Development of nanoscale local-bandstructure analyzing system

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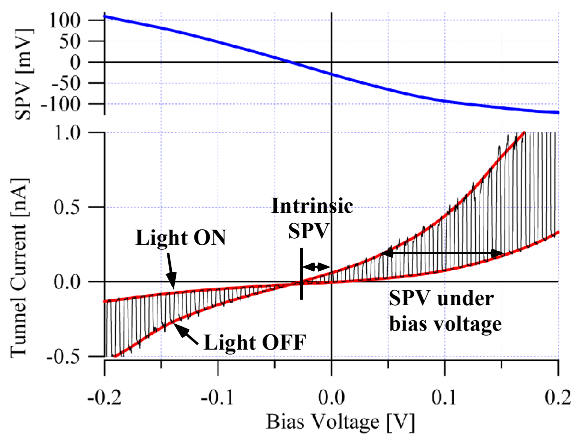
We will develop a measurement system of local bandstructure at semiconductor surfaces with a nanometer resolution using scanning tunneling microscopy (STM). Our two goals are establishing a concrete analyzing procedure and releasing a completed measurement system for it. Knowledge of local amount of surface bandbending is not only important for developing future nanodevices but for general STM measurements on any semiconductor substrate because it affects effective bias voltage.

Recently, we have developed a new technique to measure nanoscale variation of surface photovoltage (SPV) simultaneously with STM topography. Note that, SPV is photo-induced change in surface bandbending, which appears as modulation in effective bias voltage in STM measurement. Our method provides local SPV for a range of bias voltage without varying probe-sample distance in addition to current-voltage characteristics of STM at the measurement point. For instance, left figure shows how SPV is varied by bias-induced change in local bandbending. Right figure shows how SPV is modulated by nanoscale silver islands with one monolayer thickness (outlined by green lines).

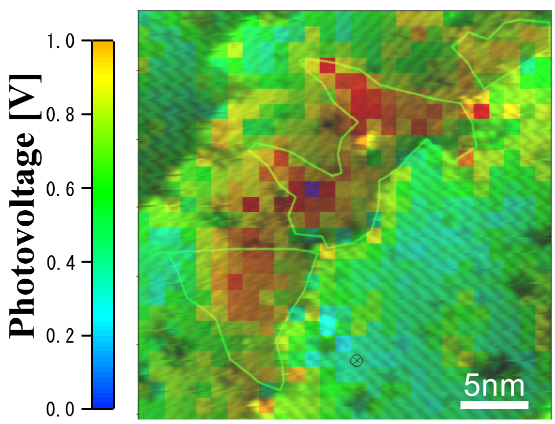
Although, our method provides extensive information about local bandstructure at semiconductor surfaces, it still has several drawbacks that commonly appears in local bandstructure measurements with scanning probe microscopy: SPV, Kelvin probe (KP) and barrier height (BH) measurement. These measurements are, in general, strongly affected by chemical and physical properties of probe apex, which makes interpretation of measured data difficult. In addition, the measurements requires special equipments and skills to use them. Consequently, they have not yet been in general usage.

In this project, we improve theoretical and technical analyzing procedures to extract applicatively meaningful parameters from combination of SPV, KP and BH measurements by STM. For this purpose, we first develop a measurement system with which a same sample can be easily measured by variety of analyzing techniques. This is required to examine the effect of probe apex properties and check the theoretical models. The system will be developed using a digital signal processor (DSP) board, which undertake all the tasks of servoing z and/or bias, modulating z and/or bias, scanning xy and/or bias, phase-locked loop (PLL) detection of external modulation, phase sensitive detection of modulated signals and data processing for analysis, so that we can easily switch between variety of measurement techniques without purchasing, modifying nor (dis)connecting/connecting electronics.

Replacement of the large part of analog circuits in the conventional STM controllers with a concurrent DSP processor of high performance and noble software logic will make the system costless. Thus, we plan the system to be released from a domestic STM company as the standard STM controllering system so that all future STM users have our new technique without extra cost.



Bias-dependent SPV for clean Si(111)-7x7 at 300K.



Spatially modulated SPV for Ag/Si(001)-2x3 at 80K.