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Development of MEMS type sensors dedicated to real-time measurement of mass concentration in aerosols

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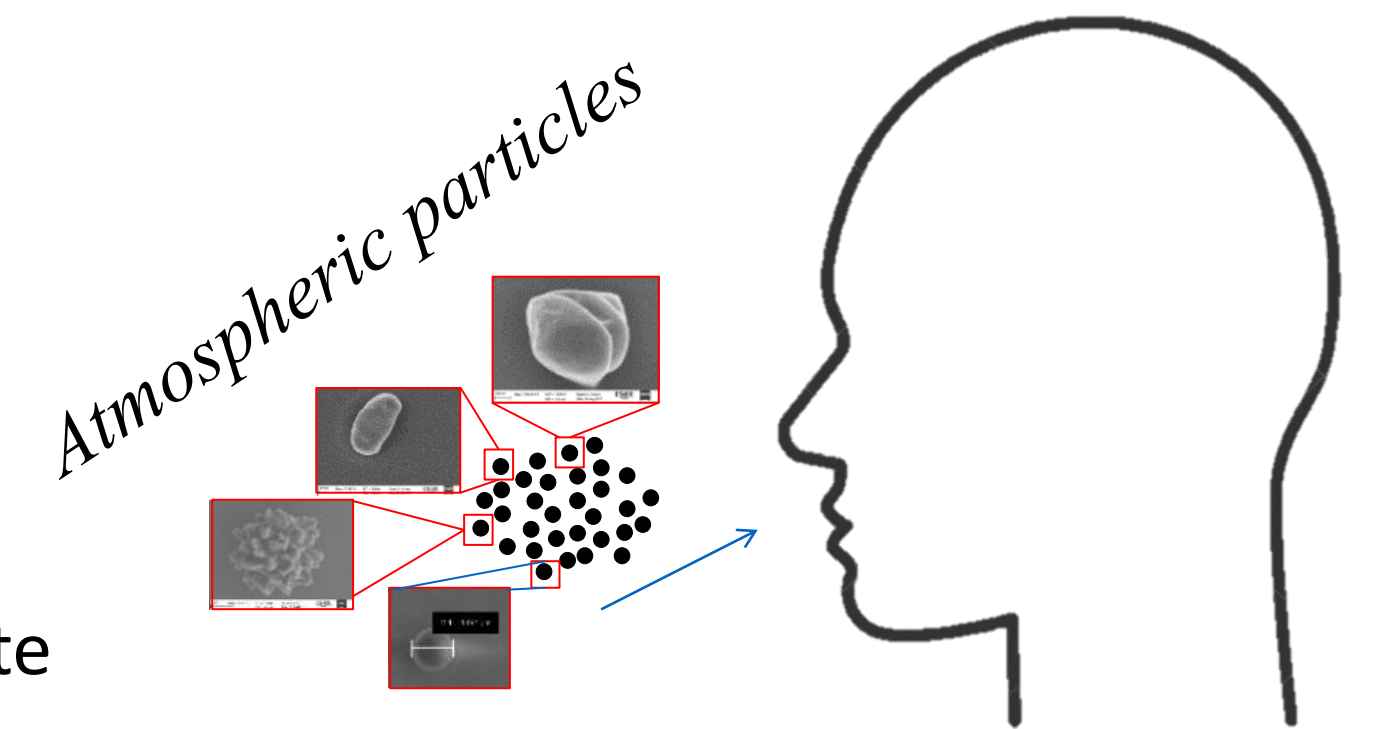
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Introduction

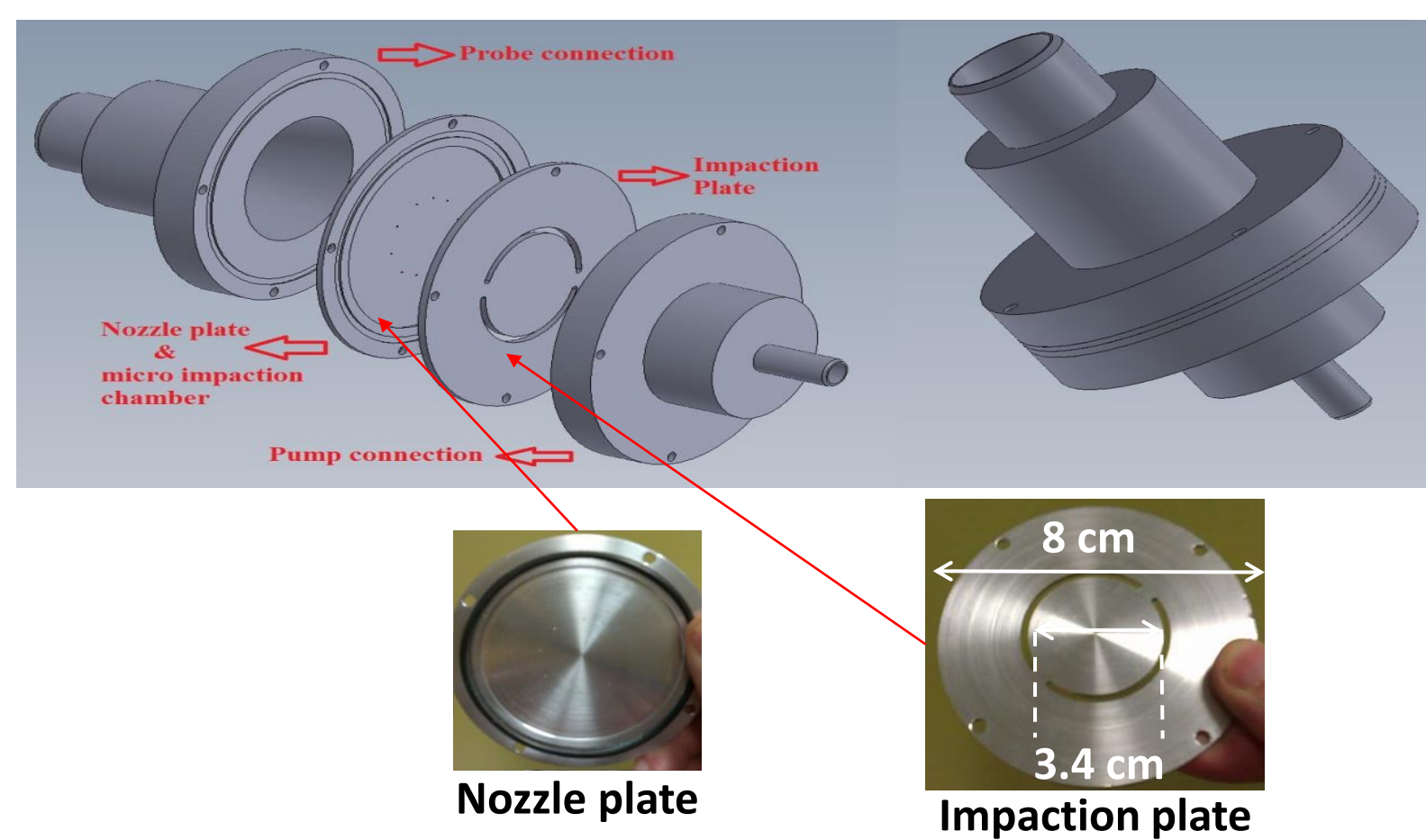
Since 2013, the International Agency for Research on Cancer has classified atmospheric pollution and the particles that compose it as compounds "definitely carcinogenic for humans" which can have harmful short and long-term effects on the body

Commonly used systems are limited because of their large size, their significant sampling times or their costs. Thus, one of the major ways of improvement of these systems is towards **their miniaturization**.

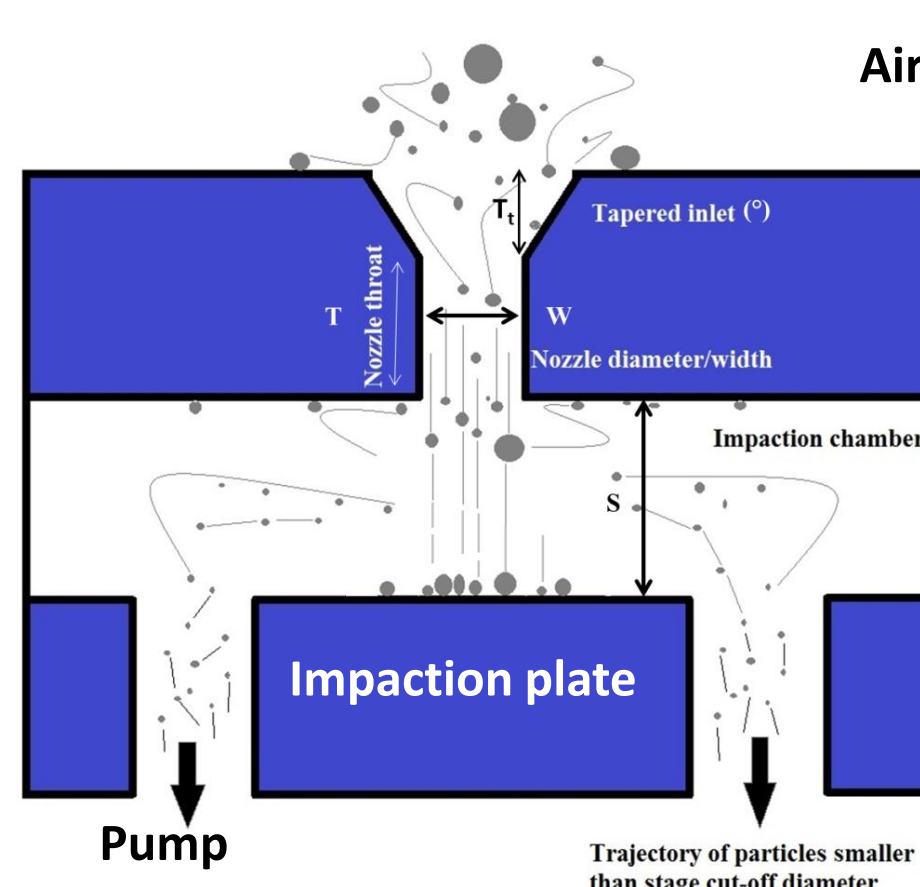
This study couples an **airborne particle sampling method** with a **sub- μm air gap resonant bulk mode MEMS mass sensor** as an appropriate option for a real-time aerosol monitoring system.



Airborne particle sampling design



Flow of particles inside the impactor

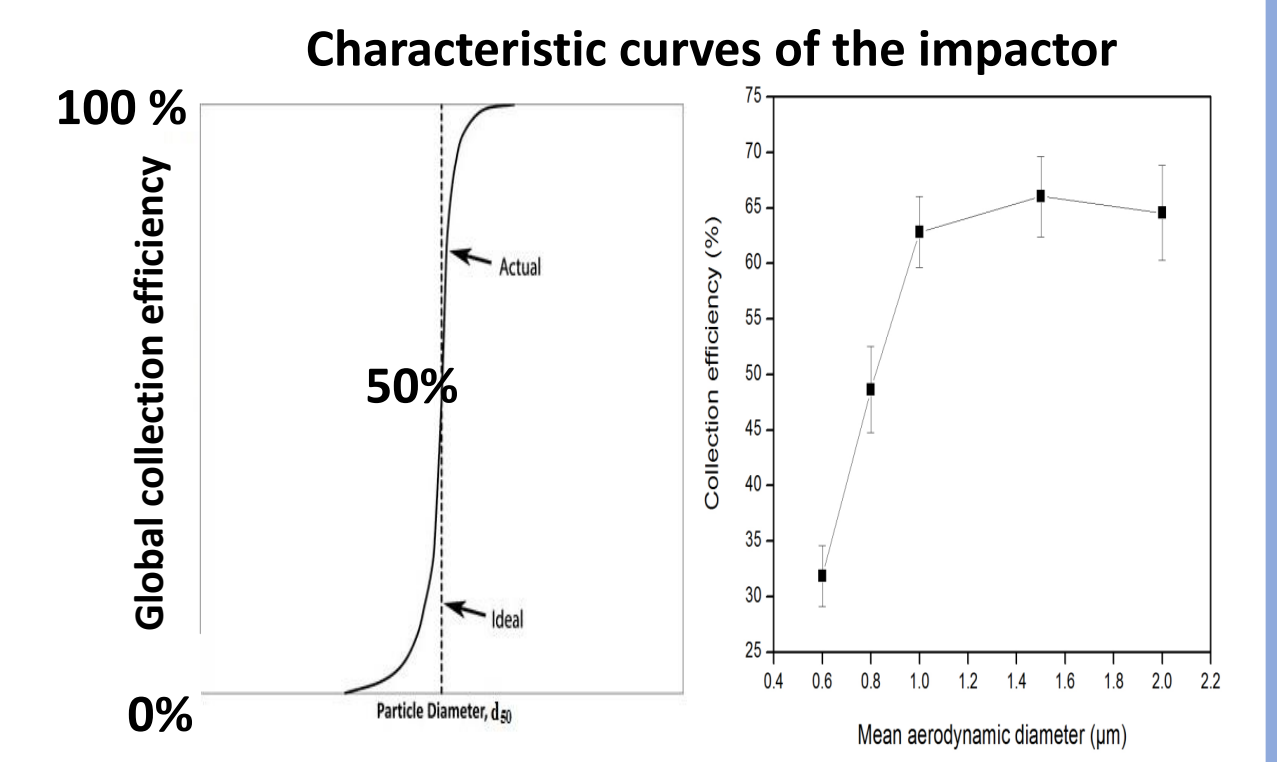


$$d_{50} = \sqrt{\frac{9W\mu St_{50}}{\rho_p C V_0}}$$

$$Re = \frac{\rho W V_0}{\mu}$$

St_{50} → Stokes number
 V_0 → Average particle velocity
 ρ_p → Particle density
 d_{50} → Cut-off diameter
 μ → Air viscosity
 C → Cunningham slip correction
 Re → Reynolds Number

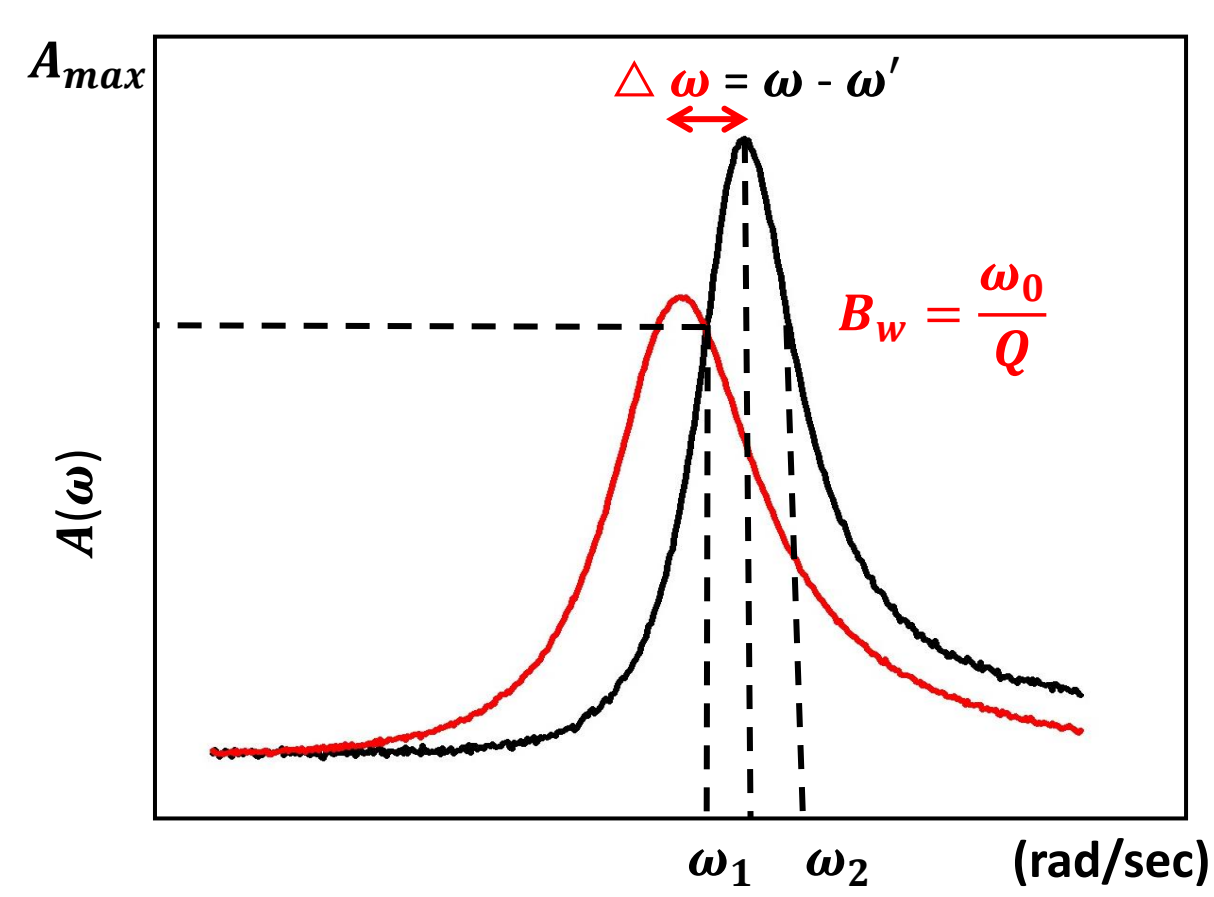
Distance between the impaction plate and nozzles (S)	1000 μm
Nozzle diameter (W)	500 μm
Number of nozzles (n)	10
Flow rate (Q)	10 LPM
Reynolds number (Re)	2825
Theoretical cut-off diameter (d_{50})	0.39 μm



$$\text{Global collection efficiency (\%)} = 100 - \left(\frac{C_{out}}{N_{in} (10 \text{ LPM})} \times 100 \right)$$

MEMS sensor principle

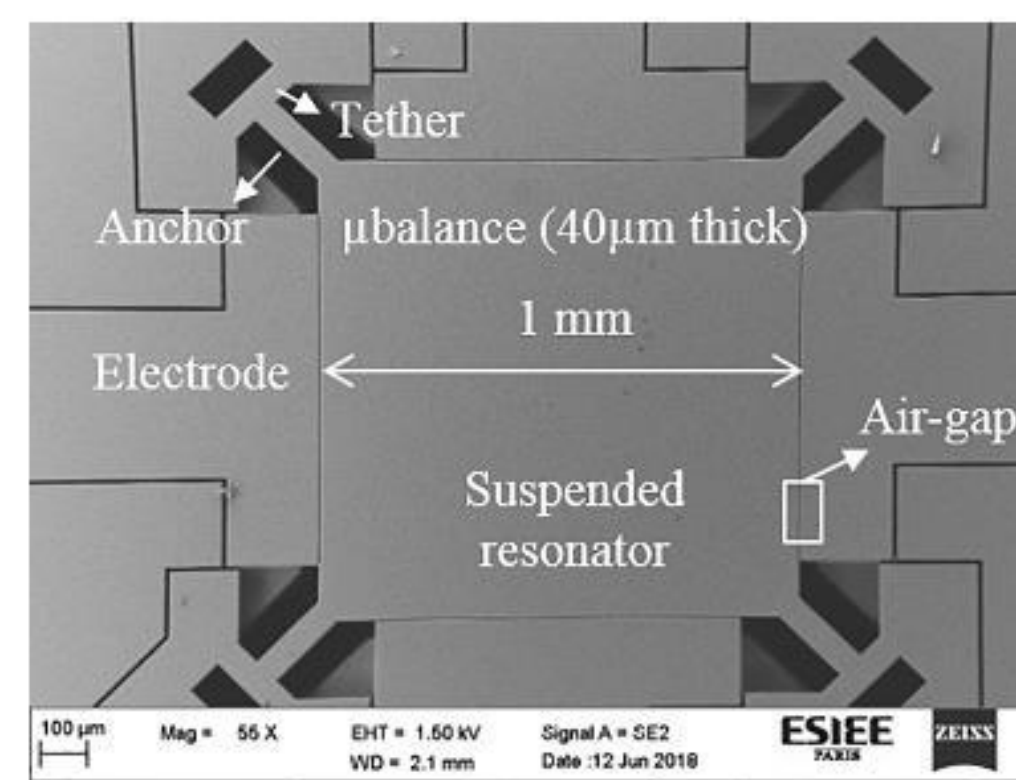
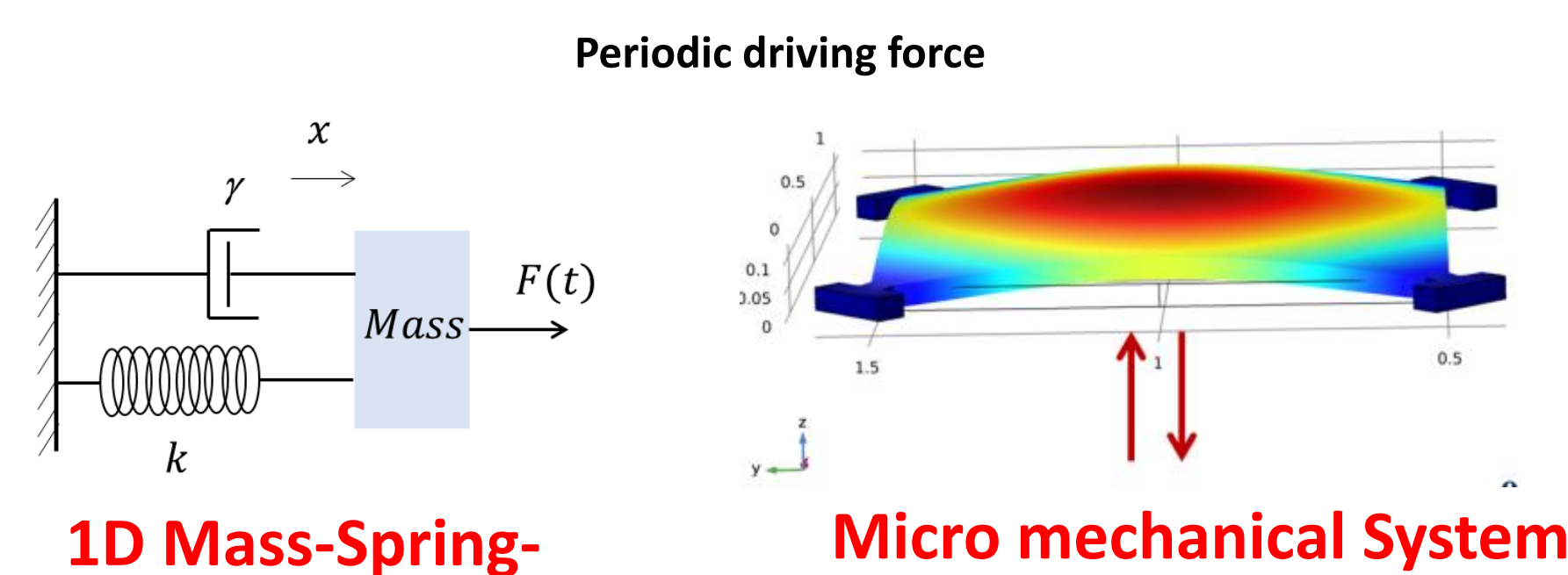
Main parameters in MEMS resonators: Q, f_r transduction



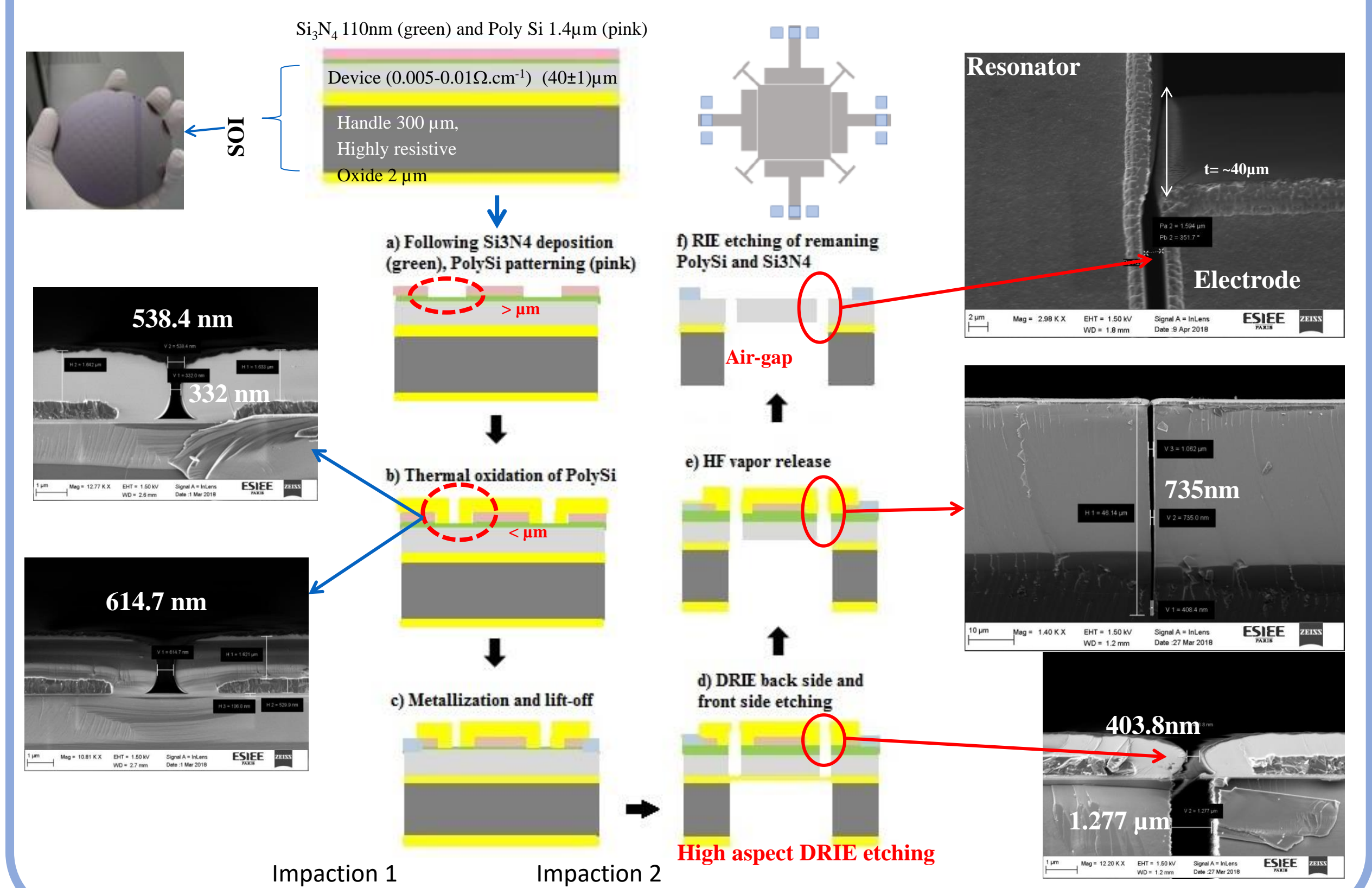
$$\omega' = \sqrt{\frac{K_{eff}}{M_{eff} + \delta M_{eff}}}$$

$$\omega = \sqrt{\frac{K_{eff}}{M_{eff}}}$$

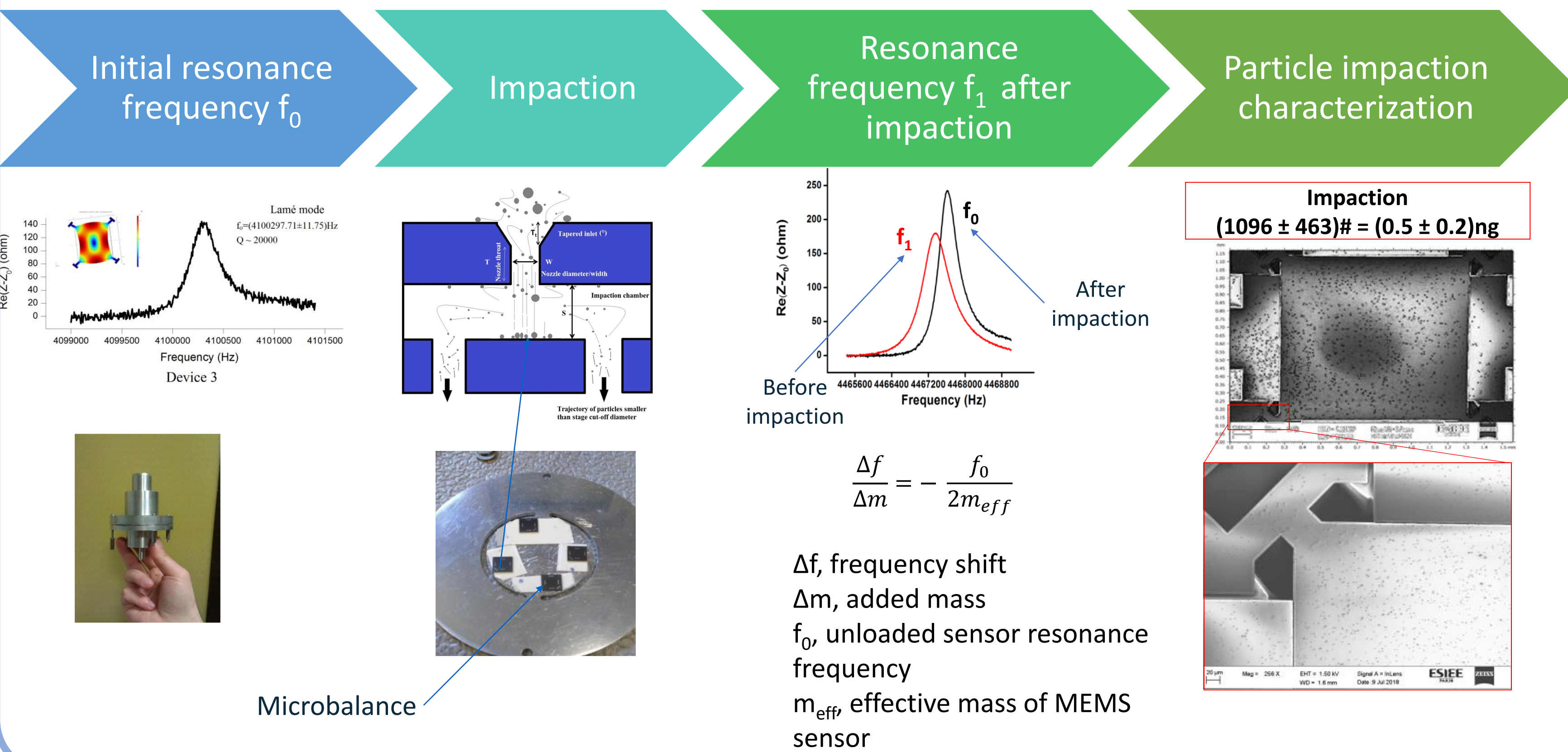
High performance MEMS → High Resonance frequency
High Quality factor



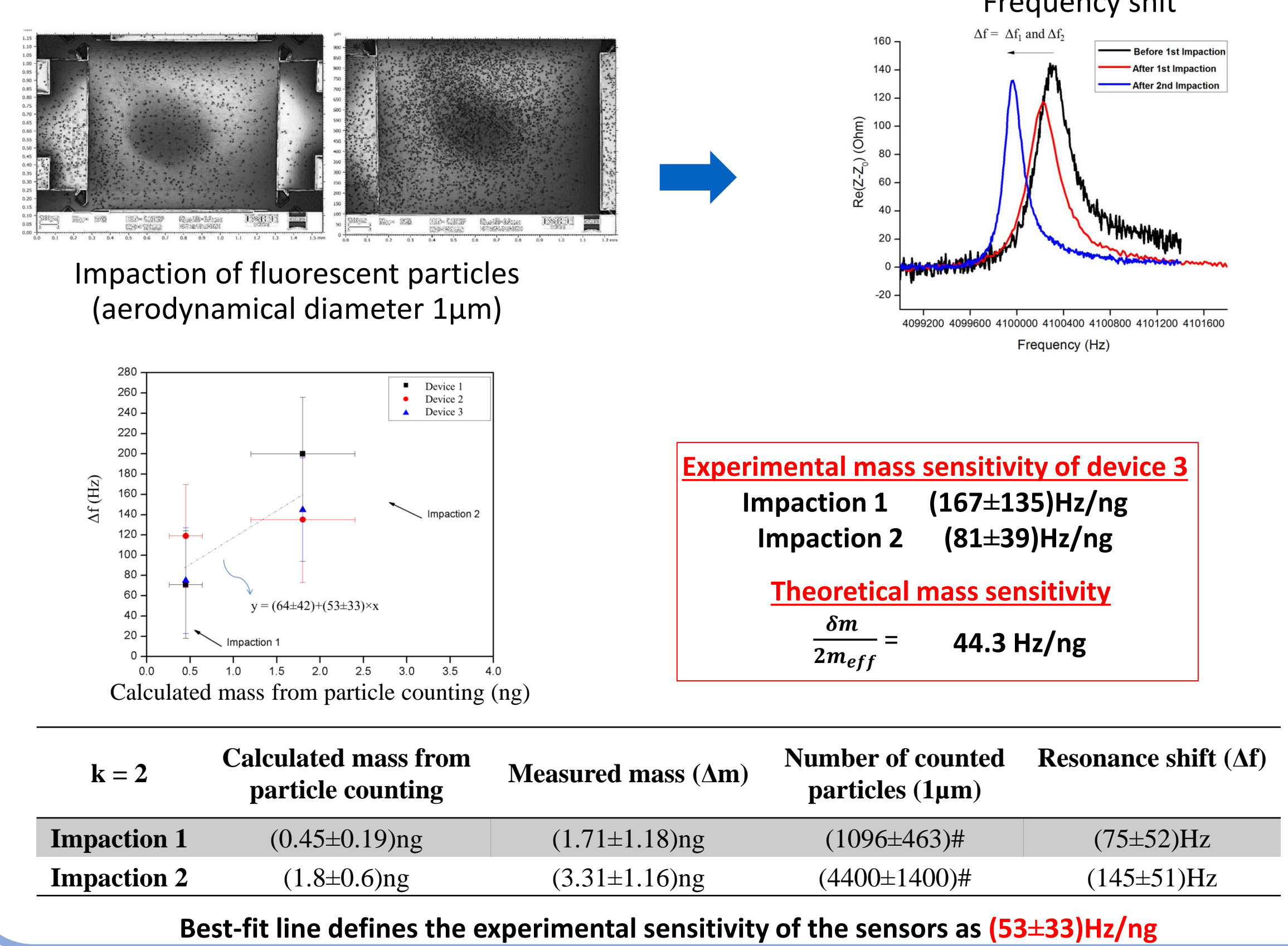
MEMS manufacture process



Measurement principle



Mass calibration experiment



Conclusions

- The impactor and the MEMS-type mass sensors have been successfully designed, fabricated, characterized and the sensors integrated into the impactor developed.
- The mass of the impacted particles is estimated by shifting the resonance frequency of the MEMS. The sensitivity is estimated at (53 ± 33) Hz/ng which agrees with the theoretical sensitivity of (44 Hz/ng).
- The proposed solution aims to obtain a micro-sensor allowing real-time monitoring while respecting regulatory directives and standards.

Future works

- Improvement of the sensitivity by modifying the surface structure.
- Development of the electrical measurement allowing the real-time monitoring
- Integration of the electrical part into the impactor system, in order to increase the reproducibility of the measurement.