Study on $(NH_4)_2S$-treated GaAs(001) Surface by Time-resolved Scanning Tunneling Microscopy

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High-density defects on semiconductor surfaces deteriorate the performance of photoelectronic devices. In order to solve the significant problem, an excellent method, surface treatment with $(NH_4)_2S$ solution, was developed. According to the previous report, $(NH_4)_2S$ treatment effectively removes surface oxide and covers the pristine surface with sulfur atoms.[1)] In this study, we have investigated the effectiveness of the treatment by measuring minority carrier lifetime on a $(NH_4)_2S$-treated n-GaAs(001) surface using the time-resolved scanning tunneling microscopy (STM) which has high resolutions of time and space.[2-3)]

In our time-resolved STM, the tunnel gap of STM is illuminated by a sequence of paired pulses and the corresponding change in tunneling current ΔI is measured as a function of delay time between the paired pulses. The decay time of photocarriers can be estimated from the delay-time dependence of ΔI.[2-3)] Often, the decay process provides two different decay times, one for the bulk-side decay process that is ordinary recombination of the minority carriers with the majority carrier and the other for the surface-side decay process where the majority carrier is depleted thus the minority carriers decay with thermal ionization from the surface-side to the bulk-side. When the sample is under STM observation, the surface-side decay also involves the recombination of the minority carriers with the injected tunnel carriers, which often accelerates the recombination especially when there are high density of surface defects. Thus, the density of surface defects can be estimated with this method.

Figure 1 shows the result. Decay time of surface-side carrier density was obtained by exponential fitting. The long carrier decay time (361 ns) for the surface-side recombination is almost the same as the detect-free GaAs surface that is cleaved in UHV.[2)] We interpret this result that surface defects of GaAs are successfully reduced by the $(NH_4)_2S$ treatment. The interpretation was supported by measuring tunneling-current dependence of carrier decay time. As shown in Fig. 2, the decay constant is independent of tunnel current, which suggest the surface defects does not accelerates the recombination of the minority carriers with the tunnel carriers at least around the measured point. We are now planning to measuring the density and distribution of the remaining surface detects on the $(NH_4)_2S$-treated GaAs surface.

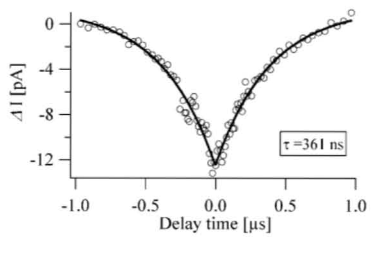

Fig. 1. ΔI vs. delay time curve obtained for a $(NH_4)_2S$-treated surface.

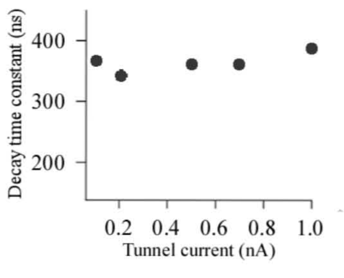

Fig. 2. Tunneling-current dependence of decay-time constant on $(NH_4)_2S$-treated GaAs(001) surfaces.

References

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