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Maskless Selective Growth of GaAs on V-Grooved Si Substrates

A. HASHIMOTO, T. FUKUNAGA, and N. WATANABE

Device Research Department,
Optoelectronics Technology Research Corporation,
550-5, Higashiasakawa, Hachioji, Tokyo, 193

Polar/nonpolar crystal growth has been intensively studied to realize novel device structures such as OEICs. Selective growth is one of the promising techniques for practical applications. The simplest way for selective growth of GaAs on Si substrates would be the GaAs growth on the original Si surface using several types of masks. However, the final height of the GaAs surface would be several microns above the Si substrate surface. This situation would naturally complicate interconnection of devices. An obvious alternative is to grow the GaAs on etched Si substrates but, there are few reports on the crystal growth of GaAs on etched Si substrates by MOCVD. In this late news, we report the first successful maskless selective growth of GaAs on V-grooved Si substrates.

(100) Si substrates were etched in a KOH and H_2O mixed solution at 70°C to form the V-grooves. The width and depth of the V-grooves were about 4 μm and 2 μm, respectively. After standard surface cleaning by a HF solution, crystal growth of GaAs was performed by MOCVD using a standard two-step growth technique.(1) The pre-annealing temperature of the Si substrates was 930°C and the growth temperature of the GaAs layer was 750°C. The growth rate of the GaAs was about 100nm/min. Cross sections were observed by optical microscope after stained etching.

A cross section of the GaAs layer after a 40 minute growth is shown in Fig. 1(a). In this case, the V-grooves are parallel to the $(0\bar{1}1)$ direction. There is no or very slow growth in the V-groove region, while there is typical growth on the (100) plane outside the V-grooves. The V-groove shape was kept even in the GaAs layer, independent of growth rate and/or total thickness of GaAs. For $(0\bar{1}1)$ oriented V-grooves, however, no growth occurs in the V-groove regions as well, but a different edge shape in the GaAs layer is observed, similar to that seen in the selective growth of GaAs on GaAs substrates.(2)

The above results indicate that different growth mechanisms exist on (100) and (111) Si planes. It is well-known that no or very slow growth of GaAs occurs on (111)B GaAs planes due to fast migration of Ga-hydrocarbon molecules on (111)B GaAs planes as shown in Fig. 1(b).(2,3) The growth shown in Fig. 1(a) suggests that the migration of Ga-hydrocarbon molecules on (111) Si planes is also very fast and that most Ga-hydrocarbon molecules which come to the (111) Si plane escape to the (100) Si planes before nucleation. The surface Ga-hydrocarbon molecules on the (100) Si planes nucleate considerably easier than those on the (111) Si planes, thus the crystal growth occurs only on the (100) Si plane. This is the principle of the maskless selective growth of GaAs on Si substrates. In the case of GaAs substrates, it is rather difficult to form the (111)B planes with fine patterns using standard etching techniques in contrast to the case of Si substrates.

In summary, we report the growth properties and the first successful maskless selective growth of GaAs on V-grooved Si

substrates. The selective growth is due to the different growth mechanisms on the (100) and (111) Si planes. Such maskless selective growth will offer more flexibility for fabricating novel device structures such as low-dimensional quantum effect devices.

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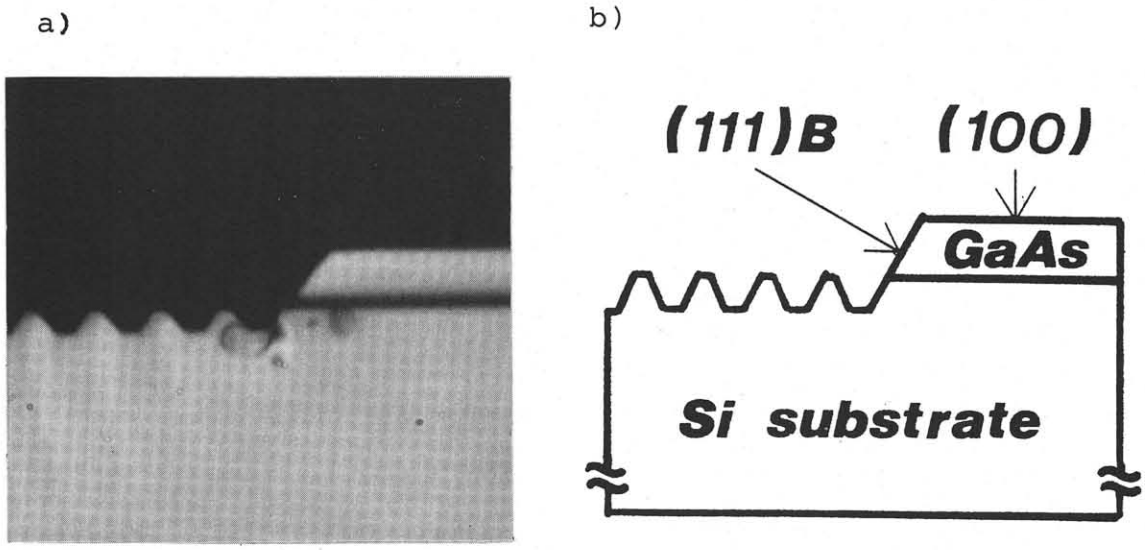

Fig. 1. (a) A photograph and (b) a schematic drawing of the GaAs layer grown selectively on a V-grooved Si substrate.