Electrochemical Production of Hydrogen Peroxide: Process, Components and Applications

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Ten Fraunhofer Institutes led by the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT have joined forces to work on the Fraunhofer lighthouse project ”Electricity as a Resource”. Their aim is to develop and optimize processes that enable low-carbon power to be used to synthesize important base chemicals. This lecture presents results of a subproject on the electrochemical and decentralized production of hydrogen peroxide, H_2O_2.

H_2O_2 is considered one of the most versatile and powerful chemical oxidants for a wide range of chemical reactions. It is environmentally friendly, selective and also highly active for various oxidation processes including paper and pulp bleaching, waste water treatment or disinfection processes. Today, hydrogen peroxide is mainly produced in world-scale production facilities consuming not only huge quantities of energy and organic solvents but also generating substantial quantities of waste. Moreover, large scale production processes of hydrogen peroxide require significant logistical resources concerning transport, storage and safety.

In contrast, the key element of the here presented small-scale process is an on-site and on-demand production concept for H_2O_2 to avoid the transport, storage and handling of huge amounts of highly concentrated hydrogen peroxide. The process is based on the electrochemical synthesis of H_2O_2 generated either by the cathodic reduction of oxygen or the anodic oxidation of water. In both cases no organic solvents are used. At the heart of the process are continuously operated electrochemical reactors employing tailored catalysts and electrodes to enhance selectivity and restrain decomposition reactions. Thereby the cathodic partial oxygen reduction is performed at optimized gas diffusion electrodes with ultrathin platinum active layer. This catalyst proofed to give higher H_2O_2 yields than Pd_xAu_y/C catalyst which have also been investigated. The anodic production is achieved at boron doped diamond (BDD) electrodes. The synthesis is conducted in acidic electrolytes which are later separated in a continuous downstream process and can be re-used in the electrochemical cell. Moreover, a new generation of proton conductive membranes has been developed based on polyphenyl chinoxaline block copolymers exhibiting not only an excellent thermo-oxidative and chemical stability but also a significantly reduced fluorine content compared to classical perfluorosulphonic acid (PFSA) membrane type materials like Nafion® or others being used in electrochemical cells.

The on-demand small-scale H_2O_2 synthesis unit can be directly connected to subsequent chemical processes where hydrogen peroxide solutions are required. This is presented here for an exemplary continuous desulfurization process. As a consequence, the downstream processing of the electrochemical synthesis includes also a concentration step, where beforehand purified H_2O_2 is concentrated to the single-digit percentage range as it is typically required in fine chemical oxidation processes. Raman spectroscopic process analysis allows tracking of the hydrogen peroxide concentration almost in real-time along the entire process chain (synthesis, separation, concentration, and hand-over to subsequent process).