Sono-Electrochemical Preparation of Platinum Nanoparticles For PEM Fuel Cells Anode Modification

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A series of experiments is presented with the primary aim of sonoelectrochemical synthesis of platinum nanoparticles (Pt NPs) from aqueous chloroplatinic acid solutions with use of polyvinylpyrrolidone (PVP) as surfactant. Furthermore, a sonoelectrochemically assisted decoration of carbon black (CB) nanoparticles, used as substrate, with Pt NPs is also investigated. Size dependence of NPs from various parameters is examined, namely pulse duration, current density and PVP concentration.

Pt nanoparticles can be utilized as an electrocatalyst in various electrochemical power sources, such as fuel cells (FC anode electrocatalyst) and dye sensitized solar cells (DSSC cathode electrocatalyst) [1,2]. The water-soluble PVP polymer chains adsorb on the forming Pt NP surface, acting as an inhibitor of spherical NP growth, promoting reduction of grain size and at the same time as a steric capping agent that stabilize NPs against agglomeration[3]. PVP-capped Pt NPs are usually prepared with the aid of a reducing agent, such as hydrogen, or methanol[4]. The alternative sonoelectrochemical method, presented here, does not require flammable reagents, has low energy demands (room temperature procedure) and gives good control over NP size.

For the nanoparticles synthesis, a method that combines galvanostatic electrodeposition with low-frequency ultrasonication (20kHz) is deployed[5]. A titanium alloy horn acts as both the cathode and ultrasonic emitter, thus referred to as sono-electrode, controlled by a potentiostat and a sonication device. During synthesis, a sequence of successive current and ultrasound (US) pulses is applied (Fig. 1). Constant-current pulses, causing Pt electroplating, are followed by ultrasonic pulses, which scale the Pt off from the surface, forming NPs. The process is automated and synchronized by appropriate hardware and software.

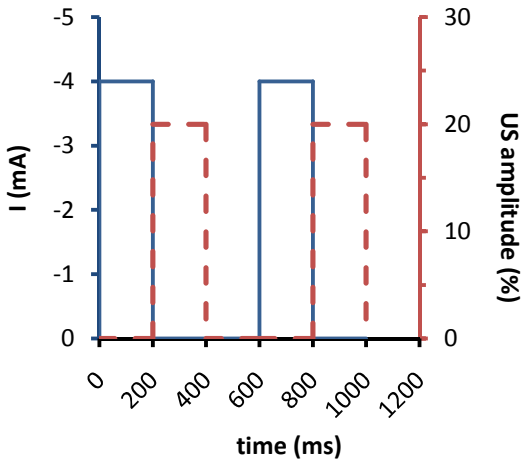

Fig. 1: Example of repetitive cycle. Galvanostatic pulse (solid line) and ultrasound pulse (dashed line).

Characterization of the resulting suspensions by the methods of dynamic light scattering (DLS) (Fig. 2), UV-Vis spectroscopy, TEM (Fig. 3) and SEM microscopy, showed that Pt NPs and NP agglomerates, with diameters in the ranges 6-10 nm and 14-25 nm, respectively, were formed. Precursor solutions and suspensions were also electrochemically characterized by cyclic voltammetry (CV).

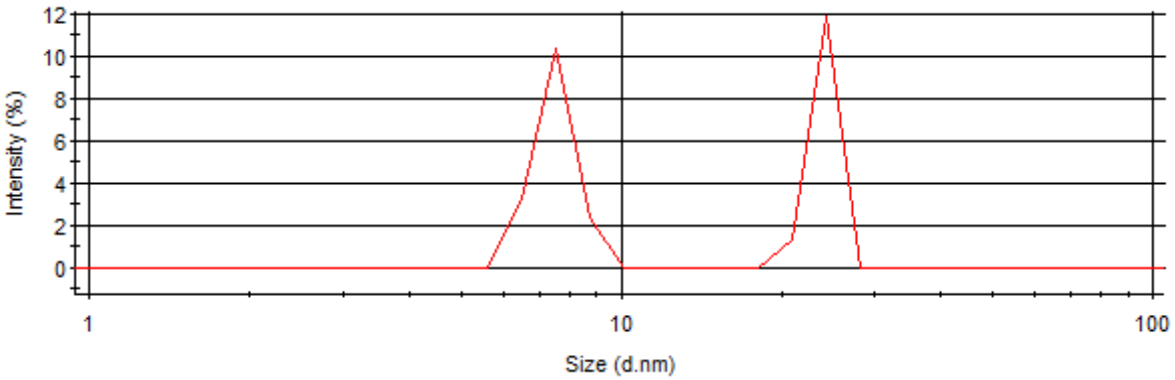

Fig. 2: DLS size distribution by intensity for one sample of Pt NPs.

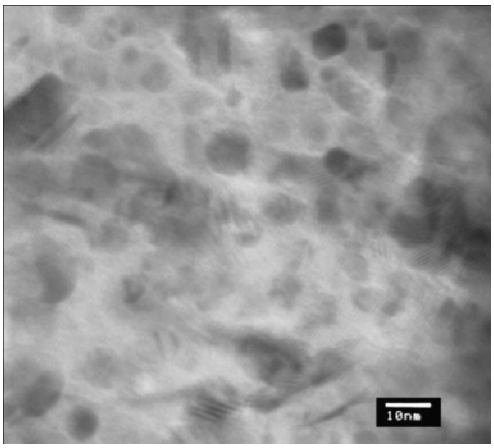

Fig. 3: TEM image of sono-electrochemically prepared Pt NPs

References

1. Bruno G. Pollet, International Journal of Hydrogen Energy 35 (2010) 11986-12004.
2. You-Jung Song, Jae-Kyung Oh and Kyung-Won Park, Nanotechnology 19 (2008) 355602-355608
3. Iris Haas, Sangaraju Shanmugam, and Aharon Gedanken, J. Phys. Chem. B (2006) 110, 16947-16952
4. Sarah Jaber, Pamela Nasr, Yan Xin, Fatima Sleema and Lara I. Halaoui, Phys.Chem. Chem. Phys. 15 (2013) 15223
5. Valentina Zin, Bruno G. Pollet, and Manuele Dabalà, Electrochimica Acta 54 (2009) 7201-7206.