

Stirring-Free Scalable Electrosynthesis Enabled by Alternating Current

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Overview

Electrochemical transformations are unfavorable while using conventional direct current (DC) electrosynthesis. The main reason is the interelectrode mass transfer, which serves as a major limiting factor for the overall efficiency and the process's selectivity. Here we provide a new method for stirring-free scalable electrosynthesis using an alternating current (AC) electrolysis. Our suggested design relieves the need for convective mass transfer and allows an easy approach for stirring-free scaled-up electrosynthesis in the electrochemical cell, which is simple to use and construct.

Background and Unmet Need

The vast majority of the electro-synthetic transformations are performed using habitual batch or flow reactor designs. Batch reactors are used extensively for laboratory-scale electrosynthesis and screening experiments due to their extreme simplicity and availability. In the reactor design, stirring usually plays a major role in the mass transfer of the redox-active species from the bulk solution to the surface of the electrodes. However, this mode of mass transfer severely limits the potential and the use of the conventional stirred batch reactors for scaled-up electrosynthesis. Improving the up-scaling efficiency comes at the expense of the significantly increased cost and the construction and application complexity of the system. Moreover, switching from one reactor design to another is often required to perform the electrosynthesis on different scales. Currently, there is no universal solution that would enable efficient scaled-up electrosynthesis as a flow reactor and, at the same time, be simple enough for the construction and its further application as a stirred batch reactor.

The Solution

Dr. Sergey Semenov and his team invented a novel method for a stirring-free design of the electrochemical reactor based on alternating current (AC) electrolysis, thus enabling electrosynthesis on different scales.

Technology Essence

AC electrolysis can, in some cases, serve as an efficient tool for mild and selective electrosynthesis. Furthermore, it may be particularly beneficial for the application in redox-neutral transformations where both cathodic reduction and anodic oxidation processes equally contribute to the formation of the final product. In our design, the periodical switch of the polarity of the electrodes, inherent to AC, allows both processes to occur at the surface of the same electrode. Thus, it eliminates the need for the interelectrode mass transfer, which could otherwise be a major limiting factor for the process's overall efficiency and selectivity, as in direct current (DC) electrolysis. In addition, the AC-derived principle of the polarity switch can ensure that both anodic oxidation and cathodic reduction can take place across the whole volume of the batch reactor, tightly packed with the stack of three-dimensional mesh/foam-like electrodes (metal meshes, reticulated vitreous carbon, carbon felt, etc.). With the small enough size

of pores of the electrode material (low pores-per-inch (PPI) values), the mass transport of the redox-active species from the inner pore volume to the electrode surface can be successfully implemented solely through diffusion.

Applications and Advantages

- Industrial-scale electrolysis.
- Speciality chemical and pharmaceuticals
- Performs the whole range of electrochemical transformations.
- Performs electrolysis in stirring-free conditions.
- Works with viscous solutions and easily handles higher substrate concentrations.
- Maximizes the reactor's working volume/number of electrodes.
- Enables high throughput experimentation (HTE) for the electrochemical screening on a variable scale.
- Enhanced control over the process's selectivity.
- Simple and available design.

Development Status

Dr. Semenov and his team invented a new method that enables mixing-free scalable electrosynthesis. The team demonstrated the five redox-neutral processes as well as net-oxidative and net-reductive transformations, performed in three different RVC-packed reactors. Their concept implies a straightforward way for scaling up the electrosynthesis, as was demonstrated on up to 50 mmol scale reactions.

Market Opportunity

Stirring-free scalable electrosynthesis is a technology that uses electrochemistry to produce chemicals and materials without the need for stirring or mixing, making it a more efficient and environmentally friendly alternative to traditional chemical synthesis methods. All types of electrochemical transformations can be successfully performed using an AC-enabled reactor, including oxidative, reductive, and redox-neutral processes, and enables industrial electrosynthesis. This technology has various market opportunities: It provides a more efficient, sustainable, cost-effective, and greener alternative to traditional chemical synthesis methods which often rely on fossil fuels and generate hazardous waste and produce a range of chemicals and materials, including pharmaceuticals, polymers, and specialty chemicals; produce energy storage materials, such as batteries and supercapacitors, which are in high demand as the world transitions to renewable energy sources; produce fertilizers and pesticides, which are essential for modern agriculture more sustainably and efficiently, reducing the environmental impact of agriculture; treat wastewater and remove pollutants, such as heavy metals, from water sources in more efficient and cost-effective method compared to traditional water treatment; use to produce active ingredients for personal care products, such as cosmetics and skin care products in a more sustainable and environmentally friendly way.

Patent Status

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