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Light-Illuminated STM Studies on InAs Nano-Structures

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1. Introduction

Recently, many techniques have been used to fabricate the semiconductor nano structures such as quantum dots and quantum wires. Among them, the natural formation of InAs quantum wires on vicinal GaAs surfaces with giant steps is a flexible method to fabricate not only quantum wires but also the InAs thin film by adjusting the quantity of the InAs deposition [1,2].

On the other hand, the light-illuminated STM is a very powerful method to characterize optical and electrical properties of semiconductor quantum structures in nano-scale resolution. In the previous work by Takahashi et al, the near-surface electronic properties of InAs dot-covered GaAs were studied by tunneling spectroscopy under laser illumination [3]. They reported that the GaAs surface depletion was more suppressed under the InAs quantum dots than the InAs wetting layer. Yamamoto et al performed the photoinduced current imaging to clarify the difference of the degree of the GaAs depletion between under the dot and WL [4].

In this report, we conducted the tunneling spectroscopy under the light illumination and the photoinduced current imaging on the InAs thin film and InAs nano-wires fabricated on the GaAs vicinal substrates.

2. Experimental Procedures

Samples we used for the measurements were fabricated by chemical beam epitaxy [1,2], and the structures are shown in Fig.1. The surface of the sample A was completely covered by the 200ML InAs, which was grown on the undoped GaAs buffer layer and the n-type GaAs (110) vicinal substrate. In the case of the sample B, InAs nano-wires were formed along the GaAs giant steps by the 10ML InAs deposition.

Figure 2 shows our experimental arrangement of the STM system. for the STS measurement and the photoinduced current detection [3][4]. Note that the optical chopper illustrated in Fig.2 was used for the lock-in detection of the photoinduced current component from the tunneling current, so not used in the case of STS measurements.

First, we conducted the tunneling spectroscopy under the light illumination [3] on the sample A. After approaching the STM tip to the sample surface, sample bias voltage was swept without the feedback control, and we the normalized differential conductance was calculated from the obtained I-V curves.

Next, we performed the photoinduced current imaging [4] on the sample B and investigate the behavior of photocarriers generated in the bare GaAs region and the InAs covered GaAs region.

3. Results and Discussion

Tunneling spectroscopy under the light illumination on the InAs thin film

Figure 3 shows the differential conductance curves obtained by the tunneling spectroscopy under the light illumination on the sample A. Wavelength of illuminated laser was 850nm.

In this figure, the conductance curve without the laser illumination is similar to that of n-GaAs, which has the conductance gap approximately equals to the GaAs band gap. When the 850nm laser light was illuminated, we observed a clear shift to the InAs-like conductance curve, which has a narrower gap.

These results indicate that the tunneling spectra without the light illumination were determined by the underlying GaAs because the InAs region was isolated from the conductive substrate. However, when the laser light was illuminated, the generated photocarriers increased the conductivity in the undoped GaAs layer and the tunneling spectra via the surface InAs thin film clearly appeared.

Photoinduced current imaging on the InAs nano- wires

Figure 4 shows the photoinduced current image and simultaneously obtained topographic image on the sample B at the sample bias of −2V and laser wavelength of 800nm. We can clearly distinguish the InAs nano-wires from the bare GaAs region. We attribute this contrast to the enhancement of the tunneling current via the InAs nano-wires by the photoinduced reduction of Schottky barrier height at the InAs/GaAs interface.

4. Conclusion

We conducted the tunneling spectroscopy under light illumination and photoinduced current imaging on the InAs thin film and InAs nano-wires. From these measurements, we concluded that the tunneling current via the surface InAs region was clearly detected when the underlying GaAs absorbed the illuminated laser light and the Schottky barrier at the InAs/GaAs interface was decreased.

References

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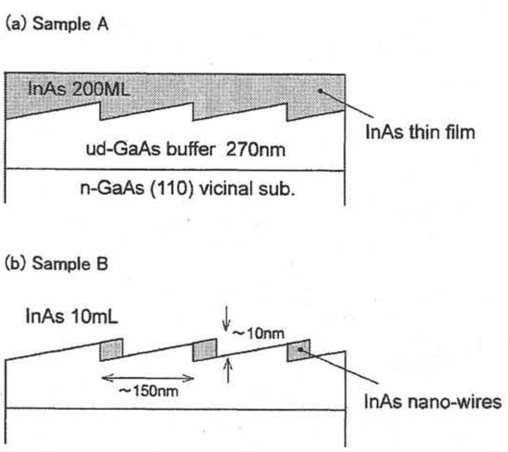

Fig.1 Schematic structures of samples.

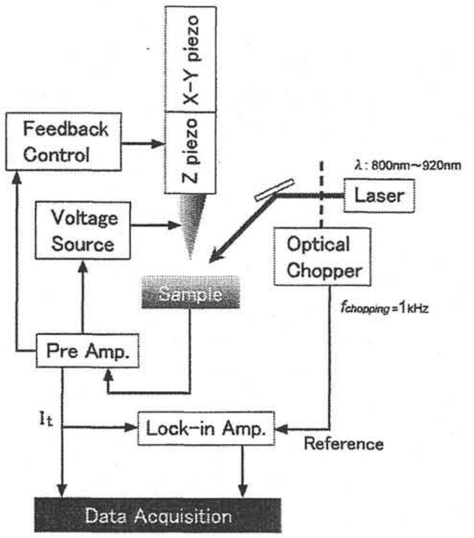

Fig.2 Experimental setup for the light-illuminated STM.

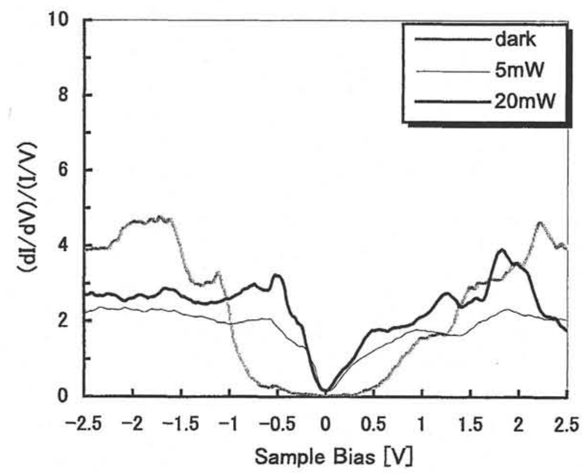

Fig.3 Differential conductance curves on the InAs thin film. Illuminated laser wavelength was 850nm.

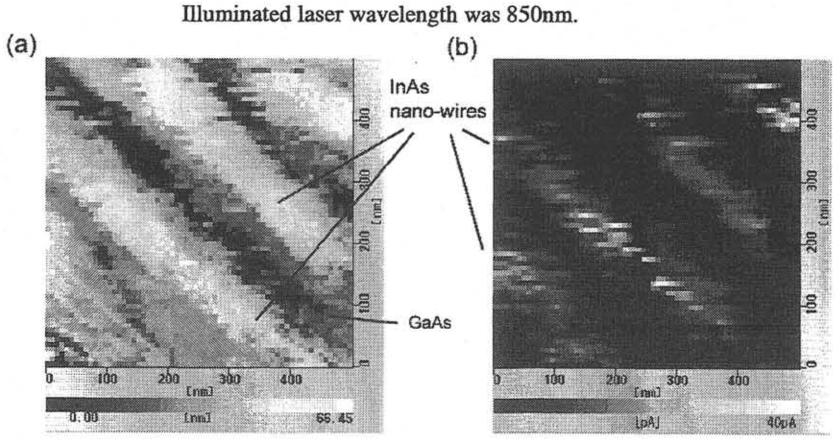

Fig. 4 (a)Topographic image and (b)photoinduced current image on the InAs nano-wires.