Optically active hBN defects to probe single charge dynamics at solid/liquid interfaces

M2 internship/PhD thesis

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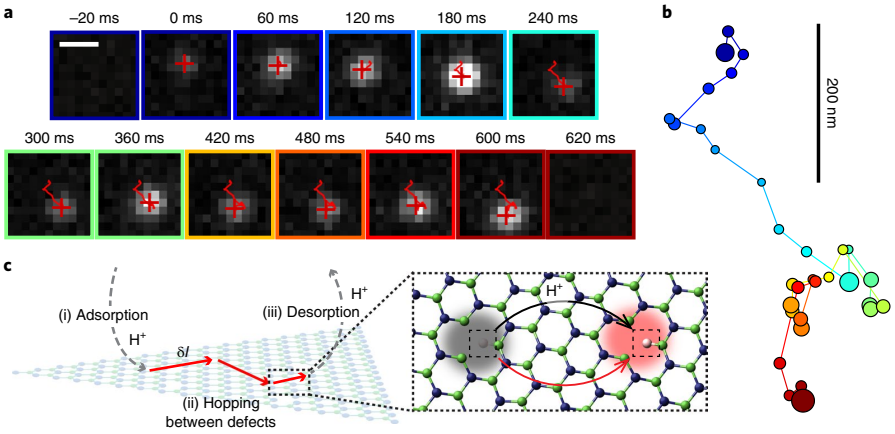
Understanding the **transport and dynamics of ionic charges at solid-liquid interfaces** is relevant to a variety of domains, from energy harvesting or energy storage, to catalysis, nanofiltration or electrochemistry [1]. However, fundamental understanding of these dynamic interfacial processes remains poor, due the difficulties in obtaining surface-specific information at both high **spatial** and **temporal resolution**. In this context, we recently demonstrated that optically active defects hosted at the surface of 2D hexagonal Boron Nitride (hBN) crystals can be used as optical markers to **track the motion of single H^+ proton charges at the hBN/liquid interface**. Applying **Single Molecule** and **Super-Resolution Microscopy techniques**, we could **reveal single excess proton trajectories through the successive protonation and activation of optically active defects at the surface of the crystal** [2, 3] (see Figure).

The aim of the internship is to take advantage of this **unique experimental system**, to investigate **at the single charge scale** various **out-of-equilibrium effects taking place at solid/liquid interfaces**. Relying on standard microfabrication techniques, we will couple the Single-Molecule Localization Microscope with electronic, ionic and fluidic transport measurements on micro or nanofluidic channels encapsulating the hBN surface. Coupling these averaged transport measurements with observations of the dynamics at the single-defect level, we will probe how the dynamic of single charges couples with external fluidic and electric forcings applied to the interface. These observations will help us to get novel **single-charge insights** on a variety of **out-of-equilibrium dynamic processes** taking place at solid/liquid interfaces. The internship can be followed by a PhD.



***Luminescence migration reveals proton trajectories**. **(a)** Time series for spatial migration of luminescence at the surface of the flake. Scale bar, 500 nm. Projected pixel size is 100 nm. **(b)** Reconstructed trajectory, colour-coded with increasing time. **(c)** Schematic depicting luminescence migration events, consisting of successive (i) proton adsorption (appearance of a luminescence spot at the surface of the flake), (ii) excess proton hopping between surface defects (diffusion of the luminescence spot) and (iii) proton desorption from the surface of the flake (disappearance of the luminescence spot).*

References :

[1] Bonn et al., Water at charged interfaces. ***Nat. Rev. Chem.*** 5, 466–485 (2021).

[2] Comtet et al. Direct observation of water-mediated single-proton transport between hBN surface defects. ***Nature Nanotechnology***, 15(7), 598-604. (2020).

[3] Comtet et al. Anomalous interfacial dynamics of single proton charges in binary aqueous solutions. ***Science Advances*** (2021).