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Plasmonic photocatalytic reactor design: Use of multilayered films for improved organic degradation rates in a recirculating flow reactor

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Abstract: Plasmonic photocatalysis was investigated by examining both the arrangement of the photocatalyst and plasmonic components, and the structure and composition of the plasmonic phase. Pd was epitaxially grown on to 50 nm Ag nanocubes. The Ag:Pd ratio was optimized to blue-shift the plasmonic absorption peak to match the bandgap of TiO_2 (~405 nm). A ~5 nm Pd coating on the Ag nanocubes (Ag:Pd = 9:1) led to the observation of the Ag nanocube's plasmonic feature. The arrangement of the photocatalyst components was tested for degradation of model organics in a slurry and a recirculating thin film photoreactor. The results demonstrated that both the arrangement of the components and the structure and composition of the plasmonic material influenced the conversion. The TiO_2/Ag composite catalysts yielded slight improvement (in thin film reactor) or had a negative effect (slurry reactor) compared to TiO_2 which was attributed to scattering light away from the semiconductor photocatalyst and/or covering some active sites. The addition of the Pd shell on the Ag nanocube yielded improved performance compared to the TiO_2/Ag composite catalysts, likely due to electron trapping. A factor of 2 enhancement in rate and apparent quantum yield compared to TiO_2 was achieved for the Ag NC layer underneath the TiO_2 layer and was attributed to light scattering of absorbed photons. The addition of the Pd shell to the Ag nanocube still provided enhancement compared to TiO_2, but was lesser compared to Ag layer due to lower scattering efficiency. The results of this study provide insights for plasmonic photocatalytic reactor design. Best utilization of plasmonic enhancement to photocatalysis is indicated via a layered design of the plasmonic and photocatalytic phases.

Keywords: reactor design; layered catalyst film; heterogeneous photocatalysis; plasmonic; titania