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Colloidal Pd-Au catalysts for 5-HMF oxidation: Effect of particle composition

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Currently, the application of biomass becomes promising due to the high renewability of the feed as well as an opportunity to synthesize a wide spectrum of valuable compounds including useful side products such as 5-hydroxymethylfurfural (HMF) formed during the refining [1]. The HMF is a multifunctional platform molecule used to synthesize various important materials ranging from healthcare products to polymers. Among others, the 2,5-furandicarboxylic acid (FDCA) is an important product of the HMF oxidation serving as an alternative source for polymer production and other syntheses [2].

Various catalytic systems were proposed for the HMF selective oxidation that influenced the selectivity towards the desired products [3], with the supported noble metals (Au, Pd, Pt, Ag, etc.) being the most abundant ones. To achieve better catalytic performance, different bimetal structures can be used [4]. However, more detailed understanding of the bimetallic catalysts is required including model unsupported systems.

The pulsed laser ablation (PLA) in liquids attracts attention as an alternative approach to obtain the high-purity colloidal particles in contrast to chemical methods that is characterized by the presence of various substances in the resulting suspensions affecting the properties of colloidal particles and limiting their applications.

This work is devoted to the study of effect of composition of colloidal Pd-Au catalysts prepared by the PLA in HMF oxidation.

The Pd and Au dispersions were prepared by the PLA of Pd and Au targets, respectively, in distilled water using Nd:YAG laser (1064 nm, 20 Hz, 7 ns). The $x\text{Au}100-x\text{Pd}$ ($x = 20, 40, 60, \text{ and } 80 \text{ wt.}\%$) dispersions were obtained by the PLA of mixtures of Pd and Au dispersions. The obtained samples were characterized by electrophoretic light scattering, UV-vis spectroscopy, and SAED. The catalytic oxidation of HMF were carried out in the Parr 5500 HR compact reactor under 5 atm O_2 and at 80°C for 22 h. The composition of catalytic mixture was analyzed by HPLC.

The UV-vis spectroscopy and SAED data clearly confirmed the formation of bimetallic AuPd particles in the $x\text{Au}100-x\text{Pd}$ dispersions. Thus, the characteristic absorption peak of Au NPs surface plasmon resonance (SPR Au) at 523 nm, which is present in the spectrum for the Au dispersion, disappears in the absorption spectra for the $x\text{Au}100-x\text{Pd}$ dispersions. The analysis of SAED data for Au, Pd and 60Au40Pd samples revealed that a lattice parameter a for AuPd particles (4.00 Å) lies between those of Au (4.07 Å) and Pd (3.95 Å). Besides, the electrokinetic characteristics of the dispersions indicate the changes of the surface properties for bimetallic AuPd samples in contrast with those of based on Au or Pd.

The results for catalytic HMF oxidation over the obtained samples show that the formation of bimetallic AuPd particles ensures higher activity and selectivity towards FDCA for all colloidal $x\text{Au}100-x\text{Pd}$ catalysts as compared with the Pd and Au samples. The best catalytic performance was observed for 60Au40Pd sample showing 40 mol.% FDCA yield against 7 and 6 mol.% FDCA yield for Au and Pd samples, respectively. These results indicate a synergistic effect in bimetallic AuPd NPs, with their composition strongly affecting the catalytic properties.

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