

In-line Plasma Damage Monitoring During He Plasma De-chuck

Effect of Helium Plasma on Low-k Damage During Dry Resist Strip

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Patent pending

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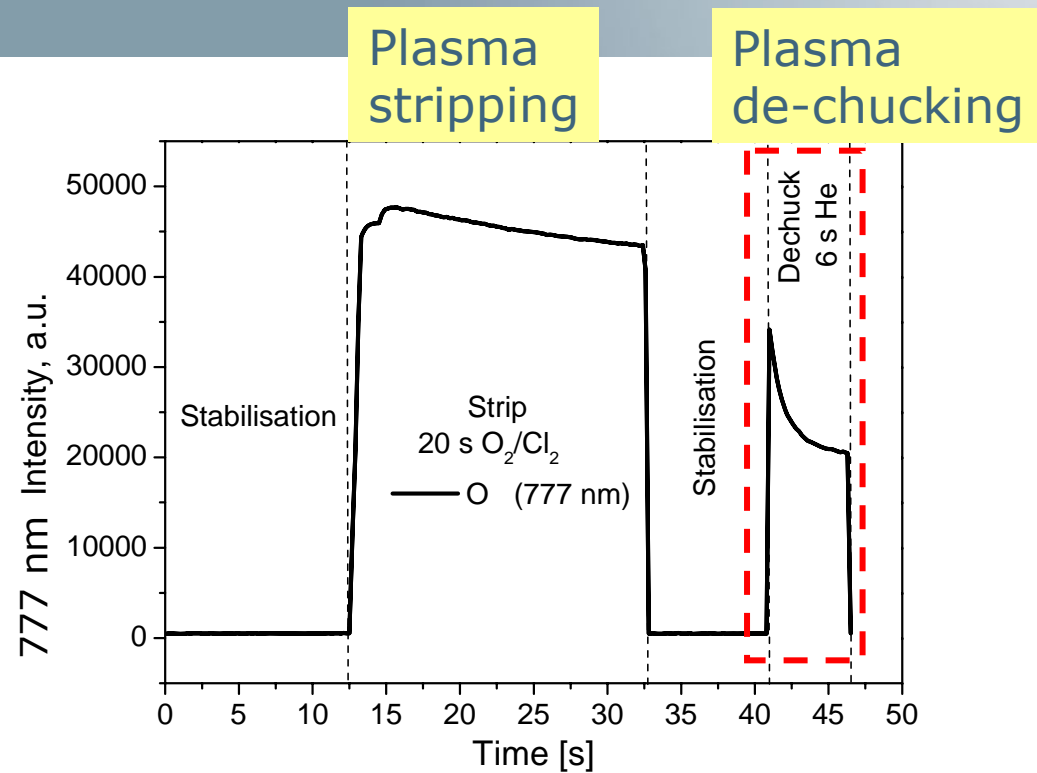
Motivation

- ◇ Porous low-k dielectrics are very sensitive to chemical and plasma damage. Therefore, it is important to study different aspects of plasma damage during the processing steps.
- ◇ *Certain challenges, which did not attract attention so far, might be related to the electrostatic “chucking” and “de-chucking” steps, which are used to fix and release wafer in industrial plasma etch systems.*
- ◇ In this presentation we analyze formation of oxygen radicals during the wafer de-chucking in He plasma and some practical aspects of this phenomenon.

Introduction

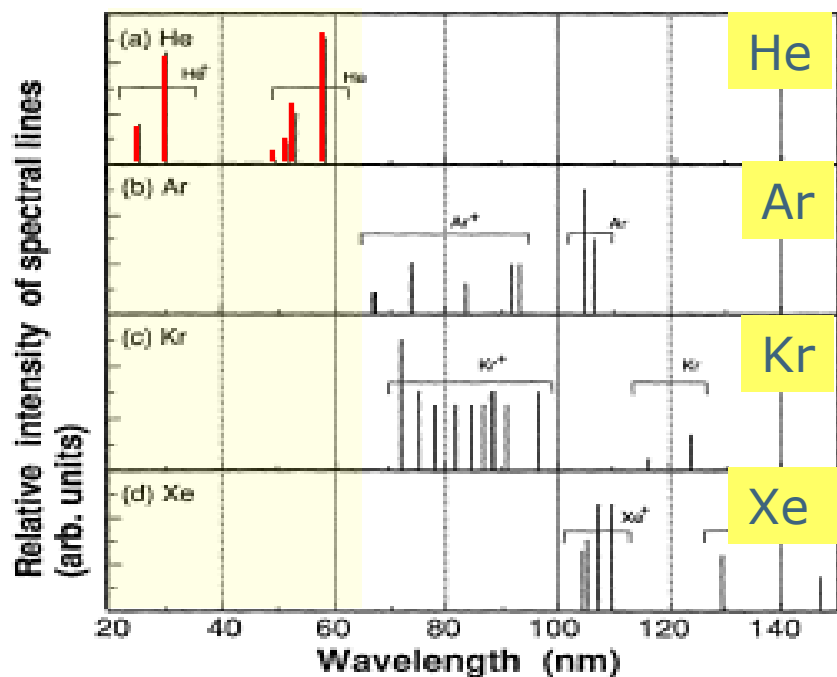
Typical steps of plasma processing:

- 1) O₂/Cl₂ gas stabilization
- 2) O₂/Cl₂ plasma strip
 $CxHx + O^* \rightarrow CO_2 + H_2O$
- 3) He gas stabilization
- 4) He plasma de-chuck



The light of 777 nm wavelength is emitted during the de-chucking step that uses pure He plasma

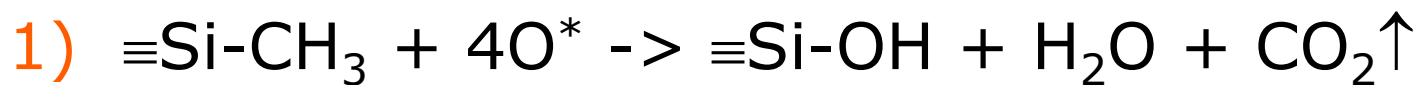
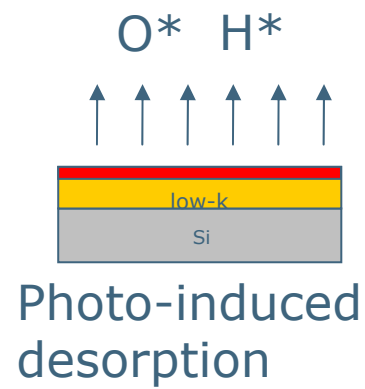
Possible sources of oxygen radicals during He plasma de-chucking



Stripping with O_2/Cl_2 plasma



De-chucking with He plasma



Water is reaction by-product and not sufficiently volatile at applied temperature

2) Chemisorbed oxygen atoms/molecules

Experimental

Tool

- LAM Versys2300 STAR plasma chamber equipped with OES (optical emission spectroscopy) analyzer with spectral resolution 2.5 nm

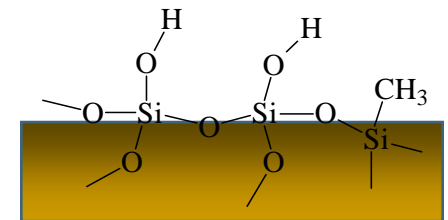
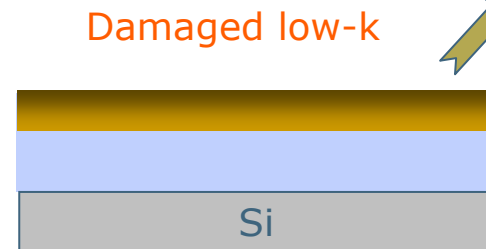
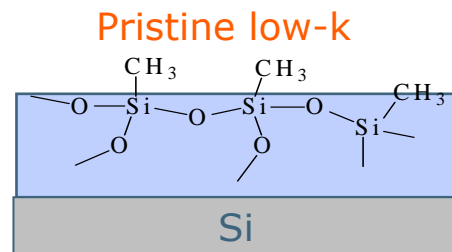
Plasmas used

- O_2/SF_6 – for WAC (waferless auto-cleaning)
- O_2/Cl_2 19:1 strip plasma – for plasma damage tests
- Pure He – for plasma damage evaluation and de-chuck

Samples

- Bare Si
- Photoresist deposited on Si
- Blanked and plasma damaged low-k dielectrics

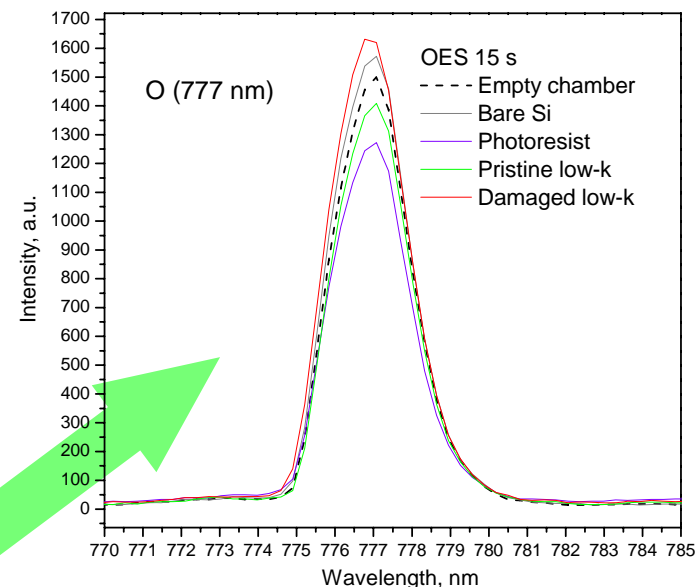
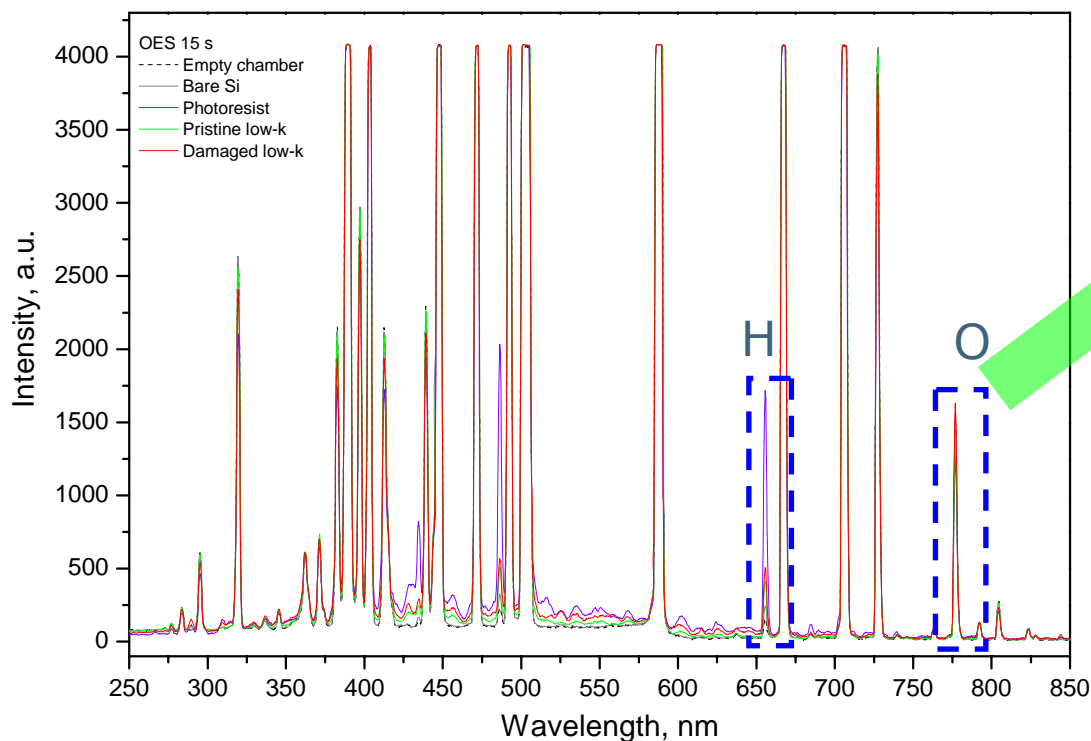
23 % porosity
2 nm pore size
 $k = 2.5$



Damaged layer

We observe O and H related peak in He plasma de-chuck for different substrates and empty chamber

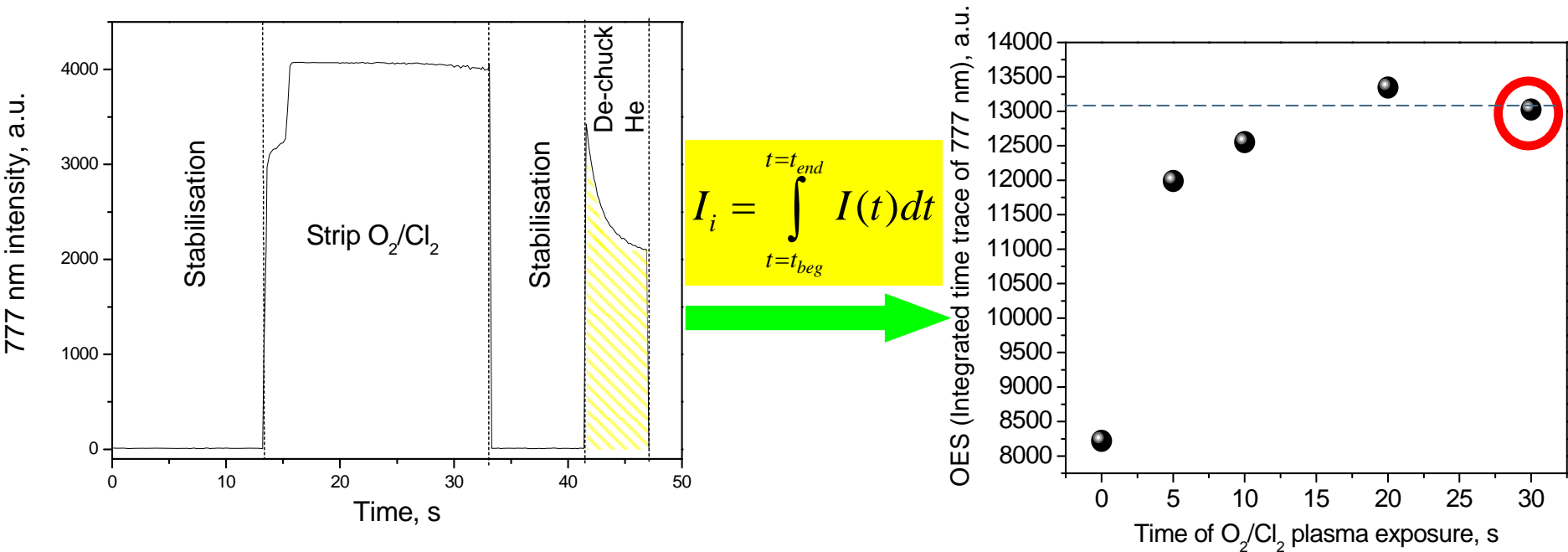
OES during He plasma de-chuck



The intensity of 777 nm varies for different samples and depends on hydrophobic properties of the sample

Monitoring of damage during He de-chuck is possible

Degree of damage \sim time of O_2/Cl_2 plasma treatment



For longer time of O_2/Cl_2 plasma exposure, the integration of 777 nm does not give accurate information about degree of damage.

Is it chamber walls effect?

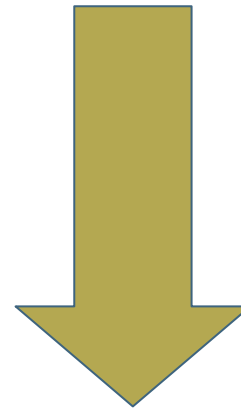
Sources of O* radicals during He plasma exposure :

-Studied wafer

-Chamber walls

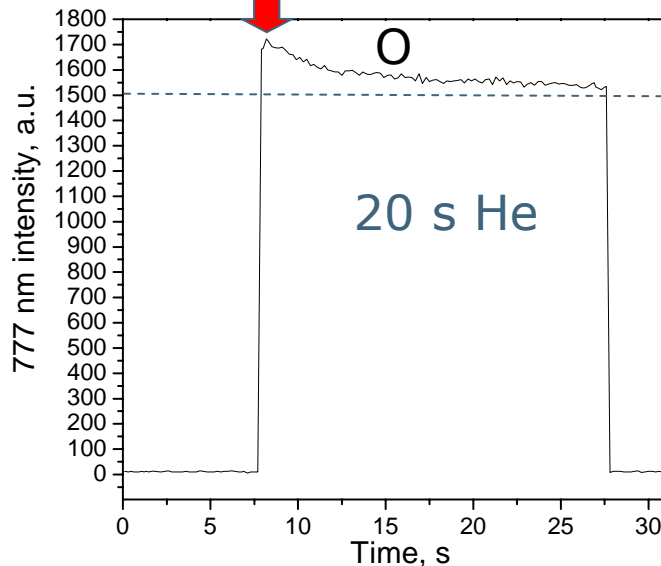
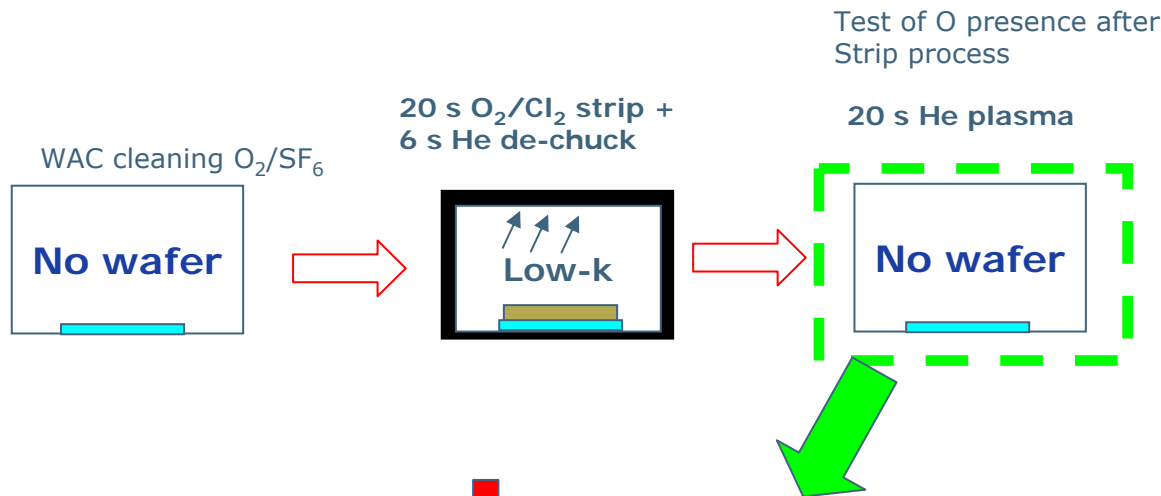


Chamber wall area \gg surface of wafer



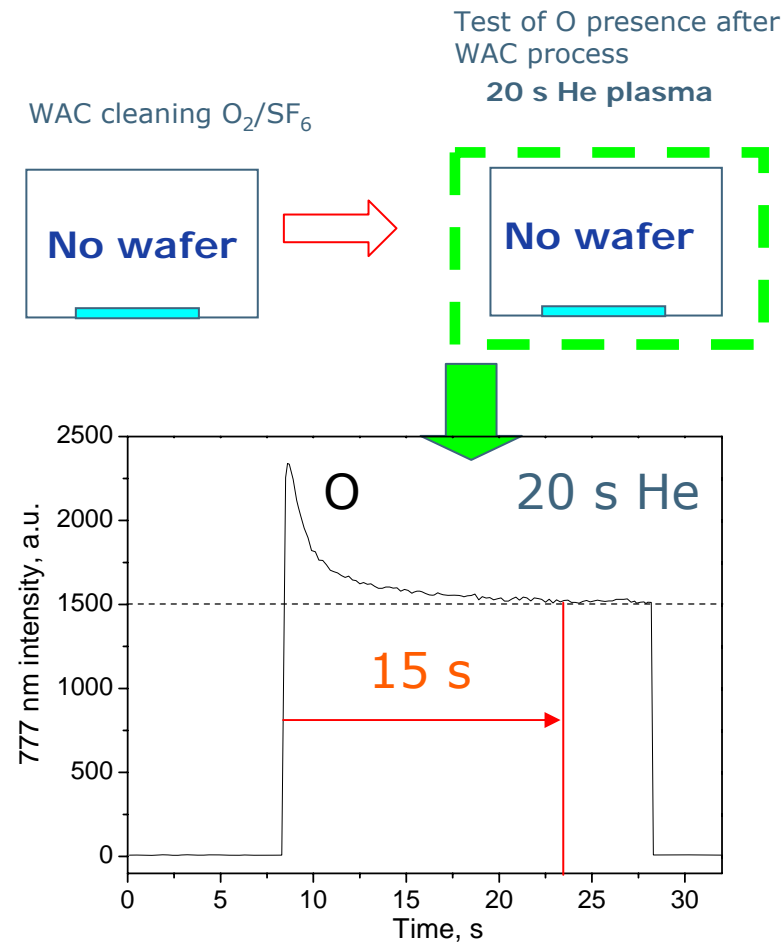
Therefore desorption from the chamber walls is important

The O_2/Cl_2 plasma introduces O to chamber walls



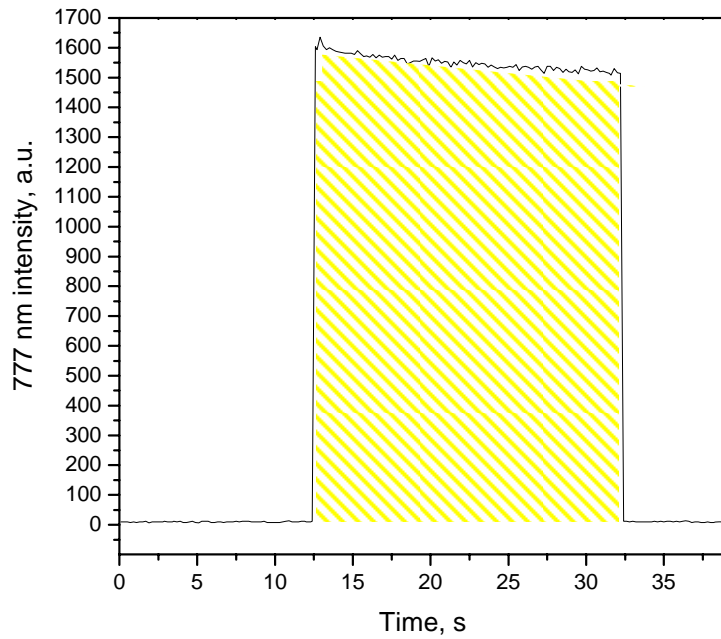
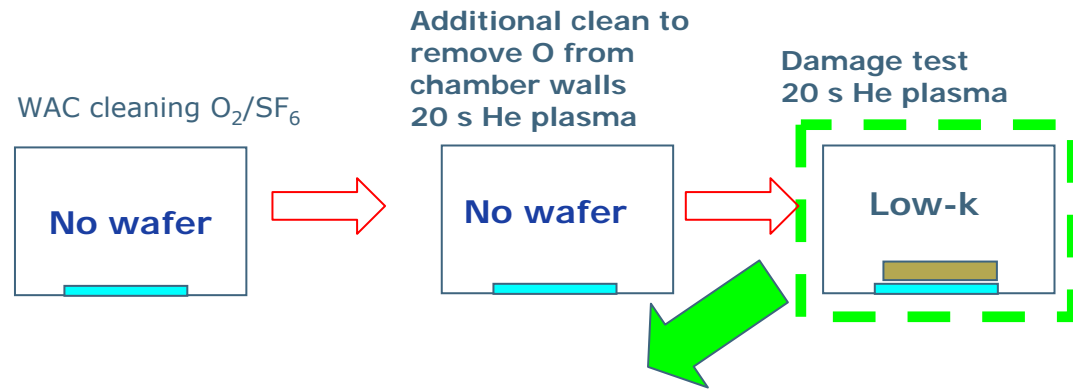
The peak of 777 nm indicates that some O comes from the chamber walls.

Standard WAC also introduces O to chamber walls

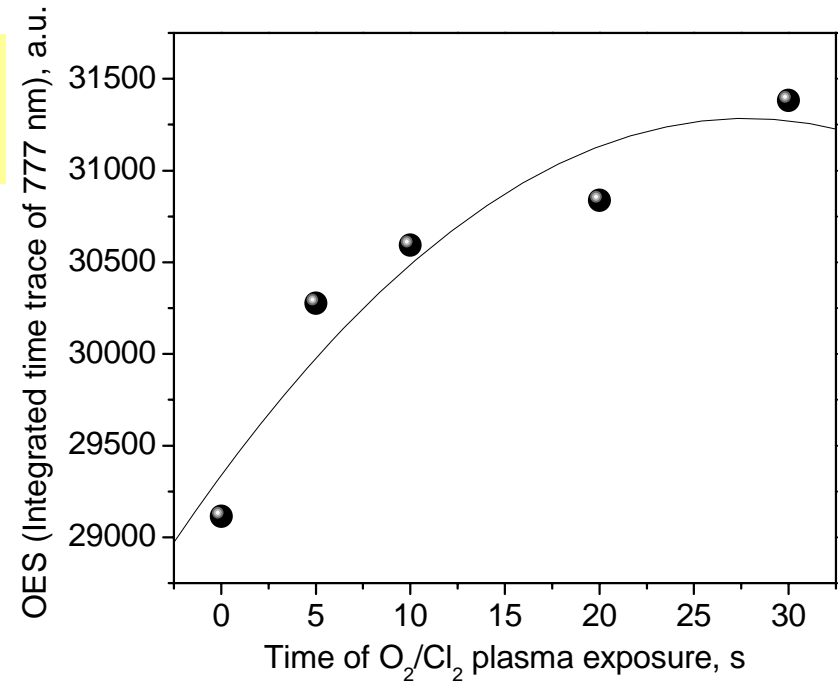


The peak 777 indicate accumulation of O on the chamber walls after WAC. The O is removed after 15 s of He 400 W treatment.

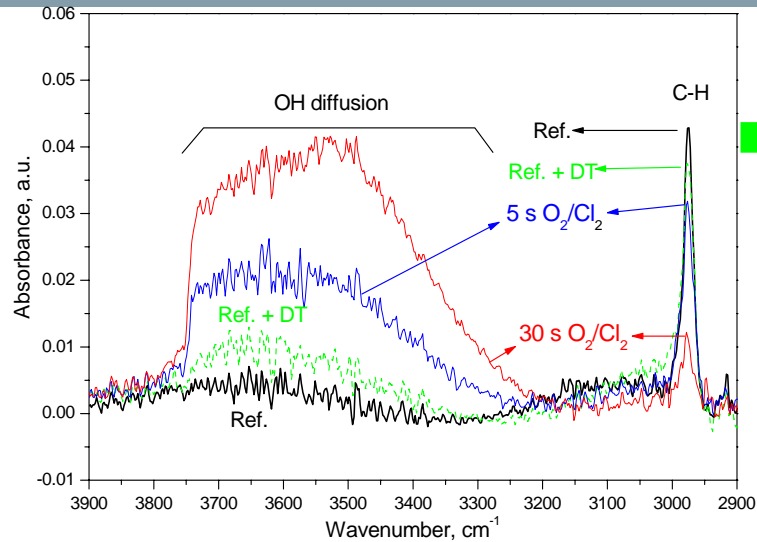
It is possible to do quantitative analysis of degree of plasma damage when chamber walls are "Oxygen free"



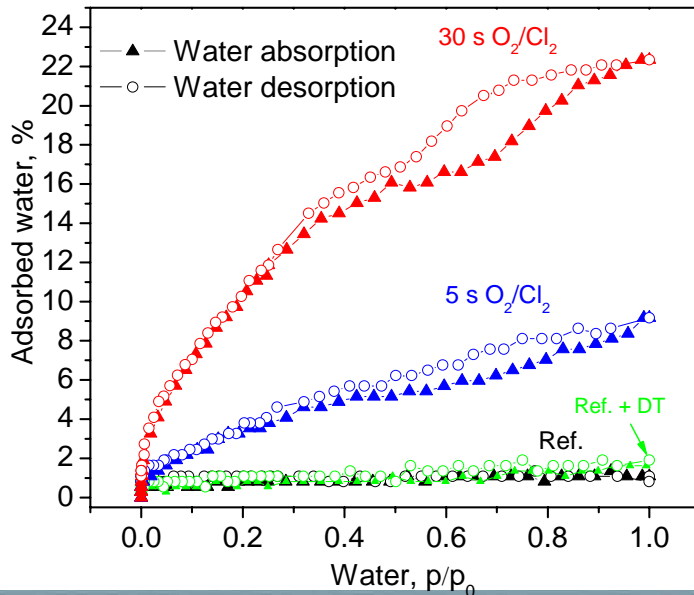
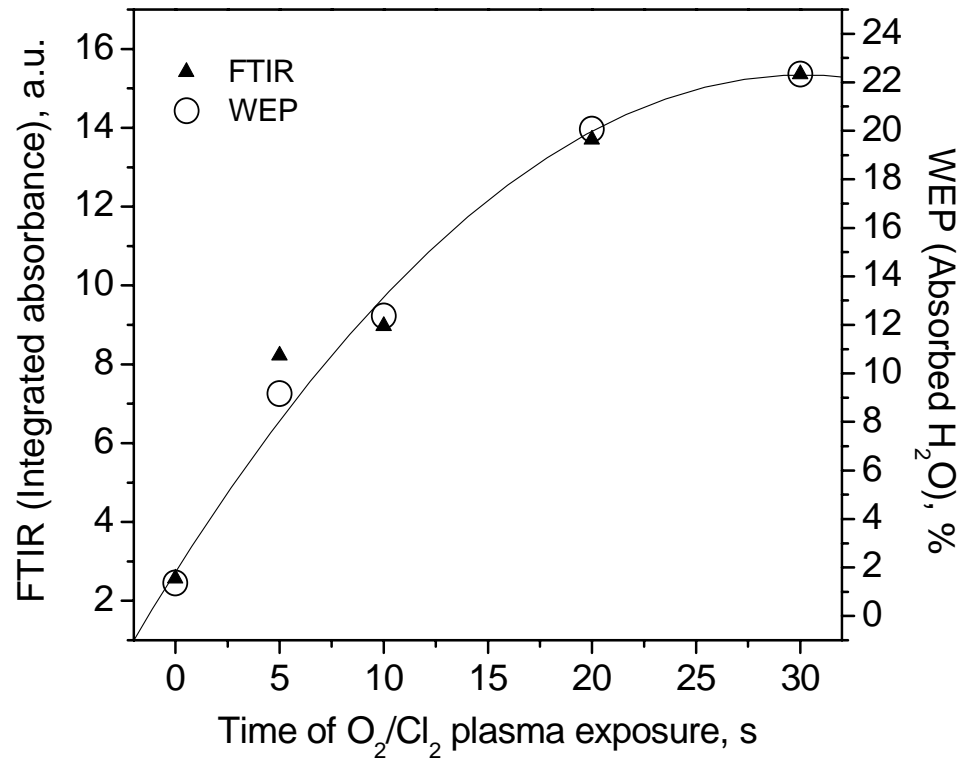
$$I_i = \int_{t=t_{beg}}^{t=t_{end}} I(t) dt$$



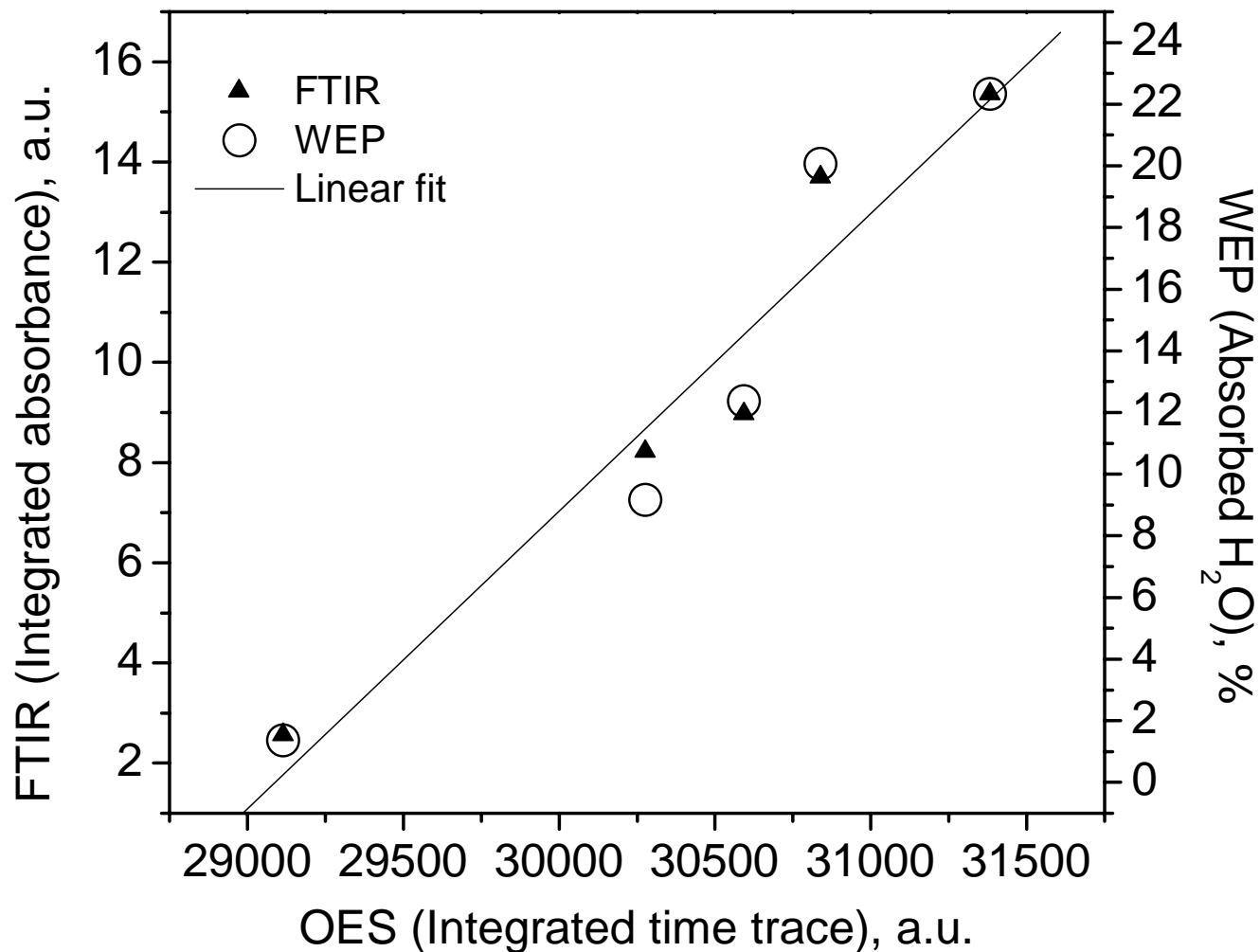
FTIR and WEP also provide quantitative data about degree of plasma damage



$$A_i = \int_{k=3100\text{cm}^{-1}}^{k=3900\text{cm}^{-1}} A(k) dk$$



Degree of plasma damage can be quantitatively asses with OES analysis



Conclusions

- A new method of plasma damage evaluation based on OES analysis has been established.
- The method is quantitative and correlates well with FTIR and WEP.
- The method is simple and does not require any additional equipment.