

Optical Properties of Three-Layer Systems of Au Nanoparticles / Al₂O₃ / Pd (or PdO)

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Abstract

This work deals with plasmonic properties of gold nanoparticles (NP) in the triple-layers system comprising this NP, isolating (Al₂O₃) and conducting (PdO, Pd) layers. A sequence of the layers and use of semiconductor material (PdO) for conducting one distinguish the system from other studies. The used order of deposition enhances the stability of nanoparticles and their durability to external actions.

The influence of the thickness of Al₂O₃ isolating layer is studied on the optical spectra of triple-layer systems. The influence of material and thickness of conducting layer is investigated also. "Red" and "blue" shift of position of plasmon resonance of NP is observed depending on the thickness of Al₂O₃. Possible mechanisms of this shift are considered. The action of conducting layer is supposed as the main reason; depolarizing influence and shielding of interactions between adjacent NP are considered.

The dependence of shift value is shown also on the material and thickness of conducting layer.

The shape of optical spectra is only slightly changed in the case of Pd conducting layer, while for PdO conducting layer distortion of spectra is observed. Possible reasons for the system's behavior are examined.

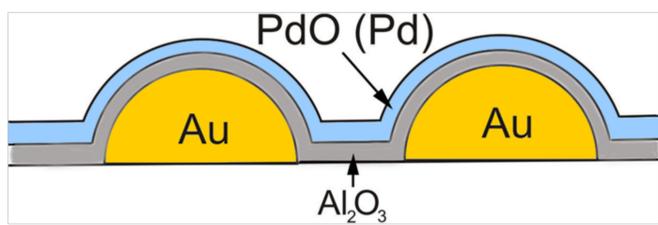


Fig.1 The order of placement of conductive and insulating layers

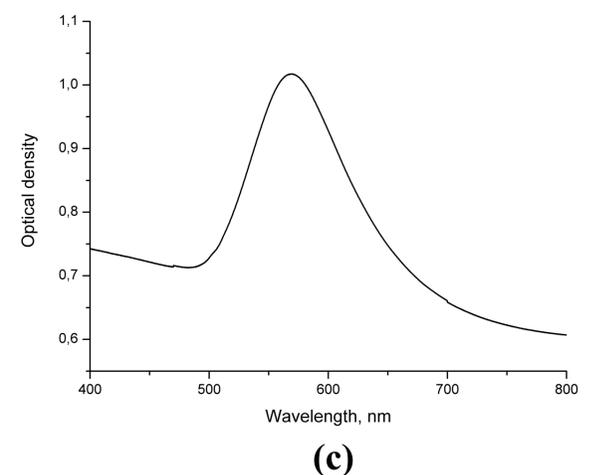
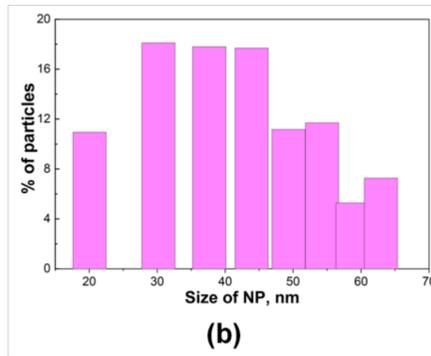
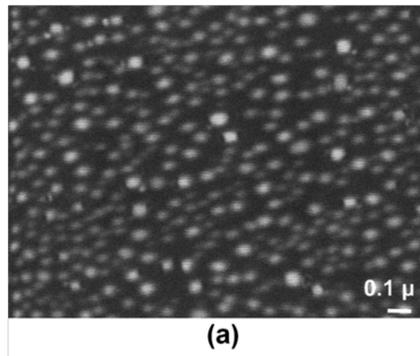


Fig. 2. SEM image of AuNP initial layer (a), NP size distribution (b) and extinction optical spectrum (c).

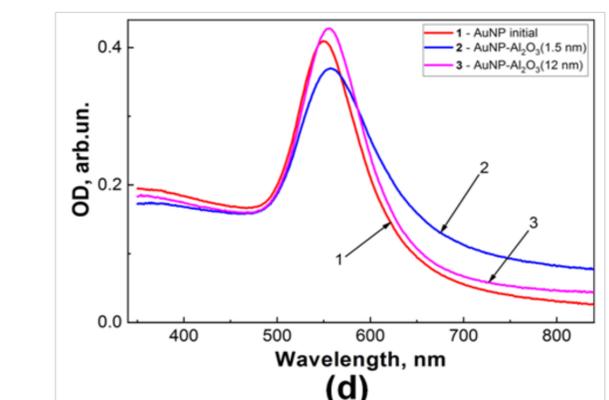
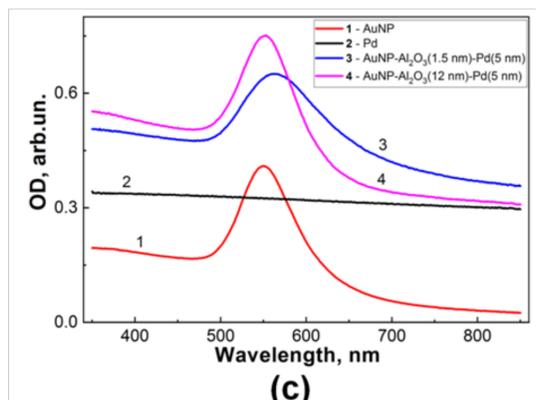
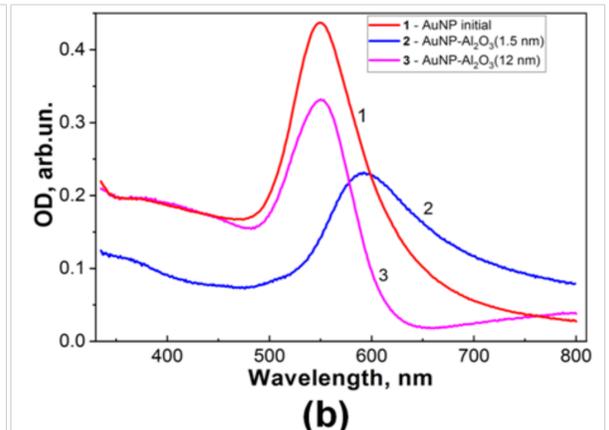
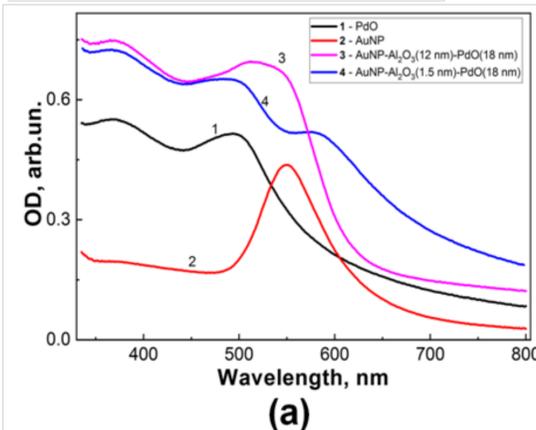


Fig.3. Extinction spectra for AuNP-Al₂O₃-PdO(18 nm) system for 1.5 nm and 12 nm thickness of Al₂O₃, and initial spectra of AuNP and PdO layer (a); calculated spectra of AuNP for 1.5 nm and 12 nm thickness of Al₂O₃ for AuNP-Al₂O₃-PdO (18 nm) system, and initial spectra of AuNP (b); extinction spectra for AuNP-Al₂O₃-Pd(5 nm) system for 1.5 nm and 12 nm thickness of Al₂O₃, and initial spectra of AuNP and Pd layer (c); calculated spectra of AuNP for 1.5 nm and 12 nm thickness of Al₂O₃ for AuNP-Al₂O₃-Pd(5 nm) system, and initial spectra of AuNP (d).

The following main features can be distinguished:

1. The largest variations are observed at the minimal thickness of Al₂O₃ layer. The most significant changes are obtained for the AuNP-Al₂O₃-PdO system.
2. Increasing Al₂O₃ thickness leads to a shift of plasmon resonance peak position of AuNP in different directions. The "red" shift of systems spectra is observed at the small thickness of the Al₂O₃ layer. But increasing thickness to 5–7 nm and more leads to a "blue" shift of peak position relatively to initial spectra of AuNP-Al₂O₃ for a given thickness of the Al₂O₃ layer.
3. The shift of peak position of AuNP-Al₂O₃ is substantially large for the AuNP-Al₂O₃-PdO system compare to AuNP-Al₂O₃-Pd one. It depends on the thickness of conducting layer for both materials of this layer.

Conclusions

1. It was shown that the deposition of a conducting layer leads to a significant shift in the plasmon resonance peak of Au NPs.
2. The direction of this shift depends on the thickness of the insulating layer, and at small thicknesses of this layer, a "red" shift is observed, and at large thicknesses, a "blue" shift.
3. Analysis shows that the "redshift" of the resonance peak is mainly due to the frequency-dependent dielectric characteristics of the conducting layer
4. The "blue" shift may be due to the shielding of the interaction of light-induced charges in neighboring NPs

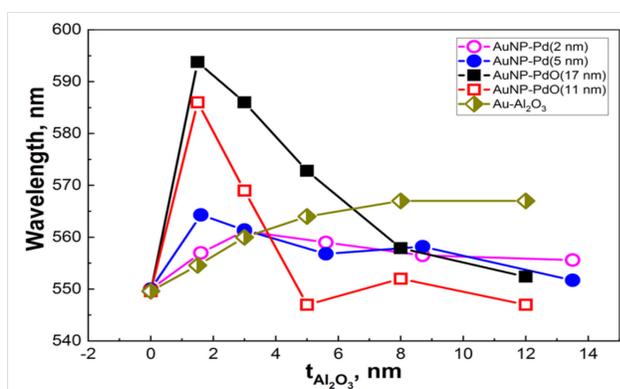


Fig.4. Dependences of peak positions of calculated spectra of AuNP on Al₂O₃ thickness for systems of AuNP-Al₂O₃-PdO (11 nm and 18 nm of PdO) and AuNP-Al₂O₃-Pd (2 nm and 5 nm of Pd). Experimental dependence of LSPR peak positions for initial AuNP-Al₂O₃ on Al₂O₃ thickness is presented for comparison.