Plasmonic properties of nanoparticles and nanofluids for effective absorption of solar radiation

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Investigation and selection of the plasmonic and optical properties of nanoparticle (NPs) and nanofluids (NFs) [1] are very significant for effective absorption and harvesting of solar radiation [2-6]. NFs represent themselves selected NPs placed in base working fluid. The selection of appropriate NPs and NFs to provide excellent absorption optical and photothermal properties of NFs and maximal efficiency of volume solar absorber for the purposes of applications of solar thermal energy taking into account the influence of NP plasmon resonances is very important for solar energy harvesting. The results of Investigation of plasmonic properties of nanoparticles and nanofluids for effective absorption of solar radiation are presented and discussed.

Theoretical investigation and selection of the plasmonic and optical properties (absorption, scattering, extinction) of spherical homogeneous metallic (titanium Ti, gold Au) and metal core-oxide shell Ti-TiO_2 NPs with the radii 50, 75, 100, 125 nm, immersed in water, and their NFs have been carried out in the optical spectral interval of wavelengths 200 - 2500 nm, including approximately 95% of solar energy, based on the computer simulation of generalized Mie theory.

Analysis of the dependencies of the NPs optical properties on radiation wavelength λ and their radii r_0 for homogeneous and r_1 for core-shell NPs have showed that single Ti, Ti + TiO_2 NPs are good absorbers for the values of r_0, r_1 ≈ 75-100 nm, in some cases till r_0, r_1 ≈ 125 nm, in the visible and infrared spectral intervals and can be proposed for their use in solar thermal systems. Au NPs of the considered dimensions r_0 =50-125 nm cannot be used in solar absorption thermal applications due to their inappropriate plasmonic characteristics (small absorption for λ> 700 nm).

The optical properties of NFs are determined by the summarized properties of water (liquid) and NPs system on the dependence on wavelength λ. Extinction and absorption of solar radiation by NFs are determined by the dominant influence of the system of Ti, Ti + TiO_2 nanoparticles with concentration 10^9, 10^{10} cm^{-3} in the spectral interval 200-800 nm for the NP radii 50-75 nm and in interval 200-1100 nm for the radii 100-125 nm. It means that the influence of NPs is larger or much larger than water in mentioned spectral intervals. It should be noted, that approximately 70% of solar energy are concentrated in in 200-1100 nm spectral interval. Water dominantly influences on the solar radiation extinction in the spectral range 1200 – 2500 nm. Moreover, extinction (absorption) of solar radiation in the spectral interval λ > 1400 nm by water is realized in water thin layer with the thickness of about ~ 10^{-1}-10^{-2} cm, that prevents the volumetric absorption of solar radiation. It is impossible to use additional absorbers (NPs) for the radiation absorption in the range of 1200–2500 nm for increasing of the efficiency of volumetric absorption of radiation and these findings should be taken into account. It is some kind of restriction on the use of NP concentration.

Ti and Ti-TiO_2 NPs are available in the nanotechnology market and can be used for effective absorption of solar radiation in the mentioned spectral intervals. Presented results can be used for the increase of efficiency of solar absorption by nanofluids and their heating and can be applied for the development of novel working nanofluids. These results are important for the development of direct thermal solar volumetric absorbers and water heaters for domestic and industrial needs, photovoltaic thermal solar cells based on the use of selected plasmonic NPs.

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