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Improvement of oxygen evolution reaction (OER) performance in water electrolysis by multiple bubble removal methods

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Background

As a result of the sustainable approach to alleviating worldwide crises such as air pollution and energy demand, the hydrogen sector has attracted industrial attention. Hydrogen production is a green solution to produce and store energy, by which we can respond to diverse applications, for instance, transportation, chemical industry, power sectors, etc.[1] Further research and development are needed, however, to increase the efficiency of water splitting and to be comparable with current fossil fuel-based power plants economically. Water splitting is suffering from slow kinetics of oxygen evolution reaction (OER) that takes place at the anode side. This inefficient OER performance is attributed to electrode activation, mass transportation, ohmic resistance, and bubble formation, which means a higher potential than **1.23V** (theoretical potential) is needed to start the reaction. This excessive potential (**overpotential**) can be reduced with different strategies such as bubble removal from the electrode surface[2].

Improvement of OER performance by bubble removal

Electrode	Rotat-ion	Sonicat-ion	WE orientation (°)	Sonotrode orientation (°)	Current (Ag^{-1}_{Ir})	η (mV)	Ir loss (%)
W0	No	No	0	-	144	392	**1.7**
W90	No	No	90	-	242	340	5.7
R1600	Yes	No	0	-	218	346	4.1
W0-S90	No	Yes	0	90	317	310	3.2
W0-S90-R	Yes	Yes	0	90	**380**	307	3.9

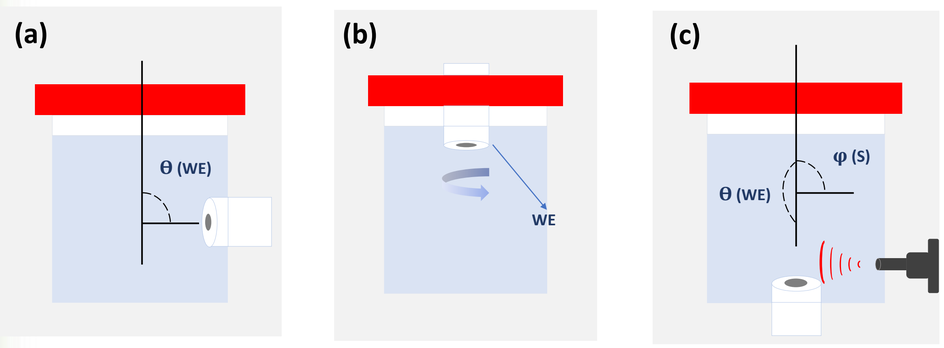


Figure 1. (a) Orientation, (b) rotation and (c) sonication setups for bubble removal

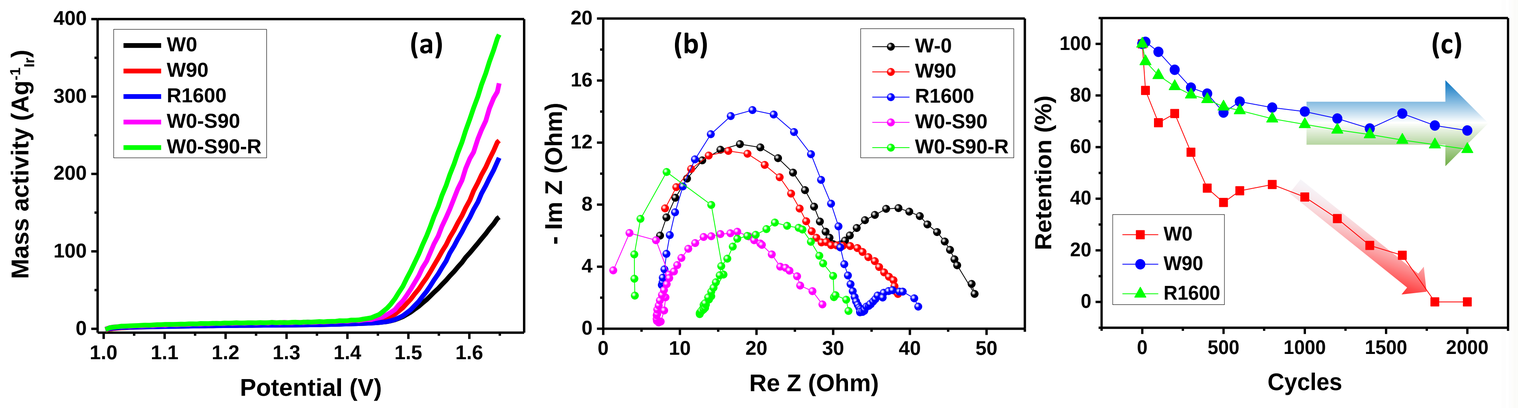
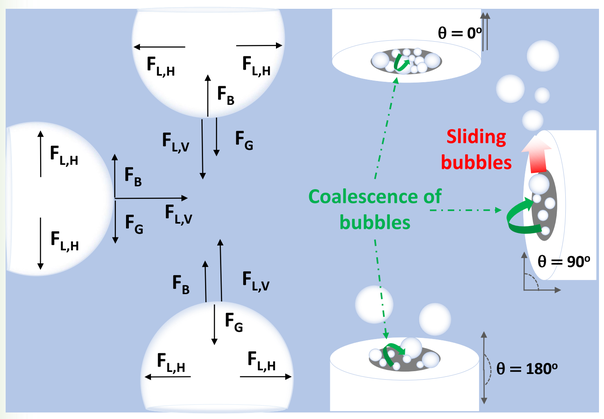


Figure 2. (a) Polarization curves showing the effect of bubble removal methods using different configurations, rotation, and sonication (b) corresponding EIS spectra and (c) Stability test for different samples

- Using 90° setup configurations improved OER activity by **68%**
- Convection caused by rotation reduces **mass transport** in the electrolyte significantly
- Applying both sonication and rotation increased output current by **164%**[3]
- **Overpotential** decreased up to 22% when the electrodes were modified by simultaneous sonication and rotation
- Extreme bubble removal via sonication resulted in minimum charge transfer

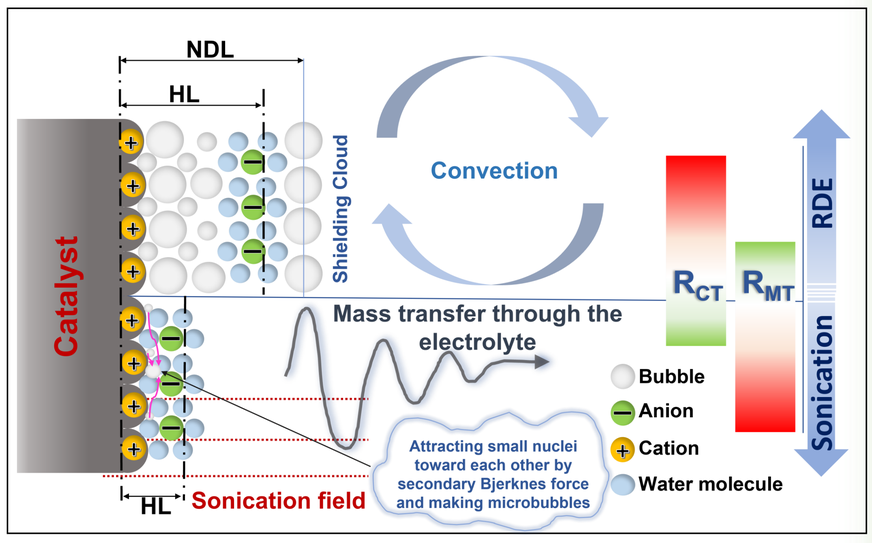
How bubble removal promotes OER?



- **Coalescence** and **sliding bubbles** are the main phenomena responsible for bubble removal without external force
- Horizontal and vertical **Laplace forces** accelerate the bubble removal process in 90° and 180° orientation of the working electrode, respectively[3]

Figure 3. Bubble attachment process in various orientations of the working electrode during water electrolysis

Figure 4. shows the phenomena resulting in bubble release due to centrifugal and ultrasonication fields in the three-electrode setup



- **Convection** facilitates mass transport through the electrolyte during rotation
- The **Shielding cloud** impedes charge transfer in the rotation modification
- **Sonication** releases the bubbles on the surface and within the network
- Mass transfer resistance increases due to of presence of the sonication field

Future works

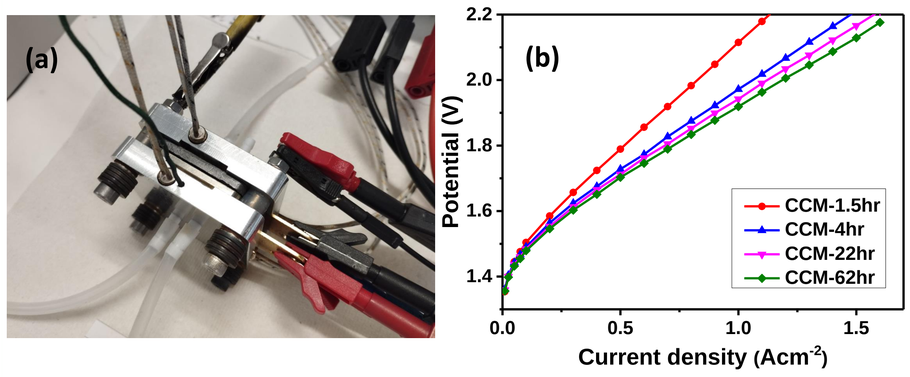


Figure 5. (a) single cell electrolyzer operating at 80°C and 2 $mLmin^{-1}$ (b) Performance of the cell for various activation time

- Improving the performance of electrolyzer by 250 mV at 1 $Acm^{-2}$with increasing activation time.

There are three reasons which make attaining complete insight into the water-splitting process a challenging subject[4]:

- Altering surface structure during the experiment
- Availability of a small number of catalytically active sites
- The short lifetime of electrochemical active centers

Our goal is to improve the performance of the single cell and to visualize the water splitting process using multi-scale imaging methods

References

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