DOCTORAL THESIS

Plasmonic properties of silver-based alloy thin films

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Abstract

The plasmonic properties of silver-based alloy thin films were studied. Silver-ytterbium (Ag-Yb) and silver-magnesium (Ag-Mg) prepared by thermal co-evaporation were investigated extensively for various thin film properties. The optical properties were intensively analyzed and discussed because the dielectric response of a material is particularly significant in terms of its plasmonic properties. The study of silver-based alloy thin films has been mostly about Ag alloying with other transition metals, but the results of Ag-Yb and Ag-Mg in this work showed that the intensity of plasma resonance is tunable, in which the idea may also apply to other silver-rich binary alloy thin films regardless of the kind of second metal components.

In our research, the Ag plasma resonance was weakened with respect to the concentration of Yb and Mg in the alloy thin films. The change in the optical characteristics around Ag plasma resonance frequency was attributed to an increase in "resonance damping". This is confirmed from modeling using classical free-electron theory. The increase in the damping was experimentally corroborated by the concentration dependence of electrical conductivity and estimated average crystallite size of Ag-Yb and Ag-Mg thin films. The reduction in electrical conductivity was not only caused by introducing less conductive Yb or Mg but also through disturbing the Ag lattice structure to promote additional electron scattering at grain boundaries.

The Ag-Yb and Ag-Mg alloys carried intermediate properties between their pure components despite the presence of Yb or Mg oxides. Besides optical and electrical properties, changes in the electronic work function were also assessed since it is also important in applications. Plasmonic nanostructures and transparent organic light-emitting diodes (OLEDs) were fabricated to demonstrate their potential applications. Two-dimensional disc-arrays nanostructures composed of pure Ag and Ag-Yb were implemented to evaluate the plasmonic properties. The damping loss in Ag-Yb caused weakened coupling of incident photons and surface plasmons when compared to pure Ag without altering the coupling wavelengths, suggesting potential plasmonic materials for tuning the coupling strength of surface plasmons by controlling the concentration of Yb which may also apply to Ag-Mg. Ultrathin Ag-Yb and Ag-Mg films were used as cathodes in transparent OLEDs for demonstration, which was beneficial by virtue of overall device transmittance though sacrificing electrical conduction leading to poor light emission unless inserting additional ultrathin lithium fluoride to modify the ultrathin cathodes.

Table of Contents