On-surface molecular sensors for application in neutrinoless double beta decay experiments

Celia Rogero [1], A. Yubero-Navarro[1,2], A. Candia[3], J. Lobo-Checa[3], D. Serrate[3]
[1]Centro de Física de Materiales (CFM), 20018, Donostia (Spain)
[2]Donostia International Physics Center (DIPC), 20018, Donostia (Spain)
[3]Instituto de Nanociencia y Materiales de Aragón (INMA), 50018, Zaragoza (Spain)

Contact@E-mail (Arial 9)

Abstract (Arial 10)

If neutrinos are their own antiparticles, a very rare nuclear process (T1/2 > 1026 yr) called neutrinoless double beta decay can occur. An unambiguous observation of such decay would open a window to answer transcendental questions beyond the physics known today, like the Universe preference for matter over antimatter or the origin of neutrino masses.
To succeed, experiments looking for these decays need to work in a highly controlled and hard-to-reach background-free regime, for which a technique called barium tagging is being developed. This technique consists in identifying the Ba2+ daughter ion generated in 136Xe double beta decays.
Recent studies [1,2] profit from the atomic resolution provided by STM to study molecular sensors with the expected ability to trap individual Ba2+ ions inside a chamber of thousands of kg of Xe gas, achieving the zero-background regime that experiments need. By bringing surface science and particle physics together in this way we expect to obtain a new perspective onto the research developed by multiple groups worldwide.
In this study we present the results obtained for the molecular sensors called FBI (Fluorescence Bicolor Indicators) adsorbed on a Au(111) surface, studied by STM and STS.
Our findings are that depending on the isomer of the sensor, these molecules arrange in different geometries (see Figure 1), and that this arrangement depends in turn on the molecular coverage, which can be controlled. We also report that the molecular interactions, forming monomers and dimers, affects the electronic structures, as their HOMO-LUMO gaps differ, and so are expected to do their fluorescent behaviors. This way, monomers and dimers could be distinguished by optical fluorescence setups.
Furthermore, we show that the proportion of monomers and dimers on the surface can be tuned by the deposition of ions such as Ba2+ or Fe2+, as these ions break dimers into monomers, thought to happen due to the chelation of the sensors by these ions. This, together with the finding that the gaps for monomers and dimers differ, allows us to prove that FBI-G2 sensors provide an effective way to detect the deposition of ions for the eventual application in single ion detection experiments.

References

[1] P Herrero-Gómez et al. Ba+2 ion trapping using organic submonolayer for ultra-low background 0νββ decay detector. Nature Communications, 13(1):7741, 2022.
[2] Iván Rivilla et al. Fluorescent bicolour sensor for low-background neutrinoless double β decay experiments. Nature 583(7814):48–54, 2020.

Figures

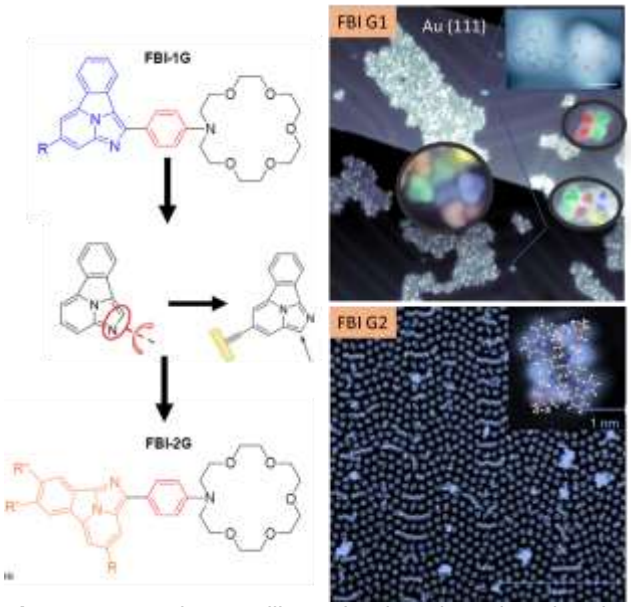

Figure 1. STM images illustrating how just changing the isomer (rotating one bond) the molecular arrangement changes from island formation to molecular dimmer formation.