Probing Electron Spin Dyamics by Time Resolved STM

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In the recent emerging field of semiconductor spintronics, it is essential to understand the spin relaxation mechanism and to find ways to manipulate the electron spin state in semiconductor quantum structures. For GaAs, spin relaxation is induced by various mechanisms associated with spin-orbit interaction. Spin flip and dephasing occur through scattering by phonons and impurities. In addition, local structures such as surface, interface and their roughness are known to strongly affect spin lifetime. To investigate the spin relaxation process in more detail, it has been desired to visualize spin dynamics with high spatial and temporal resolutions.

In this study, we have realized electron spin lifetime measurement using time-resolved STM (TR-STM). In TR-TM, a sample surface is excited by a sequence of laser pulse pairs (Fig.1). Circular polarized (CP) optical pulses were used to excite spin-polarized carriers in a sample. Since the spin direction of excited carriers depends on the polarization of CP pulses (left hand or right hand), generation of photocarriers by the same CP pulses is suppressed due to Pauli exclusion principle, while that by anti-CP pulse pairs is not. The difference in photocarrier densities between the two conditions was obtained by TR-STM measurement with a new CP modulation method.

Spin relaxation processes were observed by measuring ΔI as a function of delay time Δt between pulse pair (Fig.2(b)). In the case of an undoped GaAs sample, a decay constant around 6 ps was obtained by fitting of the spectrum with an exponential function, which is in good agreement with the electron spin lifetime (7.8 ps Fig.2 (a)) obtained by optical pump probe reflectivity (OPPR) measurement. We have simultaneously observed a component with an anomalously long spin lifetime (~1 ns Fig.3), which was not observed by OPPR measurement. Details will be discussed at the conference.

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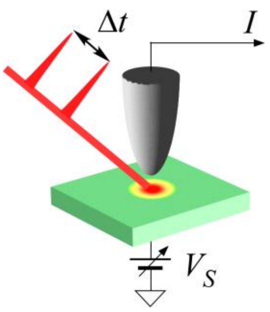

Fig.1 Schematic of time-resolved STM

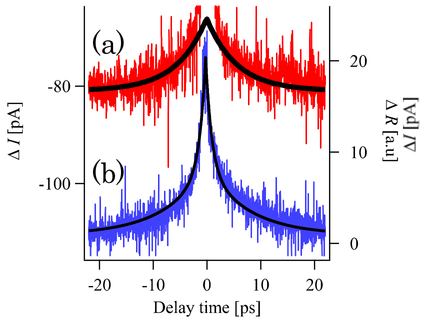

Fig.2 (a) OPPR and (b) TR-STM spectra obtained for an undoped GaAs. Peak at 0 delay in (b) is due to interference between laser pulses.

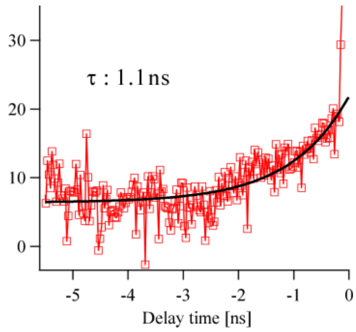

Fig.3 TR-STM component with a long decay constant.