Leti innovation for industry

HAXPES for non-destructive analysis of chemistry at buried interfaces in advanced gate stacks

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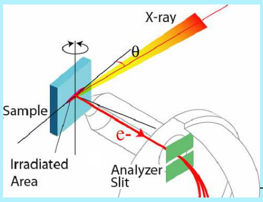
Objectives

HAXPES offers new possibilities regarding non-destructive characterization of gate stacks in technologically relevant conditions. Current developments aim at further increasing the depth sensitivity by analyzing the inelastic background (Tougaard's method).

Experimental details

HAXPES at ID32 – ESRF [1]

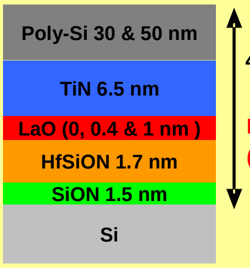


- High photon energy (2.1-25 keV)
- High energy Resolution (< 0.4 eV)
- High sampling depth (> 50 nm)
- High in-depth sensitivity (< 1 nm)
- Optimized geometry & instrumentation

HAXPES chamber at ID32

Non-destructive analysis of chemical & electronic properties of buried layers and interfaces

High-k/metal gate stack for the 32 nm node

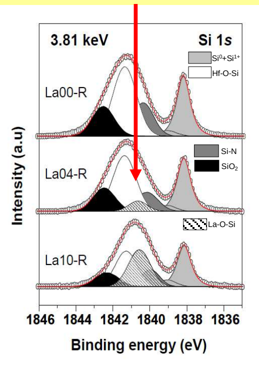


40 < t < 60 nm

Impact of spike anneal (1065°C)
- Diffusion of La ?
- Chemistry of high-k/Si interface ?

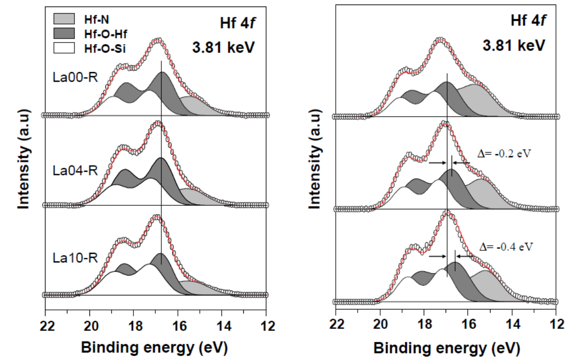
High-k/metal gate stack with TiN

After anneal: La silicate at high-k/Si interface [2]



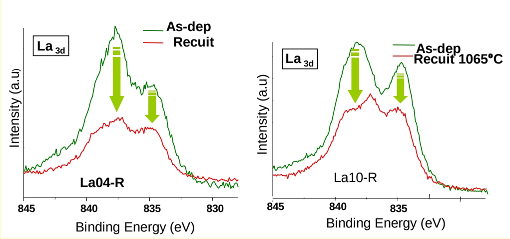
Shift of Hf 4f after anneal : interfacial dipole [3]

Before anneal   After anneal



La diffusion towards the high-k/Si interface

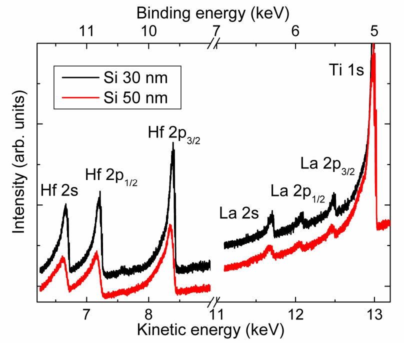
La00-R: no La
La04-R: LaO (0.4 nm)
La10-R: LaO (10 nm)

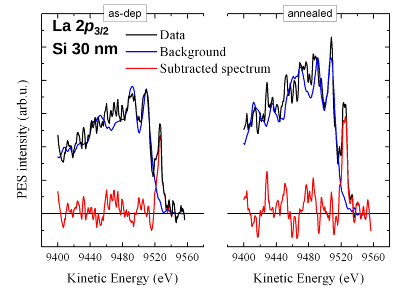


- La diffusion through the high-k
- La silicate (La-O-Si) at the high-k/Si interface
- Interfacial dipole, strength increasing with LaO thickness

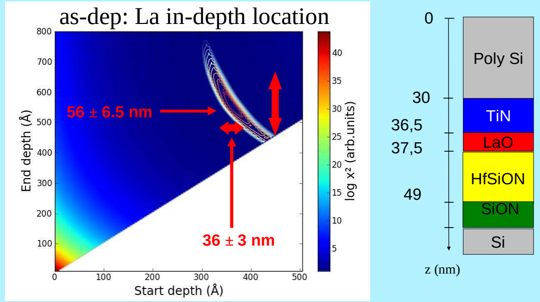
High-k/metal gate stack with TiN and poly-Si

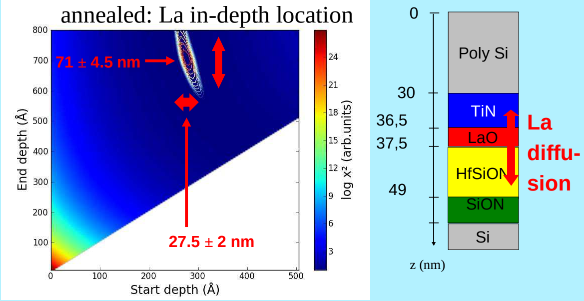
hν = 15/18 keV - high in-depth sensitivity (~60 nm)





Inelastic background modelling using Tougaard's method [4] + error calculation (weighed $\chi 2$)





Extraction of in-depth elemental profiles

Conclusions

- The capabilities of HAXPES for analysis of advanced high-k/metal gate stacks are demonstrated
  - Non-destructive analysis
  - High sampling depth (> 50 nm)
  - High in-depth sensitivity (1 nm)
  - Extraction of elemental profiles
- This paves the way to increased analysis realiability thanks to measurements without sample preparation (sputtering, chemical etching).

References

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