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DIAMOND-BASED ACTIVE ANTIREFLECTIVE OPTICAL WINDOWS WITH OMNIPHOBIC PROPERTIES

¹Sirine Ben Khemis, ¹Emmanuel Scorsone, ²Raphael Guillemet

¹Université Paris-Saclay, CEA, LIST, F-9112, Palaiseau, France

²Thales Research & Technology, Palaiseau, France

sirine.benkhemis@cea.fr

Industrial context

Infrared windows are among the key optical components in infrared detection systems with military and civil applications. However, the optical properties of these systems, commonly used in severe environmental conditions, can be altered due to the formation of biofilms or contaminants deposition. To protect these systems, we propose to extend the functionality of these optical surfaces, by developing robust « active » diamond windows allowing them to be fitted with anti-dirt, anti-fog and anti-icing properties. Once doped with boron, diamond has remarkable electrochemical properties, including the capacity of electrochemical self-cleaning of its surface. However, the high boron content also affects the optical transmission in diamond. Thus, the principal aim of the D-FACTO project is to investigate the boron doping level necessary to achieve the electrochemical self-cleaning properties of the diamond surface without deteriorating the optical transmission of the windows

Applications

Anti-reflective Optical Windows



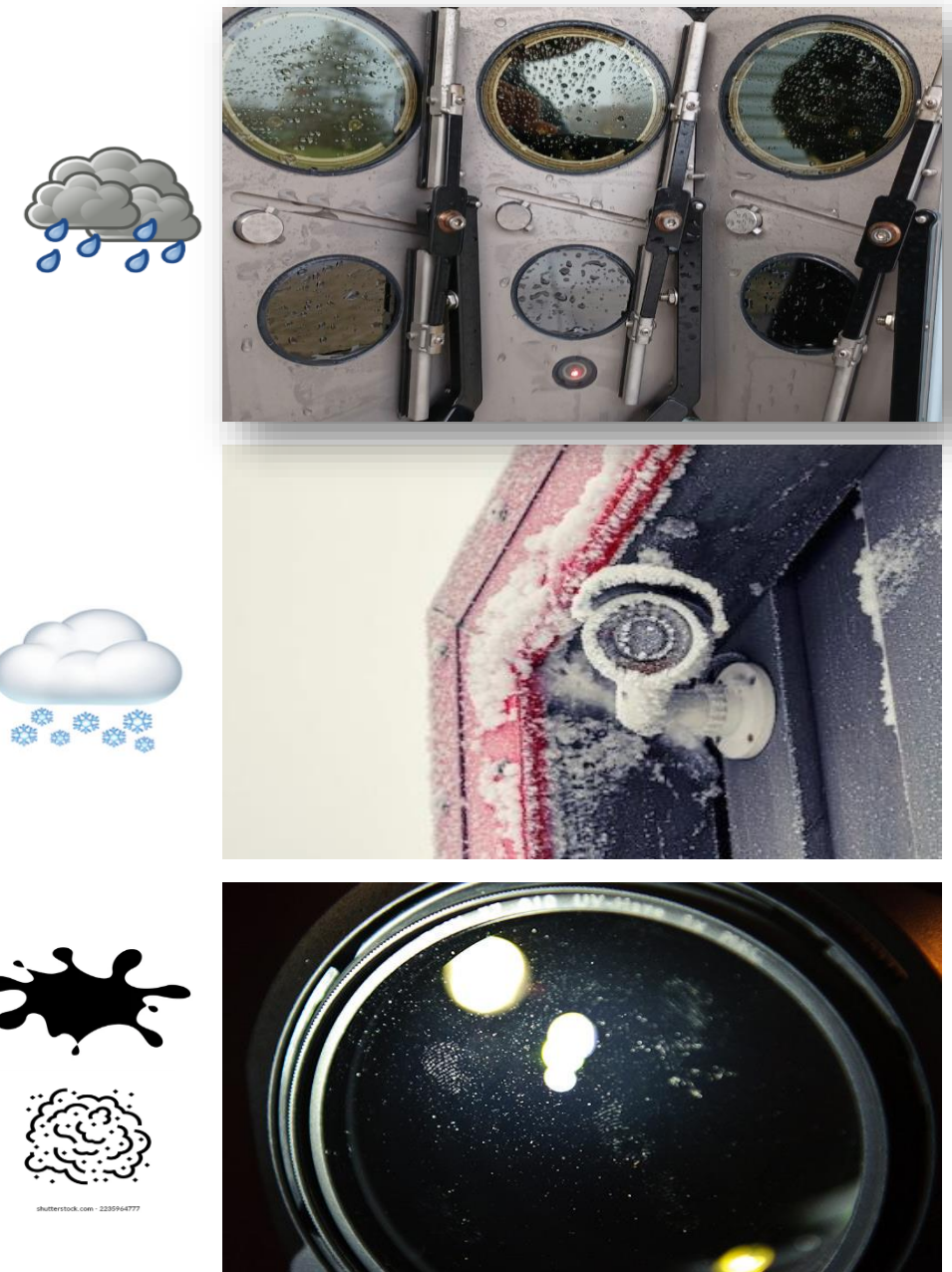
Surveillance systems



Airborne sensors

Industrial Issue

Harsh environmental condition



Effect of dust

Clearheaded footage



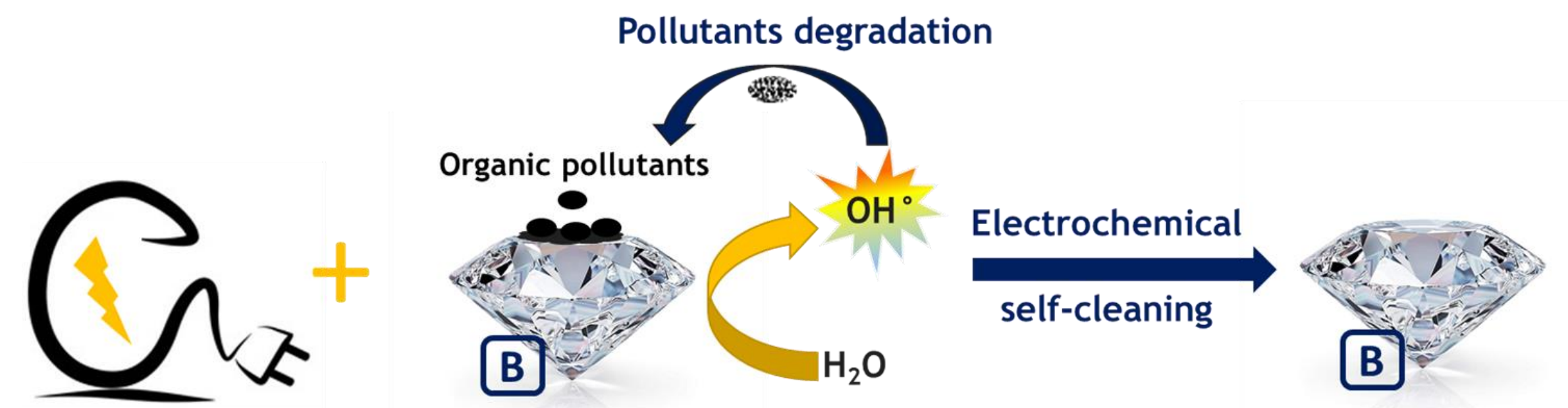
Dirt, Dust buildup

Blurry footage



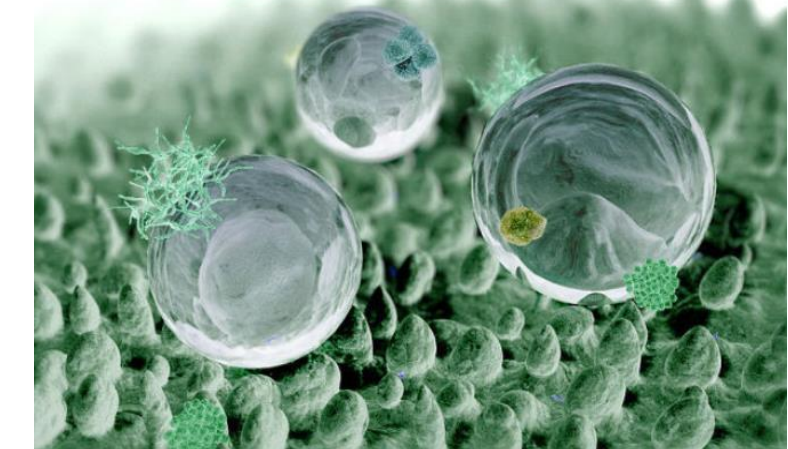
Solutions

1 Electrochemical Self-cleaning coating : Boron-Doped Diamond



2 Anti-reflective
Anti-icing
Anti-fouling

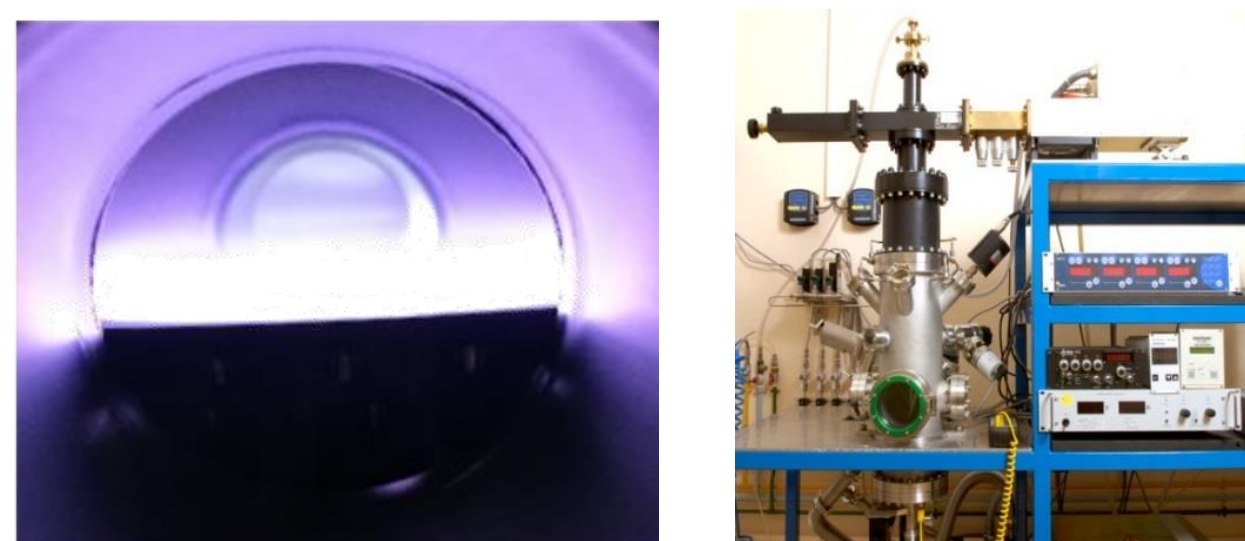
Nanostructuring



Diamond growth on optical windows

Boron-Doped Diamond (BDD) Film deposition

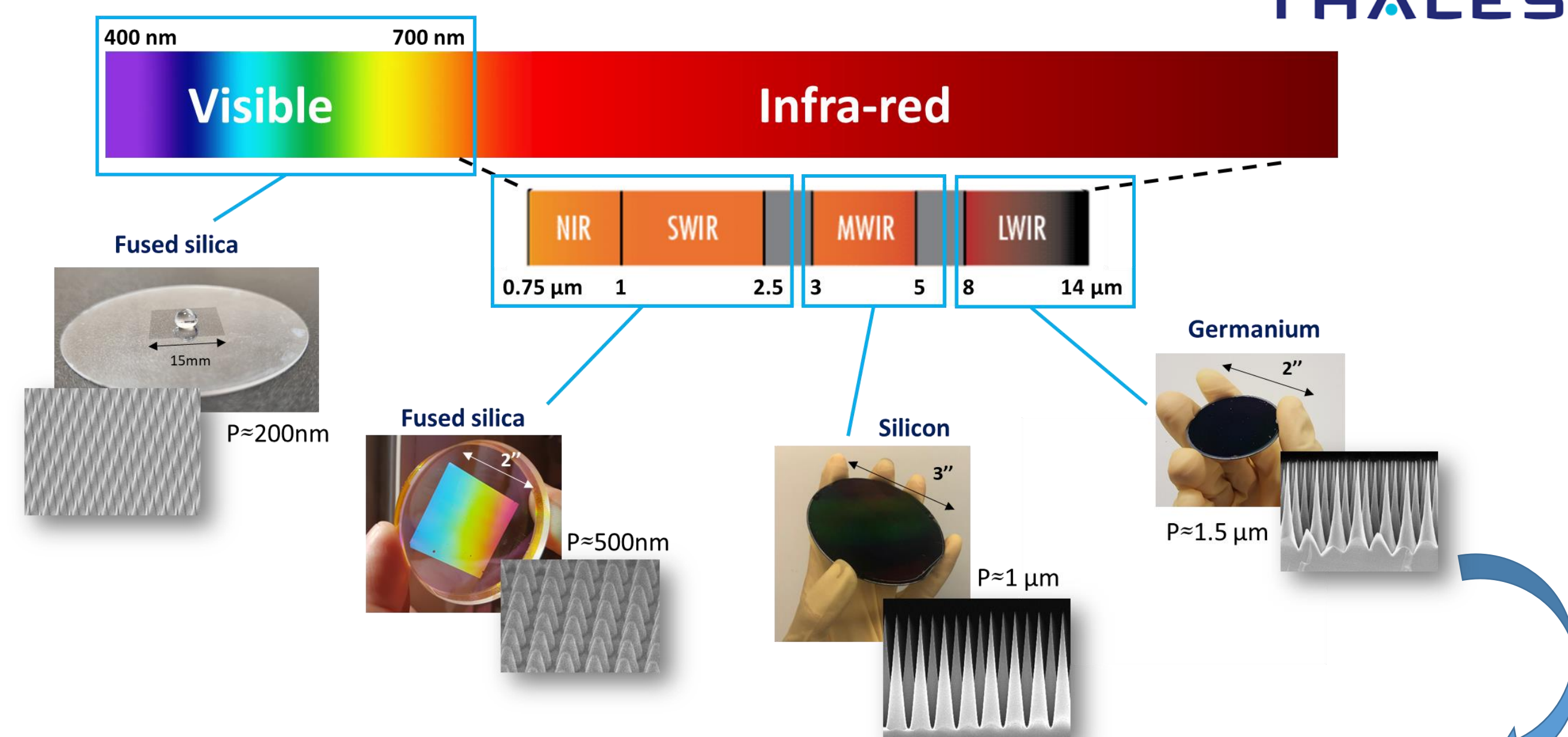
By MP-CVD in home-made reactor



Operating conditions:

- Gas : CH₄, H₂, TMB
- 500 < T °C < 900
- P mBar ~ 30

Optical windows

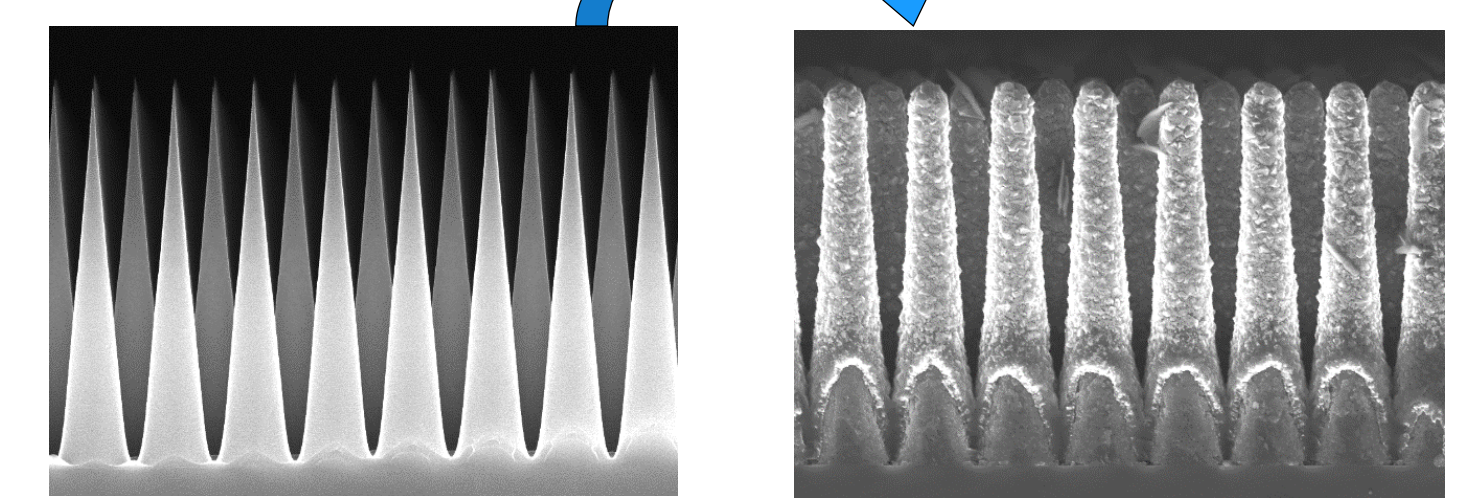


Challenge: diamond growth on Germanium (no carbide formation, low melting point, large thermal expansion mismatch between diamond and Ge) C.A. Rego, et al., Diamond and Related Materials, Volume 3, Issues 4-6, 1994

Nanostructuring

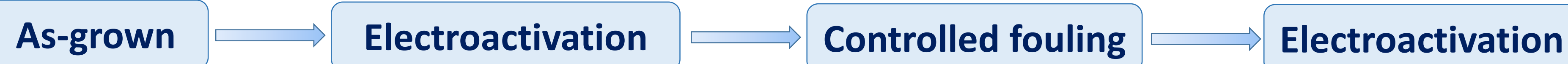
Polycrystalline diamond on nanostructured silicon surfaces

Diamond deposition

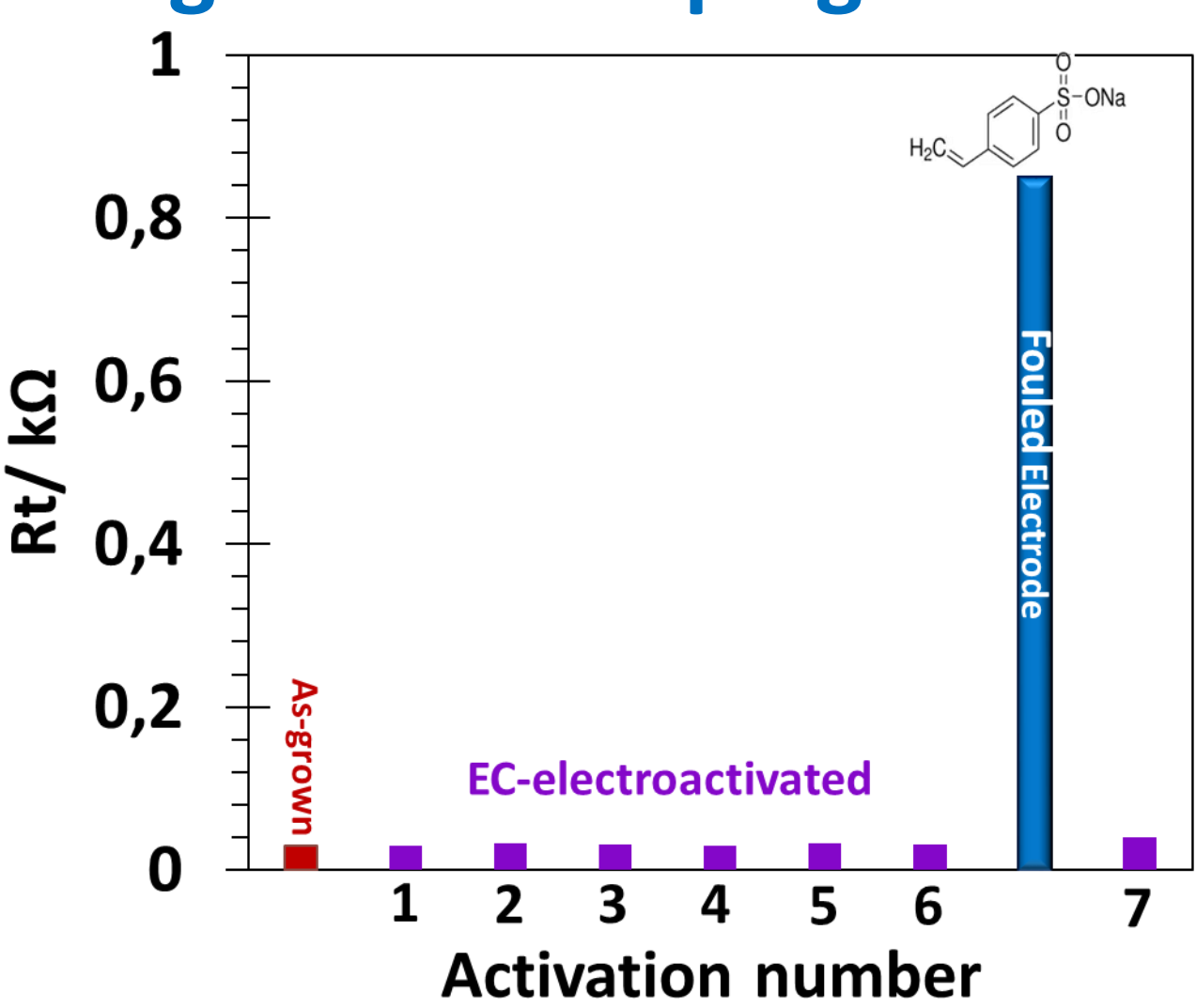


Electrochemical Self-cleaning

Electrochemical impedance spectroscopy (EIS) characterization



High-Boron doping $2 \times 10^{21} \text{ B.cm}^{-3}$



➤ Significant impact of the Boron doping on the charge transfer resistance (Rt) of the BDD electrode

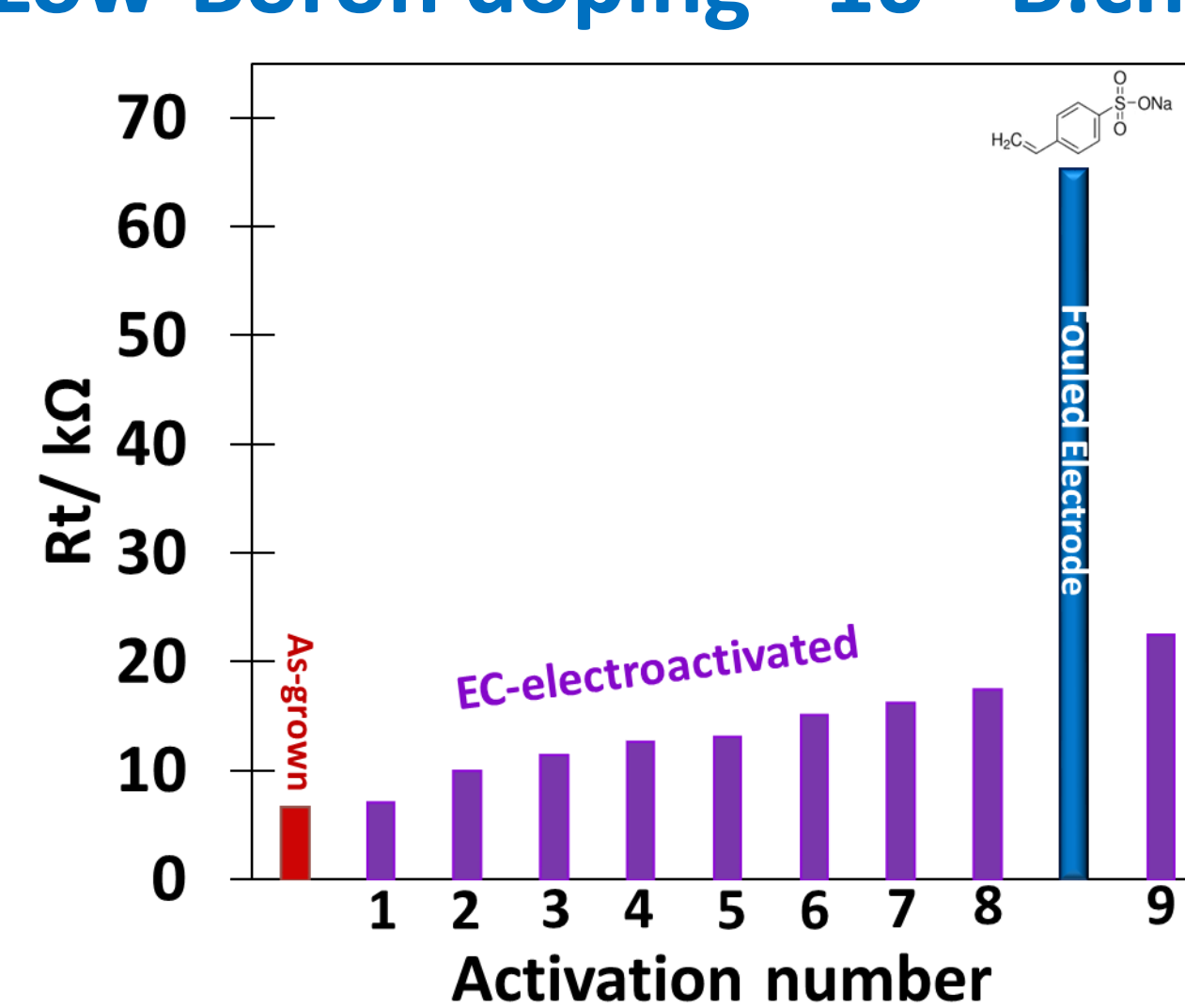
➤ Stability of the electrode after each activation « cleaning »

➤ Efficient cleaning after electrode fouling

➔ The boron content in the diamond film impacts the stability of the electrode to the activation process

Evolution of the surface termination

Low-Boron doping $\sim 10^{19} \text{ B.cm}^{-3}$



➤ Evolution of the electrode after each cleaning
Increase in Rct ⇔ Decrease of the electrochemical reactivity

➤ Efficient cleaning after electrode fouling
BUT still drifts from Rt of the as-grown electrode

Conclusions & Perspectives

➤ High boron content is well known to favor high electrode reactivity and efficient self-cleaning when using current pulse cleaning. But it drastically affects optical transmission in the IR region

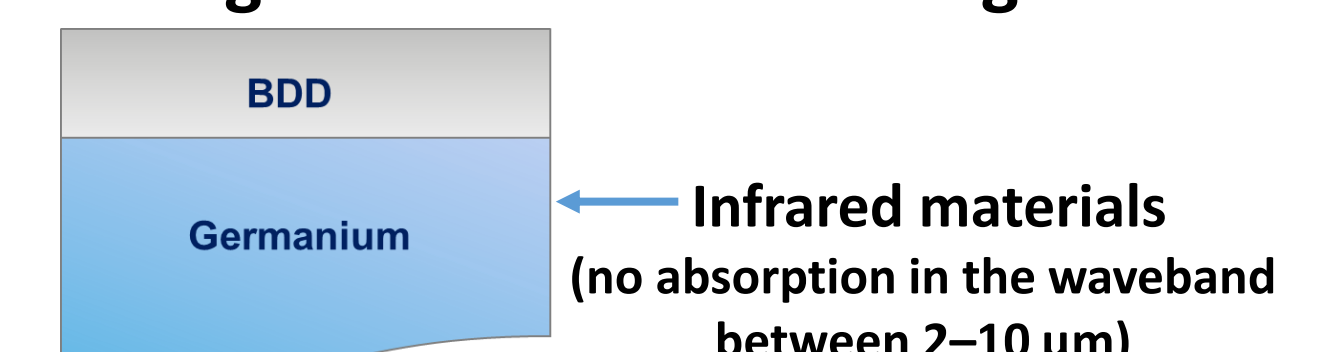
➤ Reducing too much the boron content affects cleaning efficiency and electro stability



➤ Low-Boron doped diamond: Investigating the evolution of the surface termination and/or the bulk material after successive pulsed activation.

➤ Investigation of the boron doping level necessary to achieve the electrochemical auto-cleaning properties of the diamond surface without deteriorating the optical transmission of the windows.

➤ Optimisation of the stack thin films to enhance the adhesion strength of BDD film on the germanium.



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