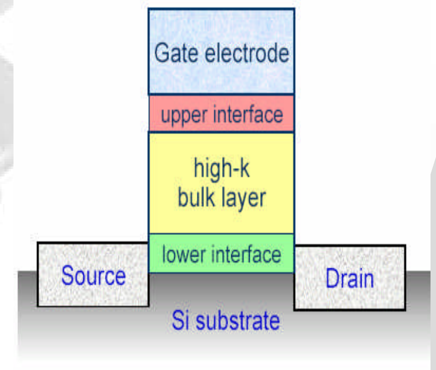
GES5

Precise Characterization of High K Ultrathin Gate Dielectrics Stacks

- New dielectrics with higher dielectric constant, referred to as "high-k materials", are replacing the silicon oxide as gate dielectric in the electronic devices. Several candidate materials and deposition processes are currently under investigation. Both for the development of these processes and for future process control, the optimization of the physical analysis procedures for these materials is necessary.

The important physical parameters that need to be characterized are:

- •the layer thickness,
- •the thickness and nature of the interfacial layer between the high-k material and the silicon
- •the interface and surface roughness
- •the material density,
- •the composition and presence of possible contaminants,
- •the crystallinity,
- •the band gap.



	2004	2007	2010	2013	2016	2019
	2003, 2005 2006	2008 2009	2011 2012	2014 2015	2017 2018	
Technology Node	hp90	hp65	hp45	hp32	hp22	hp16
GATE DIELECTRIC						
Oxynitride						
Hf (Zr)-based high-κ N, Al, Si additions						
Group III (or RE) high-κ La_2O_3, Y_2O_3, …and silicates						
Ternary oxides $LaAlO_3$						
Epitaxial dielectrics $LaAlO_3$						
INTERFACE LAYER FOR GATE DIELECTRIC						
Nitrided oxide						
No SiO_2 interfacial oxide						
GATE ELECTRODES						
Poly Si or poly Si-Ge						
Metal 1for NMOS Ta/Ru, $Ta_xSi_yN_z$						
Metal 2 for NMOS Ru, Ru/Ta, Pt, Ir, Ni						
Tools and methods for electrodes CVD, ALE, PVD; clustered with dielectric; inorganic and organic sources						

No single technique will be able to provide all these characteristics and therefore the combined effort by complementary techniques is necessary.

- GES5-GXR

Results of measurements combining DUV ellipsometry and X ray rflectometry

GXR ANALYSIS		
Sample #10	Thickness (Å)	Density (g/cm^{-3})
(σ = 1.9E-3)		
roughtness	2.6 ± 0.1	
$Hf_xAl_yO_z$	6.5 ± 0.4	2.9 ± 0.6
$Hf_xAl_yO_z$	60.6 ± 1.0	6.2 ± 0.3
Si crystal	*substrate*	

PUV ANALYSIS			
Sample #10	Thickness (Å)	Optical Index (633 nm)	Band gap (eV)
(σ = 7.1E-4)		Hf mol fraction = 47.8%	
$Hf_xAl_yO_z$	67.9 ± 0.3	n = 1.773 & k = 0.028	6.04 ± 0.02
SiO_2	11.6 ± 0.4	n = 1.457 & k = 0	
Si crystal	*substrate*		

High K

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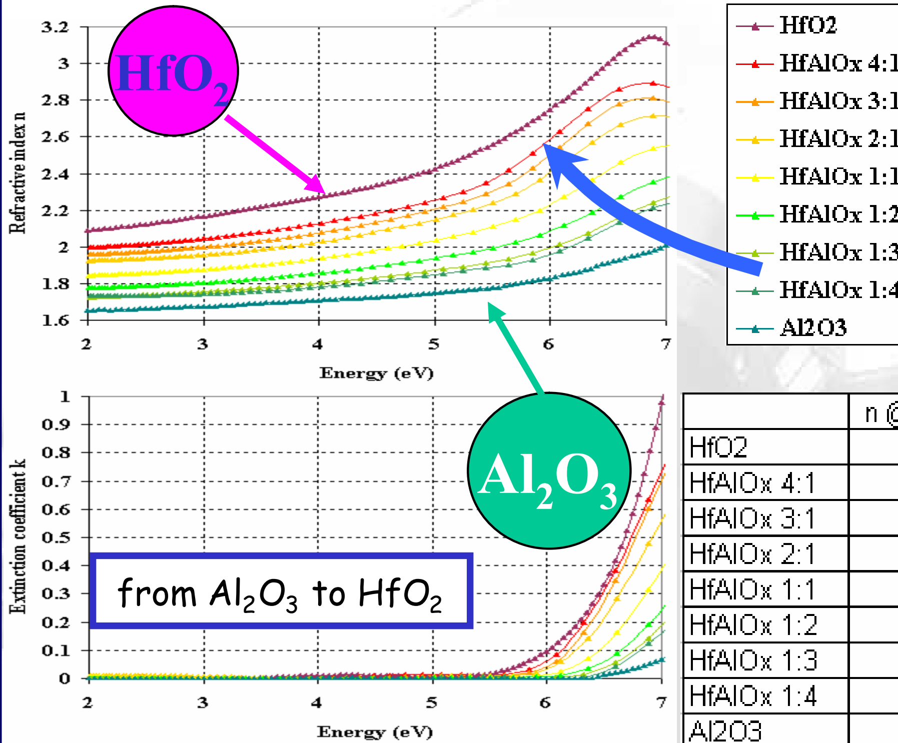
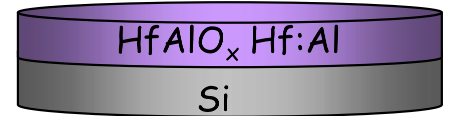
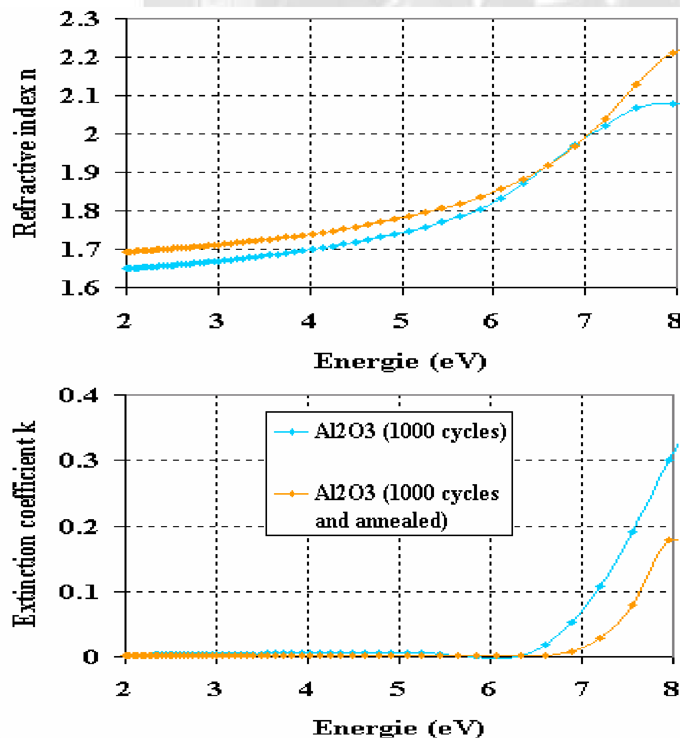
Experimental Data – HfAlOx various ratio

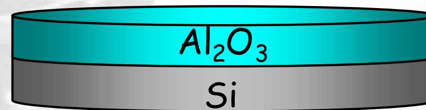




	n @ 6.5 eV	k @ 6.5 eV	XRF Hf mol. Fraction
HfO2	3.00	0.33	1.000
HfAlOx 4:1	2.82	0.32	0.864
HfAlOx 3:1	2.75	0.29	0.826
HfAlOx 2:1	2.64	0.20	0.737
HfAlOx 1:1	2.42	0.11	0.585
HfAlOx 1:2	2.23	0.06	0.406
HfAlOx 1:3	2.14	0.04	0.324
HfAlOx 1:4	2.10	0.03	0.251
Al2O3	1.92	0.01	0.000

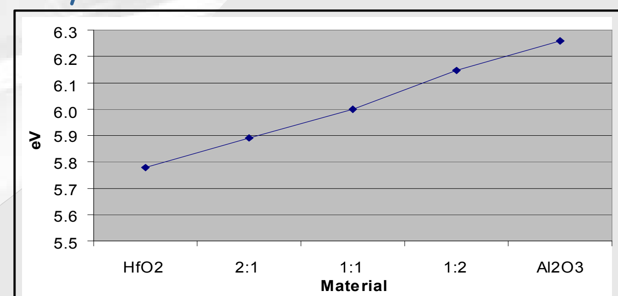
Bandgap engineering





Sample Designation	Band Gap (eV)
Al_2O_3 (1000 cycles)	**6.27 ± 0.02**
Al_2O_3 (1000 cycles) Annealed	**6.8 ± 0.2**

The position of the bandgap varies with the composition of the HfAlOx alloy:



Product GESE-GXR

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