Water radiolysis quantification upon soft X-rays exposure using a microfluidic cell

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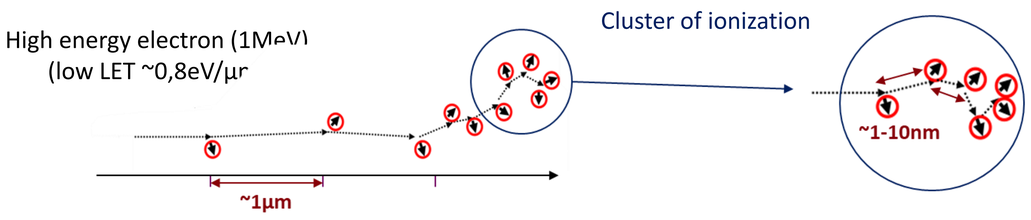
Introduction

- **Fluorescent method for direct measurement of liquid water radiolysis**

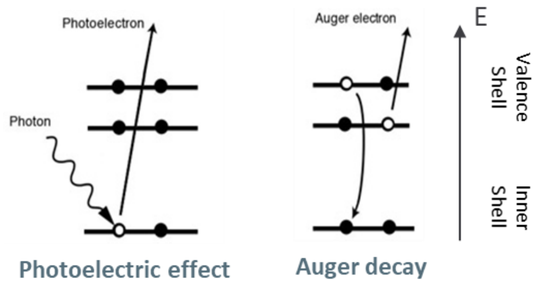
$$H_2O \rightarrow \boxed{OH^{\cdot}}, H^{\cdot}, e^-_{aq}, H_3O^+, HO_2^{\cdot}, H_2O_2, H_2$$

- **Soft X-rays allow studies on subkeV electrons**

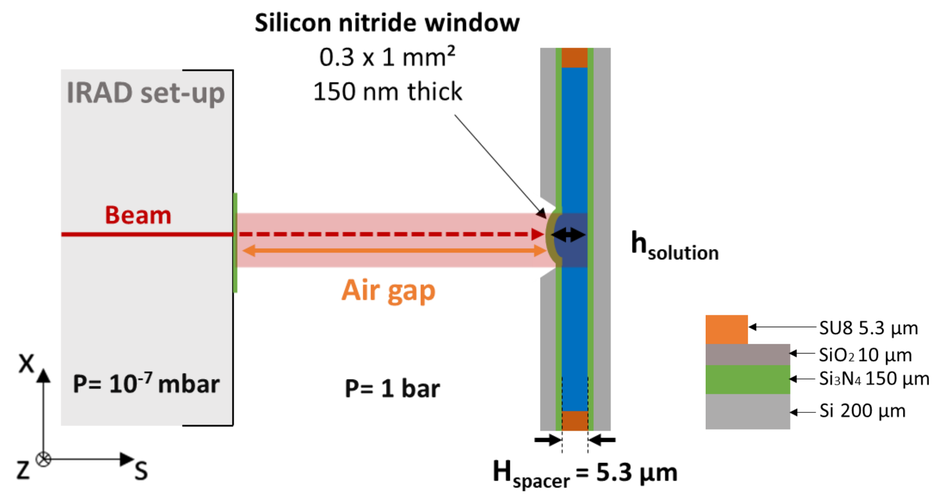


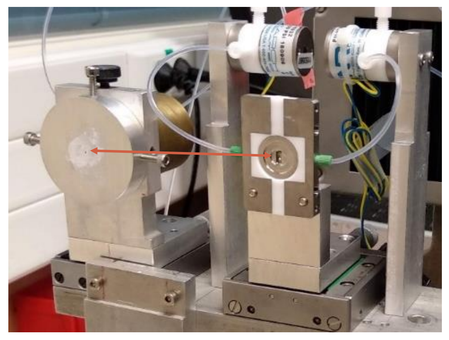
- **Soft X-rays induce core-ionization on atoms in biological sample**

Atom	C	N	O	S	Na	Mg
K-shell ionization threshold (eV)	284,2	409,9	543,1	230,9	1070,8	1303,0

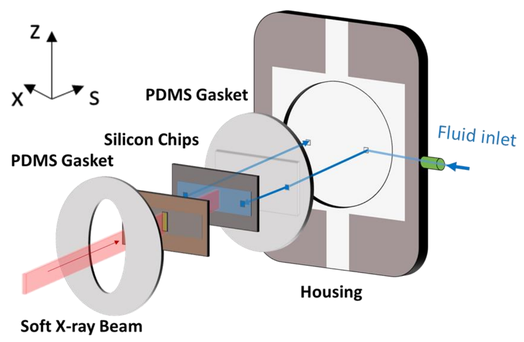


Irradiation set-up and microfluidic device





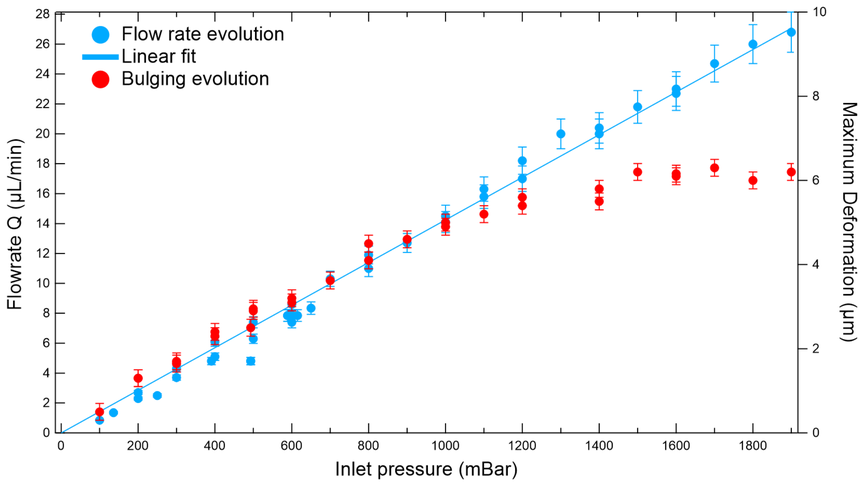
Relative position of the irradiation window and a photodiode

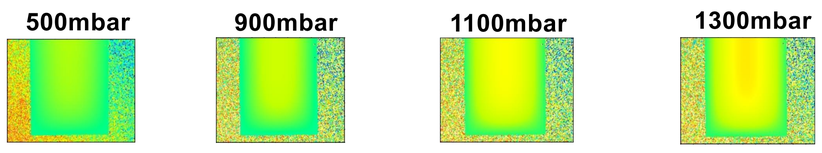


Exploded view of the microfluidic cell (not to scale)

Characterization of the set-up

Membrane deformation under applied pressure

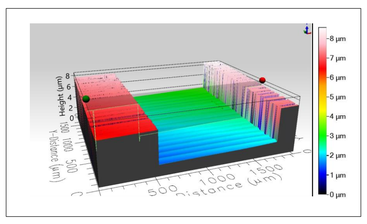


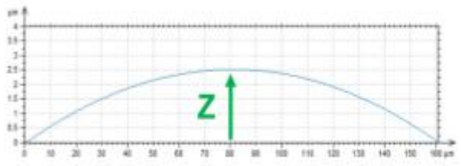


Calculation of the dose:

$$D = \frac{E I_0 T_{SiN} A_{water}}{\rho Q}$$

- T_{SiN}= transmission coefficient in silicon nitride
- **E**= energy
- Q= flowrate
- I_0= intensity of the beamline
- A_{water}= absorption coefficient in water
- ρ = density

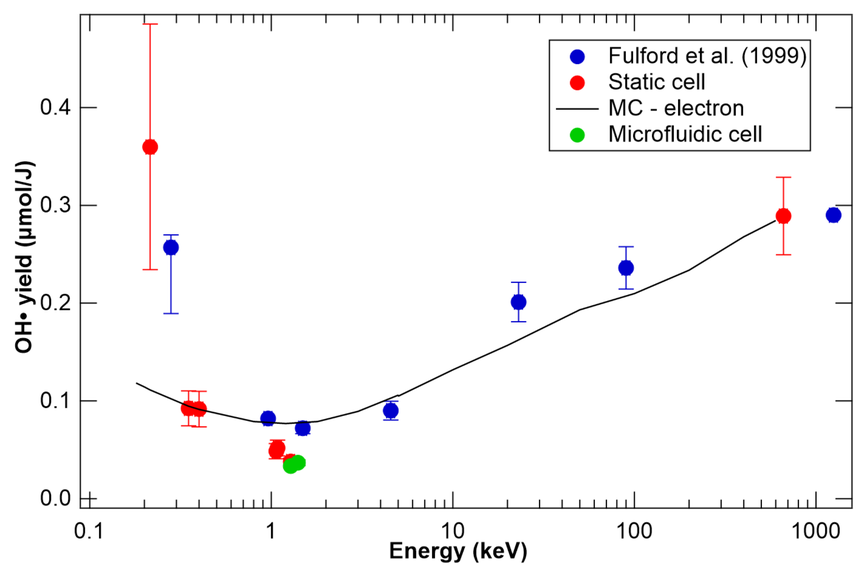




Comparison with results obtained in a static cell

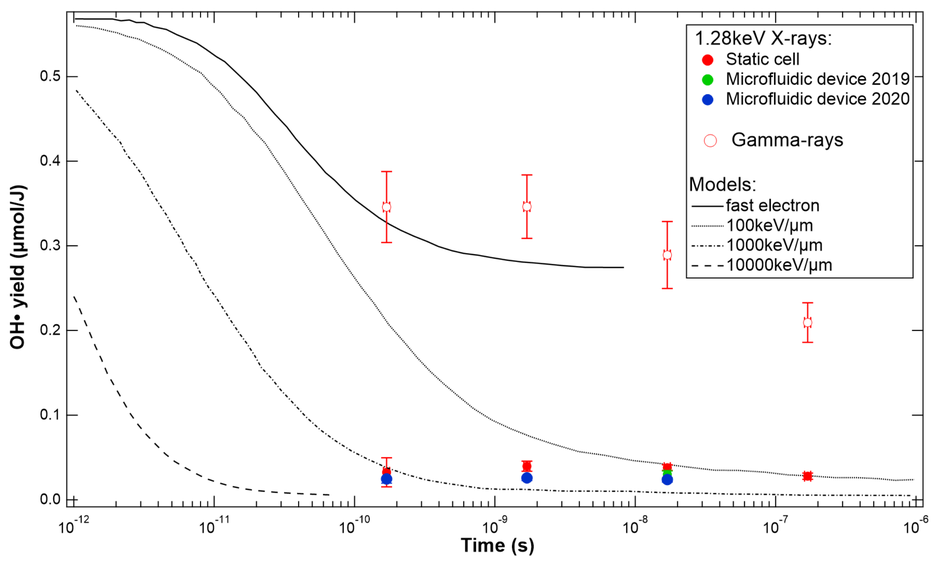
Photon energy dependence of OH° yield

Comparison with theoretical and experimental results



OH° yield evolution varying scavenger concentration

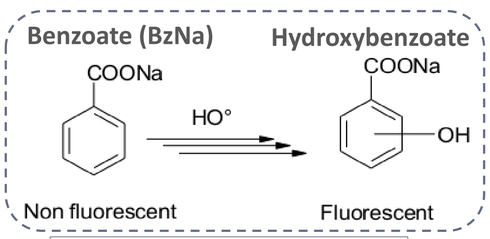
$$\text{Scavenging time} = \frac{1}{k_{OH+Bz}[Bz]} \rightarrow 170\ \text{ns to } 170\ \text{ps}$$



Soft X-rays have the same behaviour as high LET particles

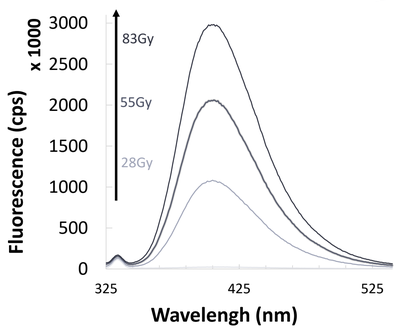
Hydroxyl radical dosimetry with soft X-rays

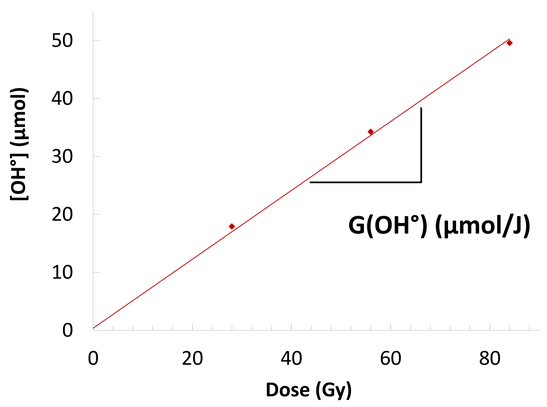
(illustrated with gamma-rays results)



$k_{scavenging} = 5.9 \times 10^9\ M^{-1}\ s^{-1}$

Developped by Amstrong (1960) adapted by Musat (2010)





- ✓ **Biocompatible technique**
- ✓ **Low detection limit**
  ~10^{-8}mol/L ↔ 10Gy

Conclusion and perspectives

- The fluorescence method developed by the team proved its robustness to quantify the hydroxyl radical.
- Implementation of a microfluidic device drastically improved sensitivity and facilitates the measurement as the flowrate is directly linked to the dose
- Research on a core-ionization threshold effect probed with soft X-rays
- Photoelectron spectroscopy measurements and additional measurement are scheduled, in order to better characterize the system

REFERENCES

- Giesel, F. (1902), *Berichte Der Deutschen Chemischen Gesellschaft*, *35*(3), 3608–3611.
- D.T. Goodhead and J. Thacker. (1977), *Int. J. Radiat. Biol. Relat. Stud. Phys. Chem. Med.* **31**: 541.
- Herskind, C., & Wenz, F. (2014), *Transl Cancer Res*;3(1):3-17.
- J.A. LaVerne and S.M. Pimblott (1991), *J. Phys. Chem.* **95**: 3196.
- M.A. Herve du Penhoat (2002), *Radiation Research*, *157*(2), 128–140.
- G. Louit (2005), *Radiation Physics and Chemistry* **72**: 119;
- J. Fulford (1999), *J. Phys. Chem A* **103**: 11345.
- LaVerne, J. A., & Pimblott, S. M. (1991). *Journal of Physical Chemistry*, *95*(8), 3196–3206.
- Huart, L., Penhoat, M. H. (2020). The Journal of Physical Chemistry A, 33(0), 1–24.

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