Plasmon-induced enhancement of light absorption in metallically nano-modified semiconductor

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Experimental data on giant enhancement of photoluminescence and absorption of light by photo-diode system's semiconductor layer covered with metallic nanospheres [1-6] provides an evidence of a possibility to significantly increase efficiency of solar cells. Application of special metallic nanoparticle coverings of photo-active surfaces has been found to induce a light converting effect, collecting energy of incident photons in surface plasmon oscillations. This energy can be next transferred to semiconductor substrate in much more efficient manner in comparison to the direct photo-effect. Experimental observations suggest, that the near-field coupling between plasmons in nanospheres and electrons in the semiconductor substrate allows for significant growth of selective light energy transformation into a photo-current in a diode system. We argue that due to nanoscale of the metallic components the momentum is not conserved in this transition, which leads to allowance of all indirect optical interband transitions in semiconductor layer, resulting in enhancement of a photo-current in comparison to the ordinary photo-effect when only direct interband transitions were admitted. Though the effect is selectively ranged to a vicinity of the resonant plasmon frequency, the gain in the total efficiency would be enlarged by possible dispersing of dimension and shape (or by a dielectric coating) of metallic nanoparticles, widening the resonant spectrum. An explanation of a large plasmon-induced PV efficiency enhancement of metallically surface-modified photo-cell is presented by inclusion of all indirect inter-band electron transitions in semiconductor due to near-field coupling with plasmon radiation of a nano-scale metallic components. The model of nano-sphere plasmon is formulated within RPA-type approach in an analogy to Pines-Bohm bulk plasmon theory [7], adjusted to large clusters [8]. Damping of plasmons is analyzed including irradiation losses due to the Lorentz friction [9]. Probability of the interband transition in substrate semiconductor caused by the coupling with plasmons in near-field regime turns out to be 4-order larger than for coupling of electrons with planar-wave photons. Inclusion of proximity and interference effects allows for explanation of photo-current growth measured in experimental metallically modified photo-diode systems.

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