Enhanced Chemoresistive Gas-Sensors from Cross-Talk with Heterogeneous Catalysys. Principles, Synthesis and Applications

Mauro Epifani
IMM-CNR

The properties of nanocrystalline materials related to environmental, catalytic and energy storage applications are strongly influenced by the chemical and structural properties of the surface. Hence the surface modification of nanocrystalline structures attracts intense applicative and fundamental interest. For instance, an oxide nanocrystal surface covered with a layer of another oxide may constitute the nanosized counterpart of bulk catalytic systems. This initial concept was successfully developed for enhancing the sensing properties of anatase nanocrystals by deposition of V_2O_5 and WO_3-like species. The successful application of catalytic concepts in the performance improvement of chemoresistive gas-sensors stimulated the search for other possible applications of heterogeneous catalysis. In this work, first the principles underlying the achieved colloidal chemical synthesis will be reviewed, showing that they are possible by suitably coupling suitable sol-gel chemistry with solvothermal processing. Then, the range of obtained structures will be discussed, with particular focus onto the complex structural evolution of the materials depending on the heating temperature and on the achieved surface composition. A review of the gas-sensing properties of these systems will then be shown. Four different well-known catalytic systems will be reviewed, e.g. TiO_2-V_2O_5, TiO_2-WO_3, SnO_2-V_2O_5 and TiO_2-MoO_3. The different systems span a range of structures, from surface modification to true nanocomposites to nanocrystal wrapping by oxide-like layers. For TiO_2-V_2O_5 and TiO_2-WO_3, a response improvement to acetone and ethanol up to two orders of magnitude with respect to pure TiO_2 was observed, demonstrating the effectiveness of coupling different oxides in synergistic configurations. For SnO_2-V_2O_5, the response enhancement to ammonia with respect to pure V_2O_5 will be used for demonstrating the properties change of thin, non-crystalline V_2O_5 layers with respect to the bulk counterpart, due to interaction with the SnO_2 core material. It will be finally shown that deposition of MoO_3 is able of boosting the sensing of reducing gases like acetone and ethanol with respect to very inert pure anatase.
Overall, these results will be meant to illustrate the potential of interdisciplinary approach to the design of materials and operating principles.