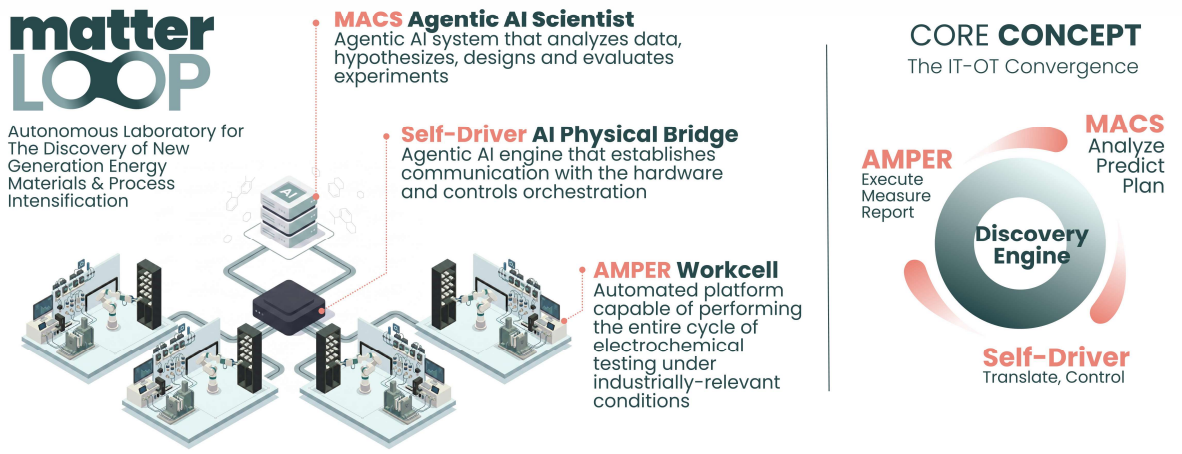
Automating flow electrochemistry with AMPER

Damian Giziński[1, †], **Shahnauze Ahsan**[1], **Julio Lloret Fillol** [1]

[1]Institute of Chemical Research of Catalonia (ICIQ), The Barcelona Institute of Science and Technology, Avinguda Països Catalans 16, 43007 Tarragona, Spain
corresponding author's email: dgizinski@iciq.es

The utilization of carbon dioxide (CO_2) as a feedstock for producing value-added chemicals represents a pivotal step toward a circular economy, with electrochemical CO_2 reduction and green hydrogen serving as critical target applications for the clean energy transition. However, catalyst development is severely bottlenecked by labor-intensive experimental workloads and widespread communication protocol fragmentation across laboratory hardware.

To resolve these limitations, we introduce the Autonomous Modular Platform for Electrochemistry Research (AMPER) that brings us closer to closed-loop self-driving laboratory (SDL) engineered to accelerate the discovery, synthesis, and validation of advanced electrocatalytic materials. This concept establishes integrated information technology and operational technology (IT-OT) architecture structured across three hierarchical layers: a cognitive reasoning engine, an automated physical AI orchestration bridge, and an industrial-scale physical execution testing unit - AMPER.



AMPER integrates modular components, including a gas chromatograph, potentiostat, automated pumping systems, robotic arm and custom module for flow cell handling. Therefore, it provides an end-to-end platform for the automatic discovery of next-generation electroactive materials needed to accelerate adoption of sustainable fuel technologies by energy sector. By automating the testing and analysis phases, AMPER eliminates the need for manual intervention, streamlining the benchmarking of catalyst performance under industrially relevant conditions that preserve actual fluid, thermal, and electrochemical dynamics.

Moving forward, this platform is expected to be introduced further into a more elaborated MatterLoop SDL concept. In this advanced paradigm, AMPER serves as the foundational physical infrastructure for a self-driving lab operating system designed to manage multi-instrument campaigns across cross-vendor equipment.