Study on electron dynamics in Au-TiO$_2$ nanoparticle system using PEEM and fs laser (4) --- vacuum level of individual particle---

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(Introduction) We are studying electron transfer dynamics in Au nanoparticle(NP)-TiO$_2$ NP system as a material of high efficiency solar cell $^{1,2}$) by using a photoemission electron microscope (PEEM) having a spatial resolution of 40-nm. By using PEEM, we can analyze electronical properties of individual particle. In order to improve performance of solar cell, increase of carrier lifetime is considered very important. Lifetime of carrier may be different in each particle, and observing individual particle could give us important information for increasing carrier lifetime. Vacuum level is one of important properties influencing carrier lifetime, and we are trying to observe vacuum level of individual particles. Here is our first report of vacuum level of Au-TiO2 NP system.

(Experiment)
Sample preparation is the same as reported previously$^1$).
High spatial resolution image was observed by PEEM and the vacuum level was observed by using DLD (delay line detector). DLD gives time-of-flight (TOF) spectra with high spatial resolution. UV laser having wavelength of 404 nm and pulse width of 2 ps was employed in the observation.

(Results) Figure 1 shows one result. Right photo shows PEEM image with DLD. We have TOF spectra for all paricles. TOF of three particles shown in the photo are shown on the left figure.
In TOF, electron counts at each time pixel are displayed. Time pixel needs to be converted to real time and travelling time of detected electrons should be converted kinetic energy. These conversions will be performed later.
Larger number pixel shows larger flight time and smaller kinetic energy electrons. Therefore, the cut of position at the right hand side shows the vacuum level position.
We see that vacuum level is not the same for each particle.
We will study relation of vacuum level with electron lifetime and brightness.

(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

![Fig. 1. Image of TiO$_2$ region and time-of-flight spectra of some particles.](image)