Carrier dynamics around localized gap states investigated by femtosecond time-resolved STM

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SUMMARY:

Carrier dynamics around Co/GaAs, which is a model system of localized gap states on a semiconductor surface, was studied by shaken pulse-paired excited scanning tunneling microscopy (SPPX-STM [1]. SPPX-STM enables us to directly image how carriers behave in semiconductors with sub-picosecond temporal and sub-angstrom spatial resolutions. SPPX-STM showed that the carrier lifetime for Co was faster than that for the bare GaAs surface. This result could be explained by the existence of the gap state on the Co site, which is absent for GaAs.

INTRODUCTION:

Localized gap states in semiconductors, which originate from defects, impurities, and adsorbates, affect dramatically the carrier dynamics through capture, emission, and recombination processes. Probing and understanding the carrier dynamics around gap states become increasingly important, as the sizes of semiconductor devices become smaller and the gap state density becomes higher. We probed the carrier dynamics around gap states artificially formed on GaAs using SPPX-STM.

EXPERIMENTALS:

For SPPX-STM measurement, the tunnel gap of STM was illuminated by a sequence of paired pulses and the corresponding change in tunneling current ΔI was measured as a function of delay time between the pulse pair. The carrier lifetime of the surface recombination was estimated from the decay time of the ΔI vs. delay-time curve. Co was deposited onto a GaAs surface cleaved in an ultrahigh vacuum chamber.

RESULT AND DISCUSSION:

STM images on Co/GaAs revealed that the Co nanoparticles were well isolated and almost the same in size. We visualized the spatial distribution of the carrier lifetime around Co-derived gap states. The carrier lifetime was shorter at Co sites. This is explained by the existence of the surface state on the Co site, which is absent for the bare GaAs surface; the carriers trap and recombination at the Co-derived gap state could be responsible for the observed faster component. Details will be discussed at the presentation.

CONCLUSIONS:

In the present research, we artificially formed gap states on the GaAs surface by depositing Co nanoparticles. We succeeded in visualizing the spatial distribution of the carrier lifetime around gap states at the high spatial resolution, and found that the carrier lifetime shorten on the Co site because of the carrier capture and recombination via the gap states.

References

1) Y. Terada, M. Aoyama, H. Kondo, A. Taninaka, O. Takeuchi and H. Shigekawa, Nanotechnology **18**, 44028 (2007).