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Plasmonic properties of aluminum nanorods in near-infrared: transparency, absorption and near-field enhancement

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Introduction. In the last decade, gold (Au) and silver (Ag) nanostructures were extensively studied for their plasmonic properties. Their interest for photoelectric conversion systems using solar energy (visible and near-infrared (NIR) range) was especially pointed out. Indeed, they can be used to improve light harvesting [1], for plasmon-assisted photocurrent generation [2] or water oxidation [3]. However Au and Ag are expensive and limited resources. Aluminum (Al) should be an interesting low cost alternative to noble metals as it can support localized surface plasmon resonances (LSPR) from deep UV to IR wavelength [4]. In this work, we present the optical properties of Al nanorods fabricated on semiconductor oxide (SCO), a suitable transparent material for photocurrent generation. We show that Al is more than a cheap substitute to Au and Ag as it supports unique optical behavior especially in NIR wavelength.

Experimental. Array of thin Al nanorods are fabricated by electron beam lithography, thermal evaporation and lift-off process. Structures are fabricated on $KTaO_3$ single crystal substrate that should allow electron transfer from Al to the substrate. Far-field optical properties are studied by visible and FT-IR spectroscopy. Experimental results are compared with finite-difference time-domain (FDTD) modeling in order to investigate the light absorption and near-field enhancement in such structures.

Results and discussion. First, we demonstrate that the LSPR position can be adjusted all over the visible and near-IR wavelength range thanks to a control of the geometrical parameters. Thus transparency can be efficiently tuned (Fig 1.a) to get active optical behavior in NIR and UV region with minimized interaction in the visible wavelength. Next, we show that Al interband transition occurring around 800 nm can be excited by LSPR leading to an extended absorption in NIR wavelength (Fig. 1.b). We also point out the key role of the dielectric confinement in the control of the light absorption and scattering properties. Finally, a near-field enhancement study show that Al nanorods provide a decent local field intensity by taking advantage of the dielectric confinement even if the value remain lower than Au. Development of more adapted geometries for near-field enhancement is lastly discussed.

Conclusion. Al nanostructures hold original optical characteristics. First, they have highly tunable LSPR from deep-UV to IR range. Secondly, they support strong localized interband transition in near-IR wavelength leading to an efficient light absorption in that region for a geometry holding a high dielectric confinement. That latter also favors an improved near-field enhancement. Thanks to those unique behaviors, Al nanostructures could be used to create a new generation of inexpensive solar systems like transparent solar cells exploiting the NIR light.

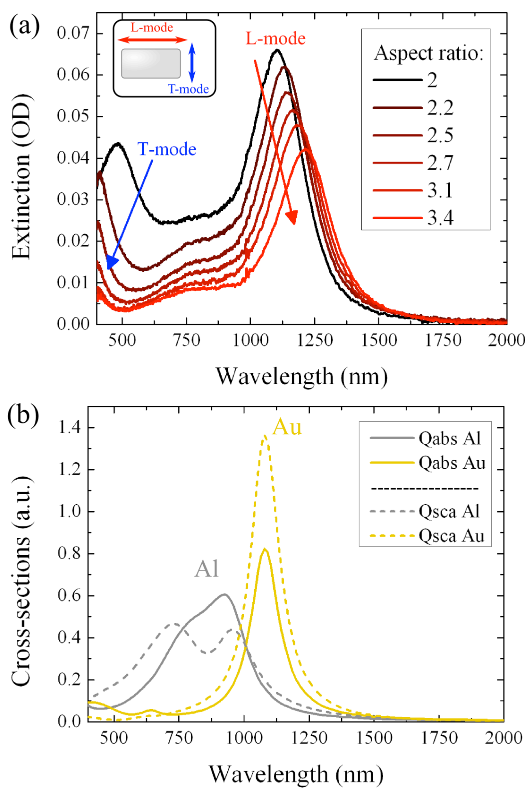

Fig 1. (a) Extinction of 130 nm long Al nanorods with different length/width aspect ratio. (b) Absorption (Qabs) and scattering (Qsca) cross-section of 130×65 nm Al and Au nanorod.

References

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