Study on electron dynamics in Au-TiO_2 nanoparticle system using PEEM and fs laser (3) --- bandgap energy and electron affinity of individual TiO_2 particle---

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(Introduction) By using a photoemission electron microscope (PEEM) having a spatial resolution of 40-nm, we are studying electron transfer dynamics in Au nanopartice(NP)-TiO_2 NP system as a material of high efficiency sollar cell [1,2]. In the last report[2], results indicating electron transfer from Au-NP to TiO_2-NP was reported. Here, we report a try of estimating bandgap energy and electron affinity of TiO_2 by PEEM.

(Experiment) TiO_2 particles of 100-nm nominal size were mixed in a liquid of Au particles of 10-nm nominal size dispersed by surfactant. A drop was dripped in one-quarter region on a Si wafer of 10 mm size, and the sample was baked at 500degC to form Au-NP attached TiO_2-NP. This region is called mixed region. The sample had also Au and TiO_2 regions. In the last experiment[2], A 10 fs pulse from a Ti:S laser having wavelength from 630 nm to 930 nm was split into two beams and combined in a Mach-Zehnder interferometer with varied delay time between two pulses and irradiated a sample in a vacuum chamber. One result obtained is shown in Fig.1. The fact that Au-TiO_2-NP is brighter than TiO_2 implies electron transfer from Au-NP to TiO_2.

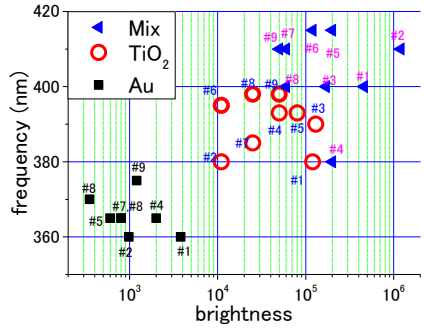

Fig.1: Ringing frequency observed in the last experiment

Ringing frequency of image intensity when delay time of two laser puslses was varied, was differennt for different region. In order to understand Fig.1, we used a laser having a narrow 13 nm bandwidth, whose nominal pulse width is150-fs.

(Results) In the case of 150-fs pulse, the mixed region was not brighter than TiO_2 region. Then, we confirmed that mixed region is brighter than TiO_2 for the 10-fs laser. The observed difference for 10 fs and 150 fs pulses may imply two wavelengths are required for making Au-TiO_2-NP bright.

PEEM image brightness changes several orders of magnitude when changing laser power. Sensitivity of MCP for detecting electrons is changed by changing voltage. 140V difference correponds 10 times difference in sensitivity. Figure 2 shows MCP voltage for recording decent image of TiO2 particles when wavelength of 150 fs laser was varied. We notice two jumps in sensitivity at 740- 750 nm and at 780-790 nm. These two jumps are considered to correspond to bandgap and ion potential energies.

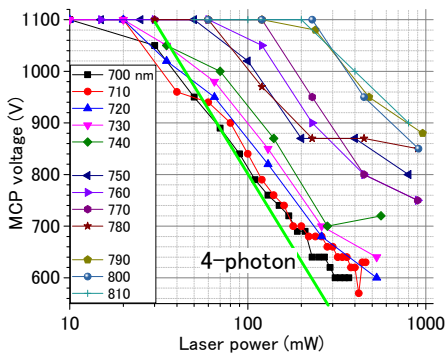

Fig.2 Image brightness for various wavelength

(ref.1) Bochao Li, et al. ; JSAP Spring meeting 2015, 13a-15-9
(ref.2) Bochao Li, et al. ; JSAP Autumn meeting 2015, 13p-2V-4