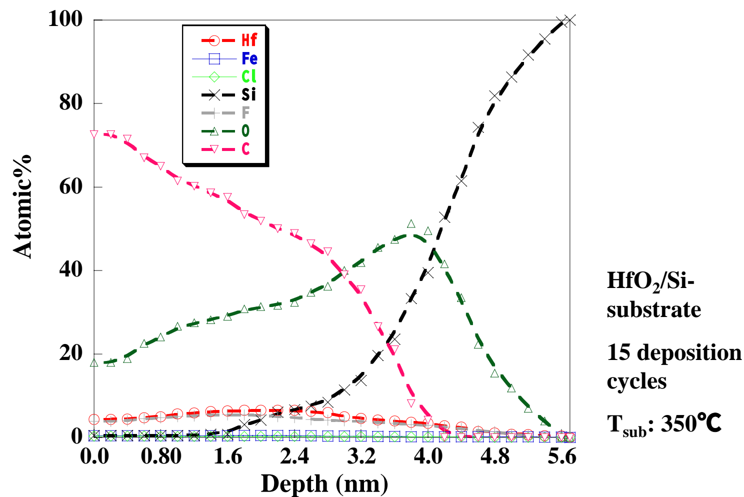
Dependence of deposited film thickness on substrate temperature



TEM micrograph of HfO_2



Composition of HfO_2 measured by Rutherhord back scattering (RBS) spectra



Summary

- Possibility of HfO_2 ALD for future gate dielectrics has been examined using $Hf(HFAcAc)_4$ and H_2O sources gases
- Self-limiting properties of film growth with $Hf(HFAcAc)_4$ and H_2O exposure time were achieved at the growth temperature of 350℃
- Carbon and fluorine atoms are observed by RBS throughout the deposited film