Manipulating single polarons on oxide surfaces

D. Wrana[1,2*], I. Sokolović[3], J. Redondo[2], P. Kocán[2], A. Alexander[2], L. Albons[2], U. Diebold[3], M. Setvin[2]

[1]*M. Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland*
[2]*Department of Surface and Plasma Science, Charles University, Prague, Czech Republic*
[3]*Institute of Applied Physics, TU Wien, Vienna, Austria*

dominik.wrana@uj.edu.pl

A polaron is a quasi-particle consisting of an electric charge interacting with its surrounding lattice distortions in a solid. In polarizable materials, polarons are directly responsible for electronic and optical properties as well as surface chemistry reactions [1]. The size and mobility of polarons depend on the strength of the electron-lattice coupling, as well as the temperature of the material. On oxide surfaces, polarons are usually localized in entities spreading over a few unit cells, therefore making them perfect subjects for the Atomic Force Microscopy (AFM) investigations. Contrary to Scanning Tunnelling Microscopy/Spectroscopy (STM/STS) this approach enables investigations not only of conductive samples but also localized polarons formed at insulators.

In this presentation, the possibilities offered by non-contact AFM will be showcased for the cases of polar and non-polar perovskites ($KTaO_3$(001) and $SrTiO_3$(001)) and hematite (α-Fe_2O_3(1-102)) surfaces. It will be presented that with the use of a conducting oscillating qPlus sensor it is possible not only to controllably inject electron- or hole-polarons but also to shape them into clouds and manipulate with the atomic resolution (see Fig. 1). Such an approach offers also the possibility to deduce the energy barriers for thermally-activated mobility of polarons as well as get insights into the catalytical reactions on surfaces, which will be showcased for the case of CO adsorption on $KTaO_3$(001), a polar perovskite surface. It will be presented that the low-noise nc-AFM enables real space measurements down to the scale of single charges.

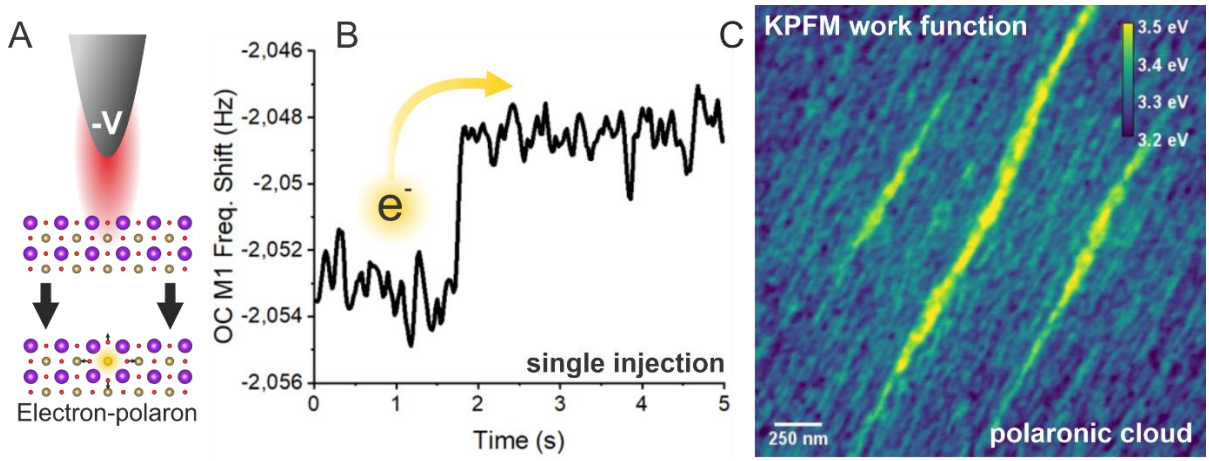

Fig. 1. (A) nc-AFM as a tool for precise manipulation of polarons. From a single electron polaron injection (B) to a microscopic polaronic cloud (C) formed on the surface of $KTaO_3$(001) perovskite (nc-AFM + KPFM loop).

[1] Franchini, C., Reticcioli, M., Setvin, M., & Diebold, U. (2021). Polarons in materials. Nature Reviews Materials, 6(7), 560-586.