【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Chemistry)

Title of Project : The development of plasmonic antennae realizing light harvesting/localization and its application to solar cells

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Research Area : Photochemistry
Keyword : localized plasmon, nanomaterials, optical physics

【Purpose and Background of the Research】

The development of a high-efficiency solar cell is critical to the development of a future low-carbon society. To produce a solar cell with high photoelectric conversion efficiency, we need to develop a system that responds to a wide spectrum of solar light, from visible to near-infrared wavelengths. However, the photoelectric conversion characteristics of an amorphous silicon solar cell commonly used today are known to drastically decrease in wavelength ranges longer than 700 nm. However, the spectral distribution in an infrared wavelength region longer than 800 nm accounts for ~40% of the entire solar energy observed on earth, and only a few solar cells can efficiently convert solar energy with such a long wavelength to electrical energy. We have recently demonstrated the first successful plasmonic photoelectric conversion from visible to near-infrared wavelengths using electrodes in which gold nanostructures are elaborately arrayed on the surface of TiO_2 single-crystal electrodes via a top-down nanostructuring process. In this study, we aim to develop plasmon enhanced photocurrent generation system with a function of optical antennae realizing light harvesting and localization, and we will optimize a structural design which can realize the efficient electronic transition from a gold nanostructure to TiO_2.

【Research Methods】

To construct an efficient solar cell that responds to near-infrared light, it is necessary to elucidate a relationship between photocurrent generation and plasmonic enhancement effects. Therefore, we will fabricate gold nanoblocks with nanometric accuracy with the following characteristics: strong field enhancement and radiation suppression owing to Fano effect or Rabi oscillation, and sharper features at the edges using an ultra-high-resolution electron beam lithography system with an acceleration voltage of 125 kV. We will improve the function of "an optical antenna" to a limit, and try improvement in the photoelectric conversion efficiency

【Expected Research Achievements and Scientific Significance】

The plasmon-assisted photocurrent generation system has the outstanding function "the optical antenna" which enables to light harvesting and localization to the nanospace of gold nanostructure/TiO_2 electrode interface. In this study, it has originality which aims at realization of the infrared light solar cell with high photoelectric conversion efficiency by improving the characteristic "optical antenna" function to a limit. Furthermore, this research also gives various knowledge to the research on the interaction between localized surface plasmon and materials in which many points remaining which are not solved scientifically, so that the acquired knowledge will give a big impact to the researchers in this field.

【Publications Relevant to the Project】

1. Y. Nishijima, K. Ueno, Y. Yokota, K. Murakoshi, H. Misawa, *J. Phys. Chem. Lett.*, **1**, 2031-2036 (2010).
2. S. Gao, K. Ueno, H. Misawa, *Accounts. Chem. Res.*, **44**, 251-260 (2011).
3. K. Ueno, S. Juodkazis, T. Shibuya, Y. Yokota, V. Mizeikis, K. Sasaki, H. Misawa, *J. Am. Chem. Soc.*, **130**, 6928-6929 (2008).
4. K. Ueno, S. Juodkazis, V. Mizeikis, K. Sasaki, H. Misawa, *Adv. Mater.*, **20**, 26-30 (2008).

【Term of Project】 FY2011-2015

【Budget Allocation】 166,400 Thousand Yen

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