Gas-diffusion electrocrystallization (GDEx): A versatile technology for the synthesis of (electro)catalytic nanomaterials

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The gas-diffusion electrocrystallization (GDEx) process is an electrochemical method for the reactive precipitation of metals in solution as nanoparticles using oxidising or reducing agents produced in situ by the electrochemical reduction of a gas in a gas diffusion electrode. This process offers a unique opportunity for synthesising crystalline nanomaterials with well-controlled properties for a wide range of applications. Here, the general principles and mechanism by which GDEx operates, as well as some examples of nanoparticles (NPs) produced with GDEx and their functionality, are presented.

The GDEx process offers a broad spectrum of materials synthesis as the nature of the product depends on the gas used. For instance, when O_2 is used (O_2-GDEx, Fig. 1a), it is electrochemically reduced to H_2O_2 and OH^-, which then react with the metals in solution, producing metal (hydro)oxide nanoparticles (NPs). O_2-GDEx has been applied to synthesise magnetic Fe oxides, Zn-Cu hydroxychlorides, and Mn-Co (hydr)oxides [1]. On the other hand, when CO_2 is used (CO_2-GDEx, Fig, 1b), the electrochemical reduction of CO_2 to CO and H_2O to H_2 occurs. CO and H_2 serve as reducing agents for the metals in solution with a standard reduction potential that is negative enough. In specific cases, CO can also serve as a capping agent. The CO_2-GDEx process has been used to synthesise mono and multimetallic NPs of precious metals (i.e., Pt, Pd, Rh, and Au) [2]. Furthermore, both processes can be combined to synthesise metal oxide/precious metals nanoparticles, showcasing the vast potential of GDEx in materials synthesis. In the same way, GDEx-made nanomaterials can serve as (electro)catalysts in a vast range of reactions, i.e., oxygen evolution reaction or alcohol oxidation.

The GDEx process offers several advantages over traditional methods as a nanoparticle synthesis method. For example, GDEx does not require the addition of additional reagents (besides the targeted metals) that can lead to the formation of undesired byproducts, reducing costs and environmental impact. Furthermore, the GDEx process is easily scalable and can meet industrial requirements. Due to its selectivity, the GDEx process can be applied to metal-containing waste streams, directly recovering these metals into functional nanomaterials that can be incorporated directly within existing processes. Overall, the GDEx process offers exciting opportunities for synthesising nanomaterials with well-controlled properties, which could be used in many catalytic applications.

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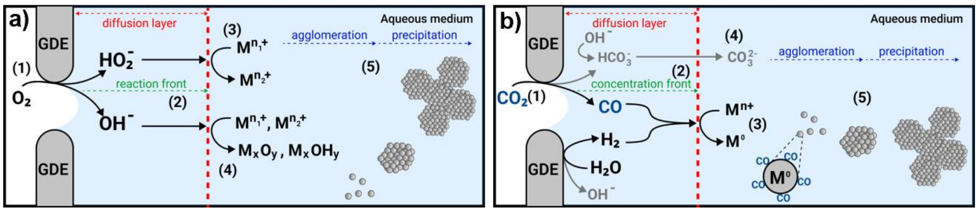

Figure 1: Schematic illustration of the GDEx process. a) O_2-GDEx, b) CO_2-GDEx.

References

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