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Growth of GaAs/InAs Anti-Dot Structure by Solid Source MBE

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1.Introduction

Fabrication of quantum-dots(QDs) has recently been receiving considerable attention. These works include etching, ion implantation, self-organization techniques and so on. However, etching and ion-implantation techniques may introduce damages into the structure and the self-organization technique still suffer from nonuniformity. In the present work, we have carried out area selective epitaxial growth of GaAs/InAs anti-dot structures using solid source MBE, and achieved uniform anti-dot structure with a dot density as high as $2.6\times10^{9}cm^{-2}$.

2. Experimental results and discussion

The anti-dot structure is investigated to achieve regular dot arrays connected by thin wires. The area selective epitaxial growth is performed by using solid source molecular beam epitaxy(MBE) at 590 ℃ on GaAs (111)B substrates. A modified migration-enhanced epitaxy(MEE) deposition sequence has proved useful to achieve complete selectivity. We performed the area selective epitaxy of anti-dot structure which provides dot arrays connected with thin wires, and achieved the smallest anti-dot structure whose diameter is approximately 90nm with a periodicity of 300nm by using EB lithography followed by the lift-off technique for the thin SiO_2 mask. When the diameter of holes excavated on the SiO_2 mask is larger than approximately 150nm, the grown anti-dots are surrounded by 3major and 3minor{-1-10} facets as shown in Fig.1(a) where the SEM image of anti-dot structure with 300nm diameter is demonstrated. However, when the diameter is lowered below 150nm, the facet-like structure completely disappears. Figure1 (b) shows the anti-dot image with 90nm diameter. The resulting sidewall is close to vertical and along the boundary between growth area and SiO_2 mask.

The growth characteristics of "anti-dots", in other word "holes" can be very different from those of "dots". In the latter, the shape of the growth front has positive curvature. Therefore, the atoms arrived at the low growth rate plane move on the surface until they reach the steps. Then they are captured by the steps at the periphery and widen the area. This process enhances the formation of facets. The phenomenon is much more prominent for smaller dots(<1 μ m). As a result the dot shape is largely modulated and the connecting between dots and wires can be deteriorated

In the anti-dot structure, the growth front has negative curvature. So, atoms arrived at the low growth rate plane at the periphery of the holes move to the edge steps and enhance the lateral step-flow growth. As a result, substantial growth takes place on the sidewall surface. Therefore, the facet formation which might deteriorate the connection between dots and wires will be greatly suppressed.

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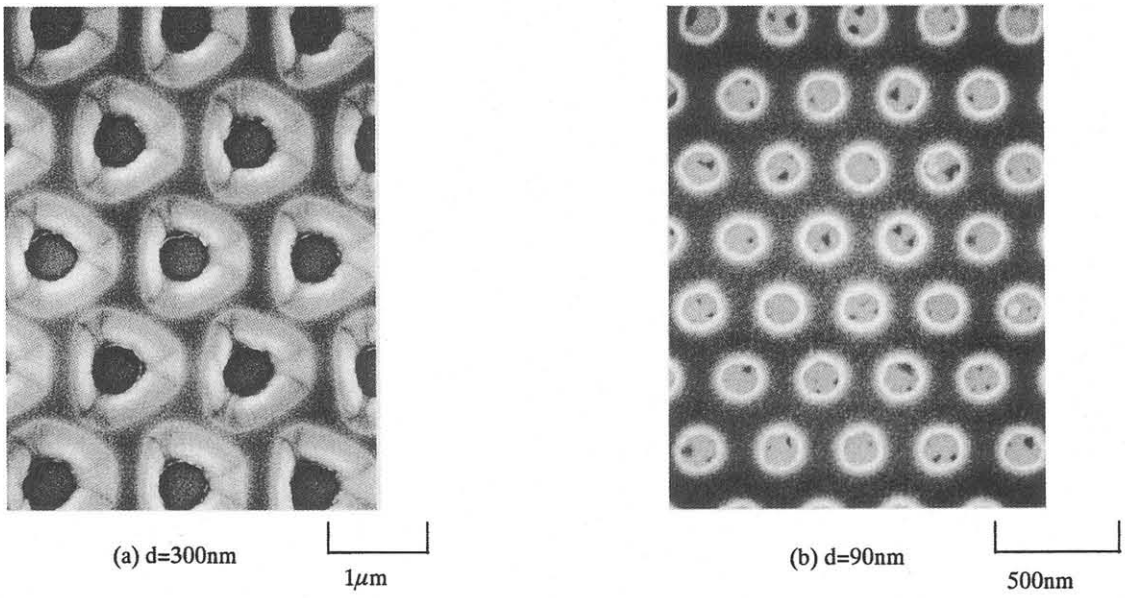

Fig.1 SEM photographs of GaAs/InAs anti-dot structures on GaAs (111)B substrates
(a) d=300nm (b) d=90nm