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# Gold supported on ceria nanoparticles and nanotubes

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ABSTRACT

The ceria nanotubes with different size have been prepared *via* a hydrothermal treatment of $CeO_2$ nanoparticles at 120 °C with two different NaOH concentrations (5 or 10 M) for 36 h. The synthesized ceria samples characterized by SEM, TEM, XRD, and UV–visible spectroscopy were used as supports for $Au/CeO_2$ catalysts preparation by DP technique using $HAuCl_4$ as gold precursor and urea as precipitation agent. The formation of gold nanoparticles (Au NPs) has been studied by TEM, *in situ* UV–visible–mass analysis at temperature programmed reduction and XPS spectroscopy. Three distinguishable steps in the formation of Au NPs accompanied by profound ceria reduction particular for ceria nanotubes have been found. Au NPs stabilized on the ceria nanotubes have been characterized with higher activity in CO oxidation than those supported on ceria nanoparticles. The structure and redox treatment of ceria nanotubes affects size of Au NPs and their catalytic activity in CO oxidation. Pre-oxidized $Au/CeO_2$-nanotubes manifest the highest activity in CO oxidation.



## 1. Introduction

The unique catalytic properties of supported gold species were studied extensively during the past decades. The remarkable ability of these materials to catalyze different reactions at low temperatures is attributed both to the presence of Au atoms with low coordination state on the surface of gold nanoparticles (Au NPs) and the mutual interaction of Au NPs and support [1–7]. The key role of gold-support interface in CO oxidation was clear shown experimentally for ceria in [8], where drastic improvement of catalytic activity of gold films was achieved by their decoration with ceria nanoparticles. It was definitely shown that the active sites for the CO oxidation on $Au/CeO_2$ are located at the interface of $Au/CeO_2$. Similar effect of gold–ceria interface was found for CO oxidation reaction by the design of a set of ceria nanotower samples with the same surface area of Au and $CeO_2$ but different interfacial lengths [9].

Recent studies revealed that nanocrystalline $CeO_2$ used as support increases the activity of gold species in CO oxidation by two orders of magnitude in comparison with conventional $CeO_2$ [10–13]. The activity of Au NPs deposited on ceria nanorods in CO oxidation was higher than those supported on ceria nanoparticles [14]. It was established that not the crystallite size, but rather surface structure, more specifically the exposed surface planes of the crystalline $CeO_2$ support, is important for achieving a high redox and catalytic activity of Au NPs supported on ceria [14–17]. The strong effect of the crystal plane of ceria on the activity of gold species was confirmed for WGS reaction [18,19], low-temperature CO oxidation [14] and preferential CO oxidation [20,21]. Au NPs supported on {1 1 0} ceria planes presented as nanorods are more active in water gas shift (WGS) reaction than those stabilized on {1 0 0} ceria planes of nanoparticles or nanocubes [18].

At the present time, there are different techniques to prepare nanostructured ceria with different shape and size such as microwave assisted heating, flame spray pyrolysis, spray diffusion process, reverse micelles process/surfactant assisted, hydrothermal treatment, sol–gel, chemical vapor deposition, thermal decomposition of cerium organo-metallic compounds, template directed synthesis, alcoholthermal treatment, nonisothermal precipitation, etc. This wide set of techniques permits to fabricate ceria nanospecies in a shape of cubes, spheres, crystals, rods, wires, discs, plates, tubes, hollow spheres, pyramids, towers and flowers [9,18,19,22–24]. Among other techniques the hydrothermal treatment possesses extraordinary advantages of single step, low temperature, controlled composition and morphology, and high

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