13年1月11日

電子情報工学専攻	学籍番号	967354
申請者氏名	曺　東鉉	

指導教官氏名	朴　康司 吉田　明

論文要旨（博士）

論文題目	Maskless Selective Epitaxy of III-V Semiconductors by Using a Low Energy Focused Ion Beam (低エネルギー集束イオンビームを用いたIII-V族化合物半導体のマスクレス選択成長に関する研究)

Selective epitaxy has been attracting much attention as a promising technique for fabricating microstructure and/or for reducing the interface defect density in lattice-mismatched epilayers. Various selective epitaxy techniques have been reported and most of them are based on the regrowth technique on a masked layer. However, these techniques have some drawbacks, such as etching damage and contamination at the regrowth interface which can strongly degrade the quality of the devices. Therefore, a maskless selective process technique can be a very promising method. This technique produces device structures with damage-free interfaces by *in-situ* doping and/or doposition.

We studied maskless selective epitaxy (MLSE) of III-V semiconductors using very low energy focused ion beam (FIB). An InGa liquid alloy ion source (LAIS) was fabricated to grow InGaAs/GaAs heterostructures which is important in the optical device structures. MLSE films of $In_xGa_{1-x}As$ on GaAs using a low energy $In_{0.15}Ga_{0.85}$-FIB and As_4 molecular beam was studied for the first time. In this experiment, we have been able to grow $In_xGa_{1-x}As$ maskless selective epitaxial films on GaAs using this growth technique. The crystalline quality of the films investigated with μ-RHEED showed that single crystalline $In_xGa_{1-x}As$ films were obtained at growth temperatures of 400 ~ 600 °C below ion energies of 200 eV. Auger electron spectroscopy was used to measure the In composition of the epilayers, showing that the In composition of the films could be controlled from 4 % to 15 % by adjusting liquid alloy ion source (In 15 at%; Ga85 at%) temperature. This result indicates that InGaAs/GaAs optical devices could be fabricated by using this maskless selective growth technique.

GaN and related materials have attracted much attention as candidate materials for optoelectronic devices in blue and near-UV spectrum regions. Maskless selective epitaxy of GaN on GaAs (100) substrates using Ga low energy FIB and dimethylhydrazine (DMHy) as Ga and N sources, respectively, has been studied. The maskless selective epitaxy films of GaN on GaAs (100) was cubic (zincblende) structure. We have found that GaN-growth depended strongly on growth temperature and DMHy pressure. And surface nitridation time of GaAs (100) had little effect on crystalline quality. The optimized growth conditions for GaN obtained in this experiment were ~610 °C growth temperature with a DMHy pressure of 6.0×10^{-6} Torr at an incident ion beam energy of 30 eV. It was also shown that cubic GaN could be grown even at an incident ion beam energy of 300 eV.

InGaN films were also studied by using InGa low energy FIB and DMHy. To investigate substrate orientation effect on InGaN maskless selective films, GaAs (100), GaAs (111)A, and GaAs (111) B were used. Cubic InGaN and hexagonal InGaN was obtained on GaAs (100), and GaAs (111)A and B substrate, respectively. The optimized growth conditions for InGaN in this growth method were about 560 °C growth temperature with a DMHy pressure of 3×10^{-4} Torr at an incident ion beam energy of 50 eV.

Maskless selectively doped films of group III-V semiconductor were also demonstrated by Sn- or Si-Ga low energy focused ion beam. This selective doping-growth method is thought to be an essential technique in the maskless selective device fabrication.

In this experiment, we have grown maskless selective epitaxy films of InGaAs, GaN, and InGaN on GaAs substrate. Thus, we can conclude this growth method is thought to be very useful in fabricating *in-situ* microstructures and optical- or electronic-devices on selective areas without mask.