Time resolved Scanning Tunneling Microscopy: Results

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The combination of Scanning Tunnelling Microscopy (STM) with optical excitation using ultrashort laser pulses enables us to simultaneously obtain ultimate spatial and temporal resolutions. Shaken-pulse-pair-excited scanning tunneling microscopy (SPPX-STM) has been applied to various semiconductor materials and devices to obtain nanoscale carrier dynamics such as recombination, drift and diffusion. In this study, we have visualized the carrier capture dynamics around gap states artificially formed on GaAs. Cobalt nanoparticles were employed as an ideal model of localized gap states which builds deep impurity levels in GaAs bandgap. Co nanoperticles with the diameter of 2~3 nm were formed by deposition onto a n-type GaAs(110) clean surface.

Figure 2 shows ΔI vs. delay-time curves obtained above (a) the bare GaAs surface and (b) above a Co nanoparticle. The lifetime of the photo-generated holes captured at the surface were estimated by fitting such curves with exponential functions. The estimated lifetime at Co, 2.3ns, was found to be much shorter than that at the bare GaAs surface, 220 ns. Furthermore, the former decreased when the tunnel current was increased. The result indicates that the photogenerated holes recombined with electrons tunneling from STM tip at the Co site. In contrast, when the tunnel current was sufficiently large, the lifetime was no more dependent on the magnitude of tunnel current. Instead, it depended on the capture rate of the minority holes into Co deep level. Since a Co nanoparticle with a larger footprint has a higher capture rate of the minority holes, the lifetime of the photogenerated holes had a negative correlation to the area of the Co nanoparticles' footprints.[1]

[1] Y. Terada et al., Nature Photonics DOI :10.1038/NPHOTON.2010.235 (2010).

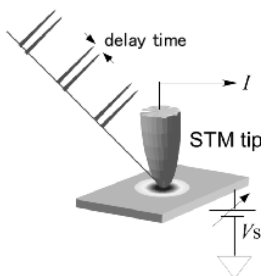

Fig.1: Schematic of SPPX-STM measurement.

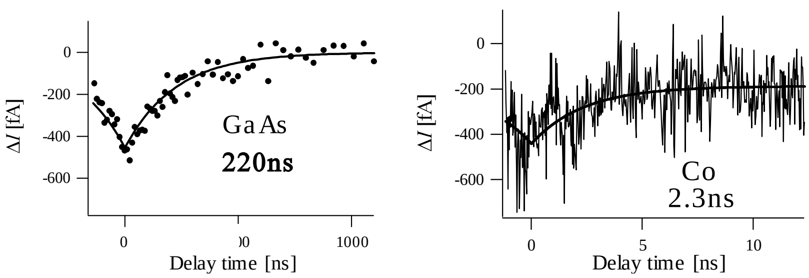

Fig. 2: Measurement of lifetimes for (a) GaAs and (b) Co.