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Fabrication of Sub-100 nm Wires in GaAs/AlGaAs Multiquantum Well by Focused Ion Beam Lithography

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The investigation of one-dimensional and zero-dimensional semiconductor systems has gained considerable interest due to the predicted enhancement of such optical properties as the oscillator strengths and the optical nonlinearities. In such quantum wires and dots, their optical and electrical properties are also effected by the surface. The large surface recombination rate originating from lots of surface states shortens the carrier lifetime. This results in the reduction of the recovery time from excitonic absorption bleaching.

In this paper, we describe sub-100 nm wire fabrication in GaAs/AlGaAs multiquantum well (MQW) by focused ion beam (FIB) lithography and the time-resolved absorption measurements of the narrow wires. We show that the strong optical nonlinearity of excitons is preserved, even in wires of the 130 nm width, and having a fast recovery time of 11 ps.

Samples used for this study were prepared from 40 pairs of GaAs/$Al_{0.51}Ga_{0.49}As$ MQWs (4.5 nm/4.0 nm). The FIB system was used to expose a trilevel resist structure consisting of a 800 nm SiO_2 film, a 60 nm Al film, and a 200 nm CMS-EX(R) resist film. The Be^{++}-FIB (160 keV) was programmed to expose line-arrays in 400 μm squares. The trilevel resist process is shown in Fig. 1. The top resist patterns were finally transferred into the MQW layers by reactive ion beam etching (RIBE) using electron cyclotron resonance (ECR) chlorine-plasma. The bottom SiO_2 film is good for the RIBE etching mask with micro-lines and -dots due to the large mechanical strength as well as its role as the ion stopping layer for FIB exposure. Figure 2. shows a SEM image of the MQW narrow wires fabricated to a 60 nm width.

We studied the recovery from excitonic absorption bleaching of the MQW wires as a function of the wire width using the ordinary time-resolved absorption measurements having a time-resolution of 1ps. We found a strong reduction of the recovery time with decreasing the wire width as shown in Fig. 3, corresponding to the surface velocity of $5x10^5$ cm/s. The strong optical nonlinearity of excitons is preserved, even in the wires of 130 nm width, and having a fast recovery time of 11 ps. These suggest possible application of MQW wires in high-speed optical devices.

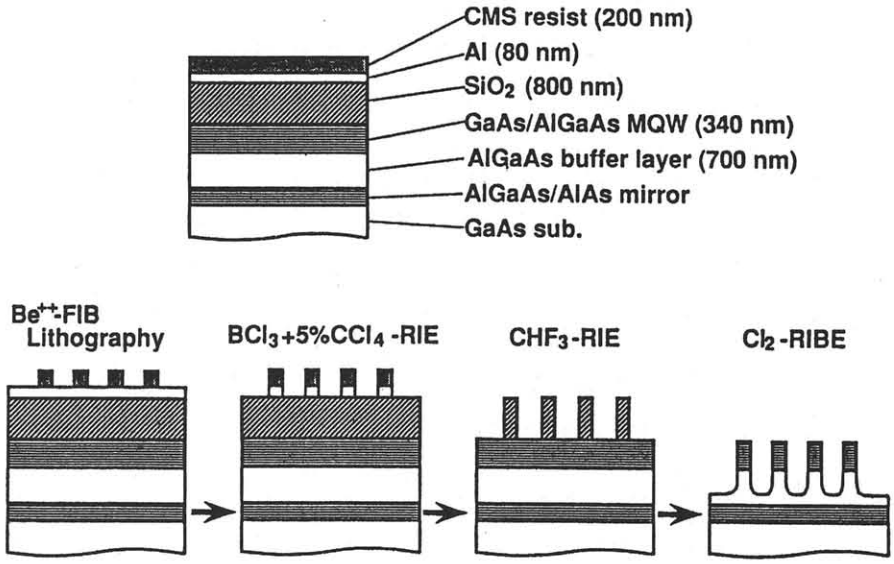

Fig. 1 Focused ion beam trilevel resist process

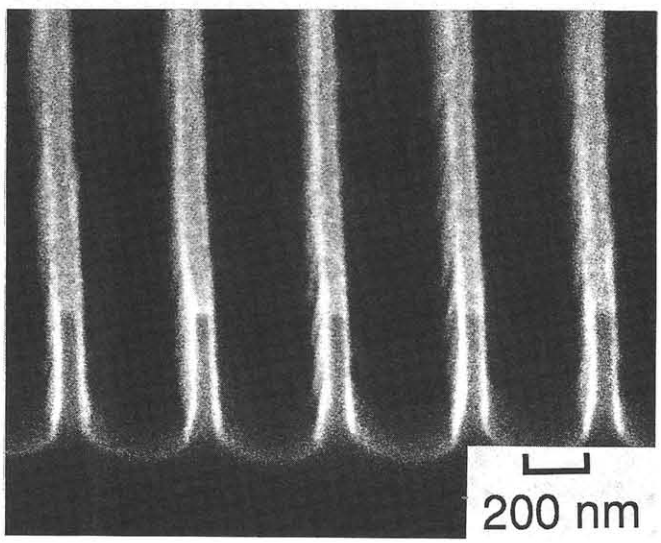

Fig. 2 SEM image of MQW narrow wires.

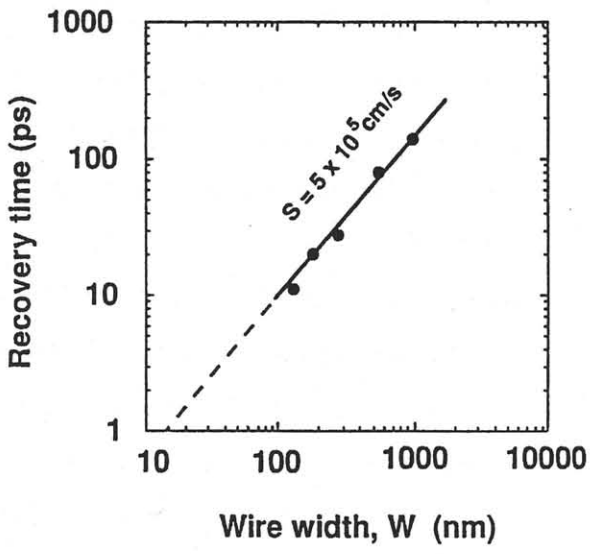

Fig. 3 Variation of absorption recovery time with wire width.