A resistive soot sensor for mass quantification through a correlation between conductance and soot mass loading

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Context and aim of the study

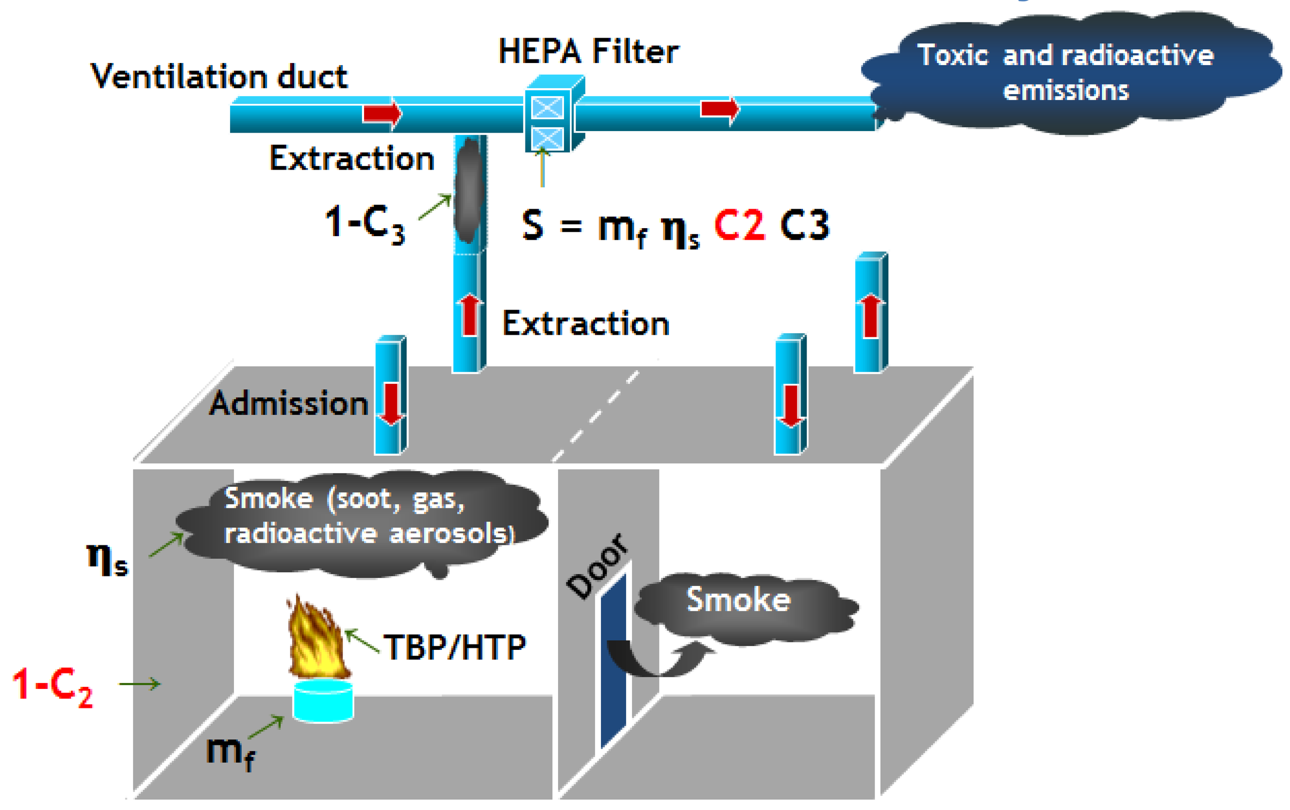
Nuclear safety

- Fire : one of the most hazardous risks in nuclear facilities
- Assess the consequences of particle emissions on containment devices, such as High Efficiency Particulate Air (HEPA) filters

Principal consequences of a fire

- Radioactive aerosol release,
- Production of a large amount of soot,
- Clogging of HEPA Filters [1],
- Modification of pressure conditions in the facility,

➔ Lack of experimental and quantitative data on soot deposition during a fire,
➔ No real time sensor to provide soot deposited fraction



S : mass of soot arriving on HEPA filters (kg),
m_f : amount of consumed fuel (kg),
η_s : soot emission factor (kg of soot per kg of consumed fuel),
1-C2 : fraction of soot deposited on the walls(-),
1-C3 : fraction of soot deposited in the ventilation ducts (-),

Deposit Characteristics

Real scale fire tests

- Relatively homogeneous deposit except on the ceiling
- Walls deposition fraction from **25 to 40 %**
- Deposit flux : **2 to 42 mg/m²/min**
- Deposit rate:

Surface of analysis	90x90 mm	3.5x3.5 mm
Deposit rate	14 to 340 µg/min	0.2 to 5 µg/min

- Deposit thickness from **5 to 8 mm**

➔ Regenerative sensor to avoid saturation

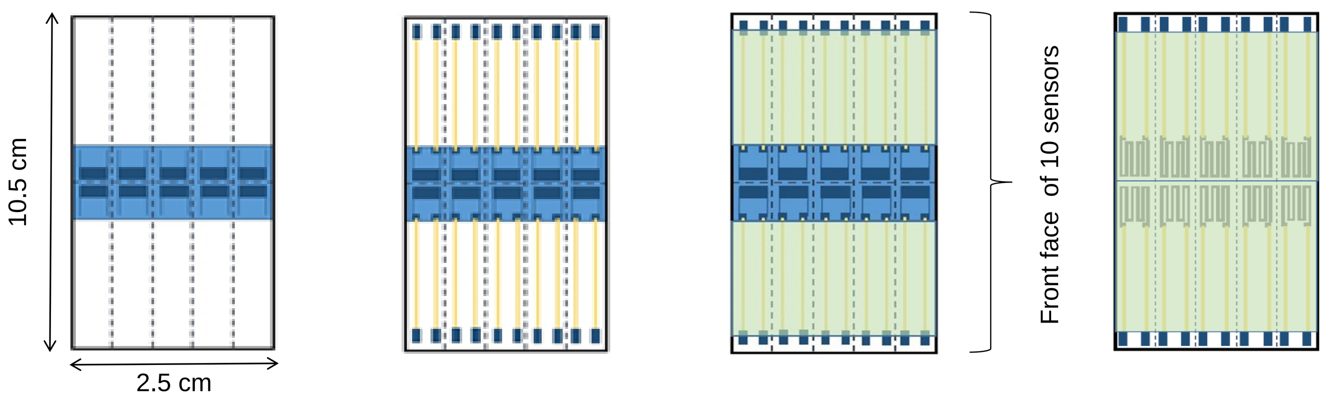
Aim of the study

- Polarization voltage influence on the deposited mass
- Correlation of the soot mass loading to the sensor electrical response

Sensor calibration : electrical response

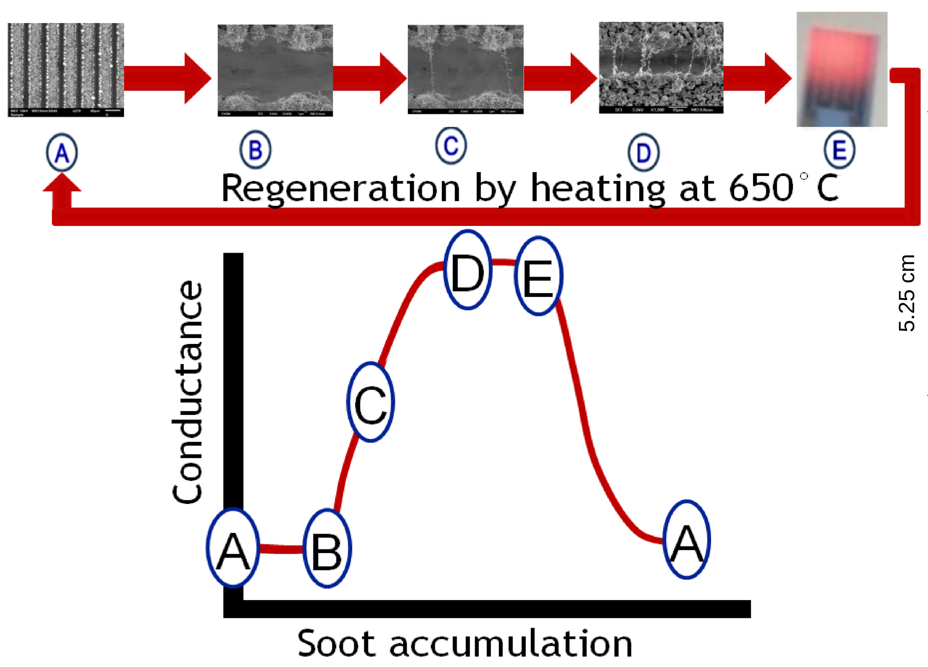
Resistive soot sensor

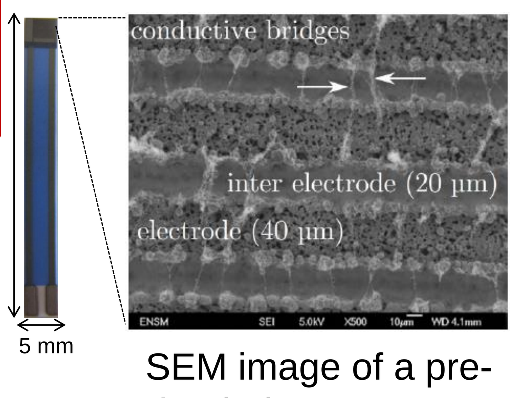
Sensor manufacturing



Screen-printed platinum and engraved IDE
Screen-printed electrodes and contact pads
Screen-printed dielectric layer
Rear face of 10 sensors

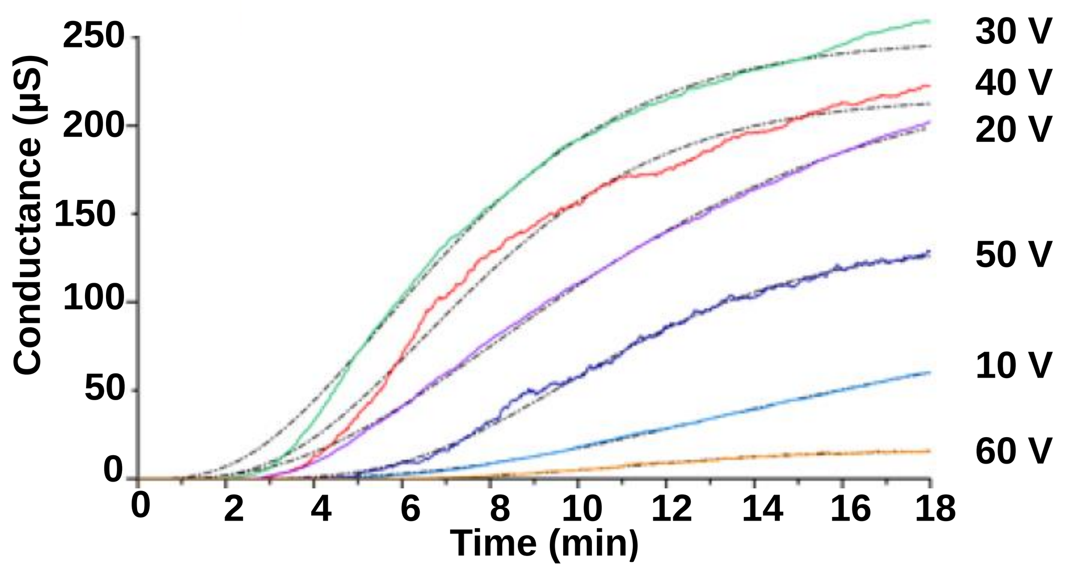
Sensor principle



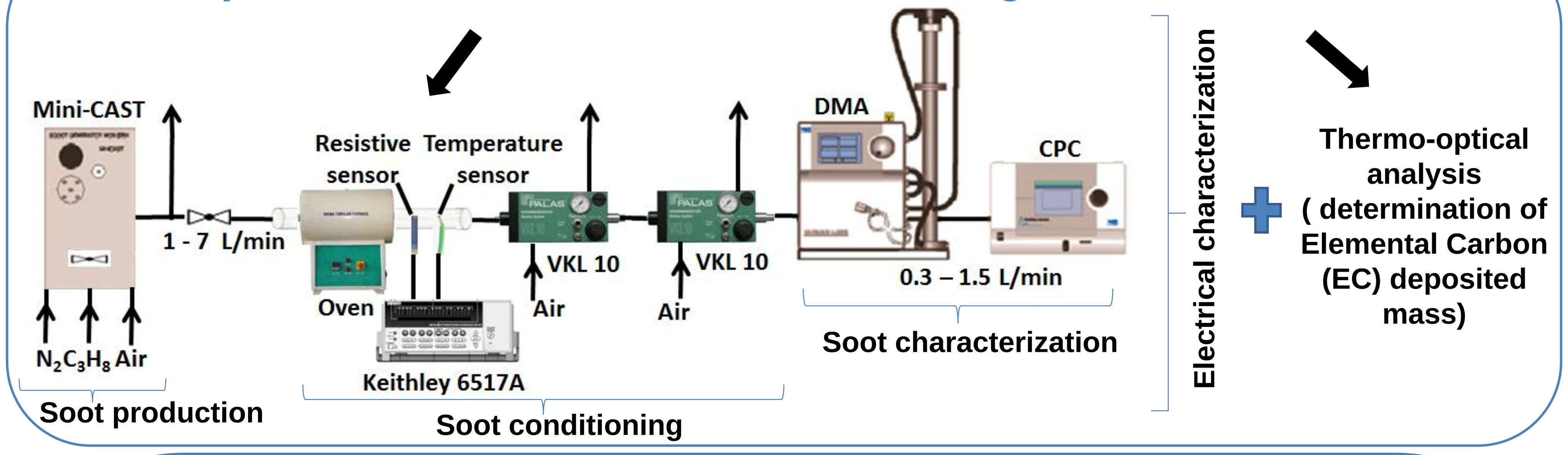


SEM image of a pre-loaded soot sensor under 30 V of polarization voltage [2]

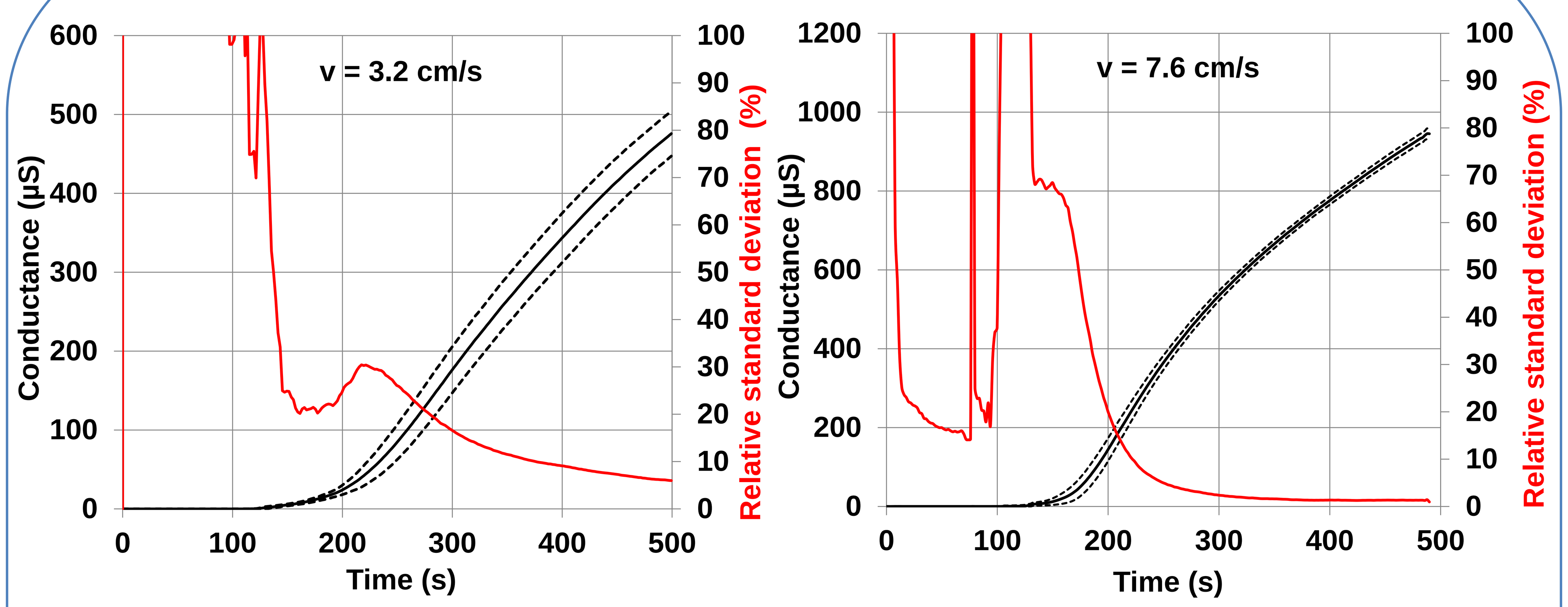
Influence of the polarization voltage on the sensor response [2]



Experimental correlation of mass loading to conductance



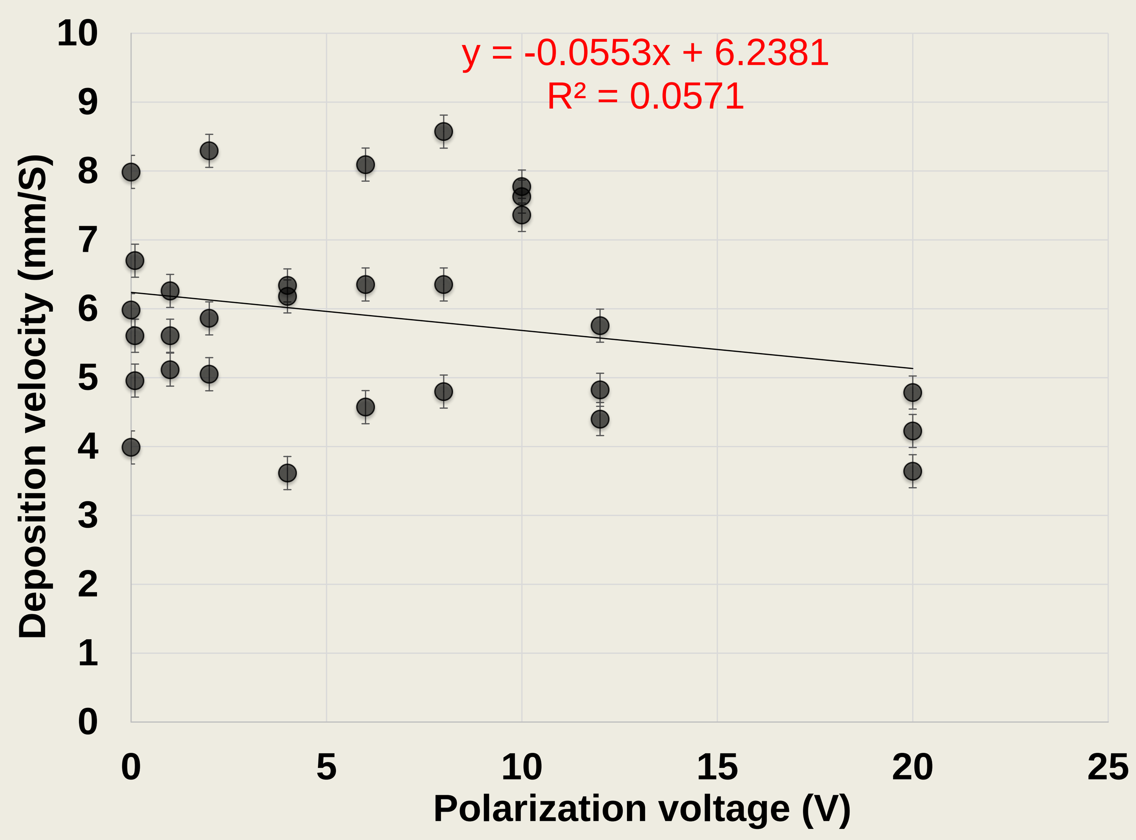
Electrical measurements



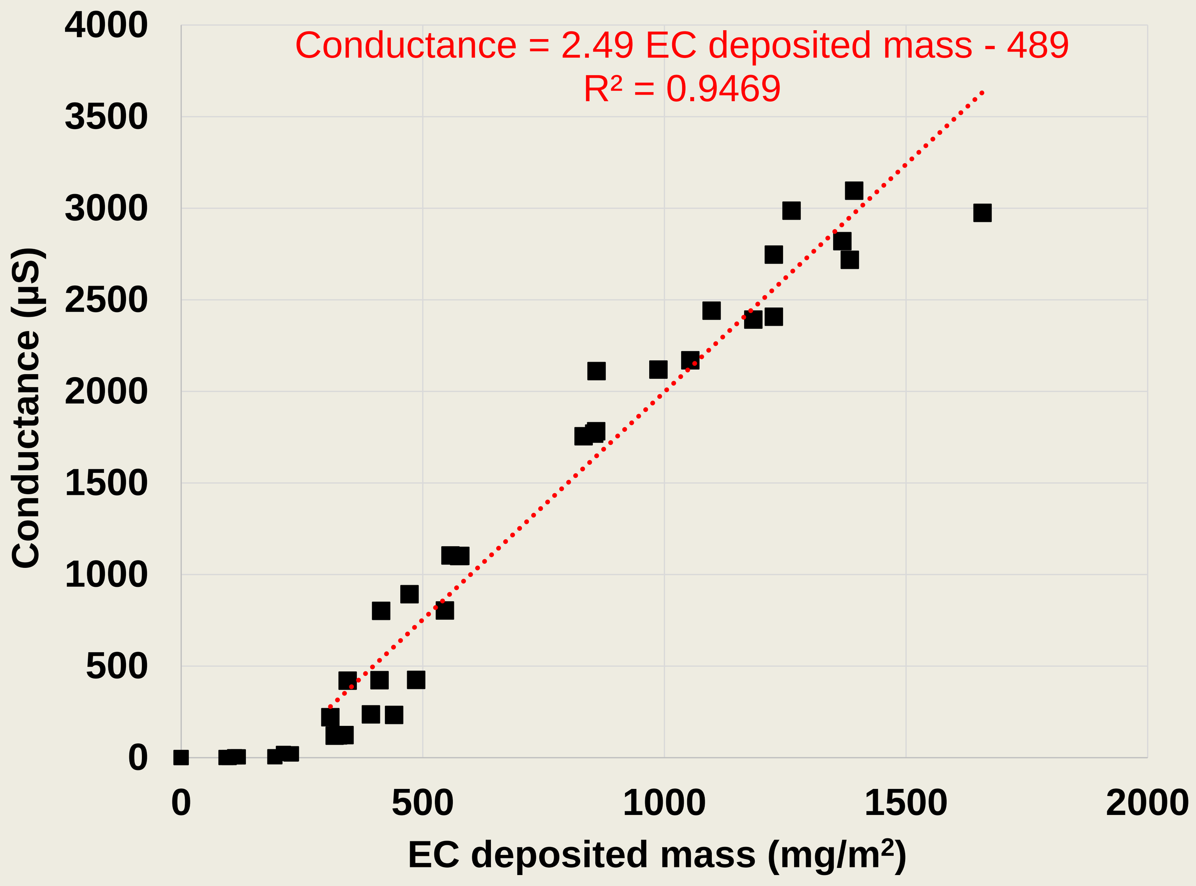
Polarization voltage (V)	Flow Velocity (cm/s)	Particle's median diameter (nm)	Concentration (#/cm³)	Mean percolation Time (s)	Mean reached Conductance at 500 s (µS)
10	3.2	200 (± 1)	9.10^6 (± 10%)	132 (± 16)	476 (± 8)
10	7.6	166 (± 0.5)	$1.5.10^7$ (± 3%)	129 (± 10)	945 (± 10)

➔ A repeatable sensor response that depends on particles' morphology and concentration

Towards real-time quantification : influence of the polarization voltage on deposited mass



➔ Same deposition velocity under low polarization voltage (0 to 20 V)



➔ Mass to conductance correlation at a polarization voltage of 10 V

Conclusions and perspectives

Conclusions

- No influence of polarization voltage lower than 20 V on deposited mass
- Soot mass loading to conductance correlation

Perspectives

- Definition of a measurement strategy to determine the required number of sensors to quantify the deposited mass in a facility during a fire
- Identification of the most relevant polarization voltage
- Application of the correlation to realistic soot particles (TBP/HTP)

[1] Bourrous S., Bouilloux, L., Ouf, F. X., Lemaitre, P., Nerisson, P., Thomas, D., & Appert-Collin, J. C. (2016). Measurement and modeling of pressure drop of HEPA filters clogged with ultrafine particles. Powder Technology, 289, 109-117
[2] Grondin, D., Geara, S., Breuil, P., Viricelle, J. P., & Vernoux, P. (2016). Influence of Electrodes Polarization on the Response of Resistive Soot Sensor. Procedia Engineering, 168, 31-34