Dry deposition of electrosprayed liquid suspensions

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Keywords: Electrospray, Aerosol deposition; aerosol-based nanotechnology, polymeric fuel cell, catalytic layers
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Granular materials formed by accumulation and adhesion of incoming aerosol particles acquire a morphological structure controlled by the form of the constitutive particles and by the way that these particles arrive and attach to the forming material (Garcia-Ybarra *et al*, 2012, Castillo *et al*, 2013).

Monte Carlo simulations of aerosol deposits (Rodriguez-Perez *et al*, 2005 and 2007) have shown the trends for controlling the deposit structure and indicated some ways to prepare granular materials from nanopowders with tailored morphology depending on their final use. A step forward in nanomaterial research consists in the performance of experimental studies that could confirm these theoretical predictions. Thus, an experimental set-up has been implemented to generate nanoparticles in a gas that are later on driven towards a collecting surface (Martin *et al*, 2012). In this study, a standard catalyst ink commonly used for preparing electrodes valuable for proton exchange membrane fuel cells (PEMFC) has been used (Martin *et al*, 2013).

The electrospray technique is used to generate nearly monodispersed sprays of small electrically charged droplets from this liquid suspension. In the electrospray cone-jet configuration (Martin *et al*, 2012) the jet breaks up forming a cloud of tiny droplets with a narrow distribution of droplet sizes. These charged droplets evaporate along their flight in the gas leaving dry charged nanoparticles which are driven by the electric field towards the collecting surface. The arriving nanoparticles accumulate on the collector plate forming a structured granular deposit.

The efficiency in the capture of the electrosprayed particles may be substantially improved if an opposite voltage, respect to the needle, is applied to the collector substrate. In this double polarization scheme, the electrospray cone-jet domain may be substantially enlarged by a proper selection of the voltage at the collecting plate and a noticeable increase in the flow rate range for electrospraying in the cone-jet mode can be achieved (Martin *et al*, 2011). Therefore, the double polarization can be used to control the electric field at the needle tip (which indeed is the key factor for achieving a stable cone-jet electrospray) as well as the electric field at the collecting plate.

In the case of low conductivity suspensions electrosprayed at moderate flow rates (♦ points in Fig.1) the deposit is formed by fractal-like structures composed by clusters (of a few catalyst particles each) arranged in a dendritic way. The dendritic arrangement of the catalyst clusters results in a highly porous deposit with an enhanced permeability and increased active surface. One may expect that all these morphological properties of the granular material may lead to high catalyst utilization when used as a catalyst layer. For larger flow rates (◊ points in Fig. 1) the deposit is formed by patched clusters of thousands of single particles. Moreover, compact deposits appear when the flow rate is large enough (☐ and △ points in Fig.1). These compact deposits result from an incomplete evaporation of the droplets during their flight toward the substrate. The deposit is formed from wet suspensions with the ethanol evaporating later on.

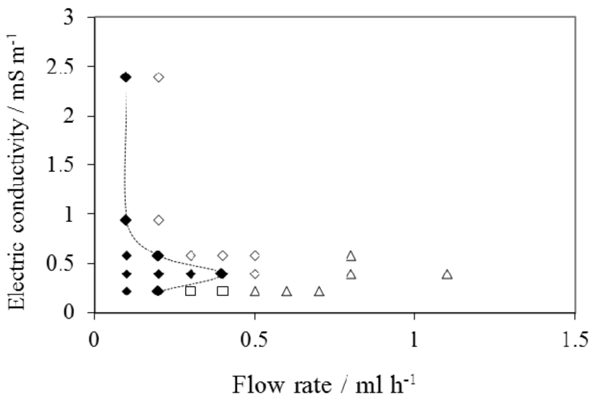

Figure 1. Phase diagram. Different types of deposit structure depending on the electric conductivity of the catalytic ink and on flow rate. Fractal-like deposits ♦, patched clusters ◊, and compact structures (☐ and △).

This work has been supported by the Ministerio de Economía y Competitividad (Spain) under Grant ENE2011-26868 and Program Consolider-Ingenio 2010 (CSD2010-00011) and also by Comunidad de Madrid (Project HYSYCOMB, S2009ENE- 1597).

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