AutoMEA – an automated electrolyser device for self-driving labs

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1. Introduction

Membrane electrode assemblies (MEA) are critical for device level testing in electrocatalysis applications, such as fuel cells and CO_2 utilization, owing to its efficiency, performance, and industrial scalability over alternative devices. However, conventional lab-scale MEAs suffer from labour-intensive assembly and human consistency. To address these challenges and enable higher throughput, intelligent experimentation, we present AutoMEA, a MEA device being designed to integrate a novel, automated assembly platform for integration into self-driving labs. The target use case is CO_2 conversion, but AutoMEA's modular design could be easily adapted to suit other electrochemical applications, including water splitting and electrodialysis for desalination.

2. Existing technology

Manual assembly of a MEA (illustrated in Figure 1) requires precise alignment and uniform clamping of the multiple stacked components. The performance of the cell is known to be influenced by the extent of compression [1, 2]. Therefore, even slight variations in bolt torque can hurt the reproducibility and credibility of the experiment.

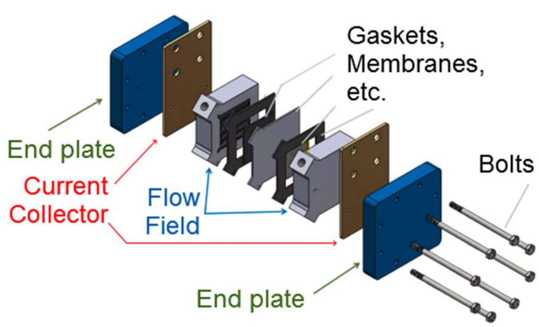

Fig. 1: Exploded view of an example conventional MEA. Adapted from [2].

Automating the clamping process takes away human error and was previously achieved hydraulically by Soni et al., accelerating their cell assembly by 14 times compared to a manual process. Their device was integrated into a workflow enabling the autonomous fabrication and characterization of gas diffusion electrodes [3].

Building upon this, AutoMEA incorporates sensors, controllers, and other mechatronic components, the combination of which has not been implemented before to elevate MEA experimentation even further. These additions not only provide more scientific insight about the samples being tested, but also diagnostic data that builds trust in experimental and operational reliability.

3. Design exploration

AutoMEA explores the feasibility of using stepper motors, which could be designed to move faster than a typical hydraulic system. The challenge is achieving speed, accuracy, and precision to ensure pressure is applied precisely and uniformly. Our approach is to use a combination of coarse and fine controls, as well as implement load and distance sensing for closed-loop control so that the samples are not crushed by accident. These sensors also enable the experimentalist to study the effect of compression on performance from stress-strain data. In addition, we are also exploring improvements in thermal control, potentially leading to insight on reaction thermokinetics and heating-cooling requirements at the industrial scale.

In our presentation, we openly discuss several of the design and control challenges encountered and how they were overcome, sharing valuable insight into MEA design and implementation into a self-driving lab environment. High-throughput experimentation in SDLs require devices that are both reproducible and adaptive to experimental variation without a prohibitive cost. Balancing these requirements simultaneously unlocks new capabilities in control and testing for many labs, extending beyond MEA experimentation.

4. Accessibility

AutoMEA emphasizes accessibility and modularity by prioritizing DIY components and accessible fabrication methods such as 3D-printing and simple CNC machining, the dependence on more proprietary and expensive options is mitigated. This approach significantly lowers the entry barrier for labs, even though the design is more complex than a conventional MEA. The modularity makes it easy for a researcher to repair or modify the device to suit their specific experimental needs.

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