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Superstructures of Colloidal Nanocrystals

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Gels and aerogels manufactured from a variety of nanoparticles available in colloidal solutions have recently proven to provide an opportunity to marry the nanoscale world with that of materials of macro dimensions which can be easily manipulated and processed, whilst maintaining most of the nanoscale properties. The materials carry an enormous potential for applications. This is largely related to their extremely low density and high porosity providing access to the capacious inner surface of the interconnected nanoobjects they consist of. The aerogel materials may be further processed in order to achieve improvements in their properties relevant to applications in optical sensing and catalysis.

The commercialization of polymer electrolyte fuel cells (PEFC) is still hindered by the cathode electrocatalyst for the oxygen reduction reaction (ORR) not fulfilling the criteria of low cost, high performance, and high durability. We recently developed a facile strategy for the controllable synthesis of nanoparticle-based bimetallic Pt_xPd_y aerogels with high surface area and large porosity, which act as highly active and stable catalysts for the ORR in PEFC cathodes. In addition to excellent durability the Pt_xPd_y aerogels show superior electrocatalytic activity towards the ORR with the $Pt_{80}Pd_{20}$ aerogel exhibiting a five times mass activity enhancement compared to commercial Pt/C catalysts. Extensions of this strategy will briefly be outlined.

In a further study, we prepared and analyzed a new class of hierarchical aerogels composed of multimetallic Ni-Pd_xPt_y nanoparticle building blocks (NBBs) with continuously engineered shape and compositions. This approach results in aerogels with hierarchical structures organizing the nanoscale regulated architecture and macroscale three-dimensional network structure, leading to an abundance of exposed edges and a high surface area.

In a final example we`ll line out how core-shell structuring of pure metallic aerogels can be tuned towards highly efficient Pt utilization for the oxygen reduction reaction.

The reminder of the presentation will be devoted to a) ordered superstructres of nanoparticles, and b) nanocrystals incorporated into macrocrystals of varying compositions. The ordered superstructures (mesocrystals) are composed of IV-VI semiconductor nanocrystals (8 – 15 nm in diameter) and stretch to dimensions in the 100 micrometer range. In the latter superstructures the nanocrystals exhibit remarkable photostabilities and enhanced emission quantum yields holding promise for colour conversion applications.

Acknowledgement
We thank the European Research Council (ERC AdG AEROCAT - 340419) for financial support.