# Interfacial Dipole Measurement of Dielectric/Silicon Interface by X-ray Photoelectron Spectroscopy

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## Abstract

Interfacial dipole presented at the interface of dielectric/silicon has been measured by x-ray photoelectron spectroscopy. With a use of high energy x-ray source, the band bending profile of silicon can be determined. A large negative potential shift with $La_2O_3$ on silicon substrate has been observed. The obtained shift is in good agreement with electrical characterization.

## Introduction

A negative threshold voltage ($V_{th}$) control with $La_2O_3$ incorporation for high-k gate dielectric has been a widely known technology for future high-k gate stack. Electrical characterization has revealed that the main potential shift exists at high-k/$SiO_2$ or high-k/Si interface as an interfacial dipole [1]. In this report, the interfacial dipole has been measured by x-ray photoelectron spectroscopy (XPS).

## Experimental

A thin layer of $La_2O_3$ was deposited on a HF-last $p^+$- and $n^+$-Si wafers by e-beam evaporation at 300 °C, followed by Tungsten (W) gate electrode formation. Samples were subjected to annealing at 500 °C, resulting in a formation of La-silicate interfacial layer. XPS measurement was performed with synchrotron radiation source at x-ray energy of 7940 eV at BL47XU of SPring-8 [2]. During the measurement, the gate electrode was electrically connected to the substrate so that the Fermi energy of metal and silicon coincides.

## Results and Discussion

Figure 1 shows the Si 1s spectra of W/$La_2O_3$/$n^+$-Si and $p^+$-Si. Peak broadening with $p^+$-Si is attributed to large band bending in the substrate. Signal from n+-Si shows a sharp and symmetrical profile, which indicates that the substrate is at flat band condition. As the binding energy (BE) of interfacial La-silicate showed little difference in energy, a potential shift to bend down the substrate must be located at La-silicate/Si interface. The band diagram can be drawn as in fig. 2.

## Conclusion

The interfacial dipole has been measured by x-ray photoelectron spectroscopy. From the binding energy profile, a large potential shift is found to locate at high-k/Si interface.

## Acknowledgement

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## Reference

[1] K. Kakushima, et al., ECS Transactions, 13(2), pp. 29-37 (2008).
[2] K. Kobayashi, et al., Appl. Phys. Lett., 83(5), pp. 1005-1007 (2003).

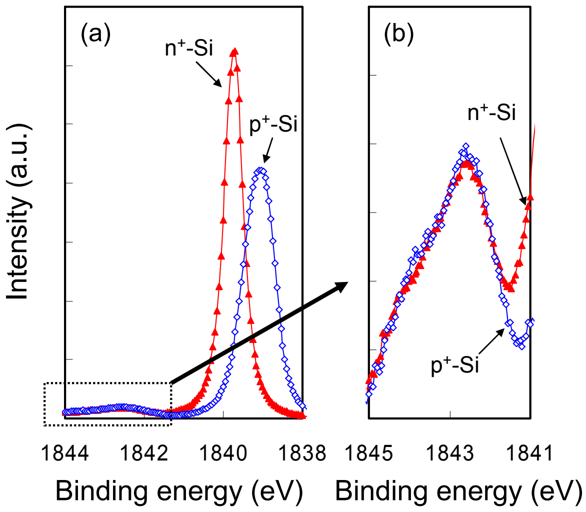

Figure 1 (a) Si *1s* spectra of W/$La_2O_3$/$n^+$- and $p^+$-Si. Peak broadening is observed with $p^+$-Si, attributed to band bending of substrate. (b) BE of La-silicate showed little energy different.

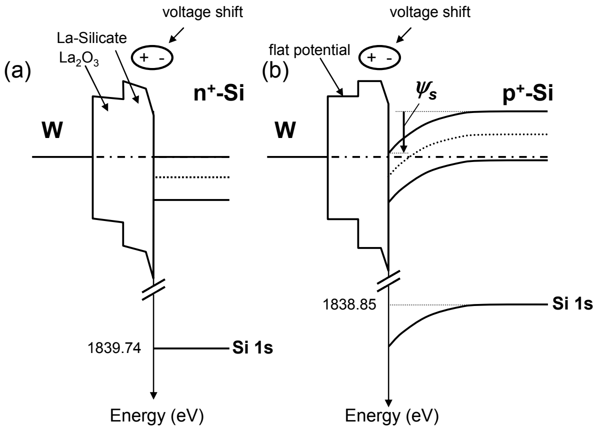

Figure2 Band diagram of (a) W/$La_2O_3$/$n^+$-Si and (b) W/$La_2O_3$/$p^+$-Si. A large voltage shift exists at high-k/substrate interface.