ABSTRACTS OF PUBLISHED PAPERS

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CONDENSED MATTER AND MATERIAL

Highly Efficient Nitrogen Doping Into GaAs Using Low-Energy Nitrogen Molecular Ions

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Mat.Res. Soc. Symp.Proc. **510** (1998) 73-78

Low-energy N_2^+ ions were irradiated during the epitaxial growth of GaAs. Ion acceleration energy and ion beam current density were varied in the range of 30-200 eV and 3-37 nA/cm^2, respectively. GaAs growth rate was kept constant at 1 µm/h and the thickness of N-doped GaAs layer was about 1 µm. N concentration was obtained by using secondary ion mass spectroscopy. Strong N-related emissions were observed in the low-temperature photoluminescence spectra, which indicates that N atom is efficiently substituted at As site and is optically active as an isoelectronic impurity. (With the reduction of As_4/Ga ratio, PL emissions presumably related to NN pairs or GaAsN alloy were observed. The results revealed that N substitution is quite dependent on the As flux used for GaAs growth.

Combined ion-Beam and Molecular-Beam Epitaxy Method (CIBMBE) For the Doping of Low-Energy Nitrogen Ions Into GaAs During MBE Growth

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Semiconductor News **7** 4 (1998) 139-142

Low-energy N^+ and N_2^+ ions were irradiated during the epitaxial growth of GaAs using combined ion-beam and molecular-beam epitaxy method (CIBMBE). Ion acceleration energy and ion beam current density were varied in the range of 30-200 eV and 3-37 nA/cm^2, respectively. GaAs growth rate was kept constant at 1 µm/h and the thickness of N-doped GaAs layer was about 1 µm. N concentration was obtained by using secondary ion mass spectroscopy. Strong N-related emissions were observed in the low-temperature photoluminescence spectra, which indicates that N atom is efficiently substituted at As site and is optically active as an isoelectronic impurity.

Low-Energy Nitrogen-Ion doping into GaAs and its Optical Properties

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Materials Science and Engineering **A253** (1998)
301-305

Extremely low-energy atomic (N^+) and diatomic (N_2^+) ions were irradiated during the epitaxial growth of GaAs using combined ion-beam and molecular-beam epitaxy method (CIBMBE). Ion acceleration energy and ion beam current density were varied in the range of 30-200 eV and 3-37 nA/cm^2, respectively. GaAs growth rate was kept constant at 1 µm/h and the thickness of N-doped GaAs layer was about 1 µm. N concentration was obtained by using secondary ion mass spectroscopy. Strong N-related emissions were observed in the low-temperature photoluminescence spectra, which indicates that N atom is efficiently substituted at As site and is optically active as an isoelectronic impurity.

Optical and Electrical Properties of Si^+ ion-Implanted GaAs

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Materials Science and Engineering **A253** (1998)
306-309

Low-temperature photoluminescence (PL) measurements of Si^+ ion-implanted GaAs samples varying ion beam current were investigated. Electrical measurements proved that higher activation rate can be obtained by using low ion beam current (3 nA/cm^2) compared to higher one (60 nA/cm^2). In the PL spectra, broad emission at 840-850 nm can be observed with the dose higher than 2×10^{13} cm^{-2} and it is more noticeable when using high ion beam current. Since the broad PL emission appears when electrical activation rate decreases, we tentatively attributed this broad emission to defect-related one.

Formation of Polycrystalline β-FeSi$_2$ Layers by Ion-Implantation and Their Optical Properties

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Materials Science and Engineering ***A253*** (1998)
284-291

Polycrystalline β-FeSi$_2$ was made by ion beam synthesis (IBS) using implantation of Fe^+ ions into Si. Results from two-step annealing (2SA) and three-step annealing (3SA) processes are discussed. X-ray diffraction data exhibited that for 3SA samples, β-FeSi$_2$ is grown at specific annealing conditions, whereas it is always formed for 2SA samples. The formation of β-FeSi$_2$ layer with thickness of 59 - 79 nm was confirmed by Rutherford backscattering (RBS) measurements. 3SA-sample showed a direct band-gap energy (E_g) of 0.88 eV and 2SA-sample of 0.80 eV. In the 2K photoluminescence spectra, two emissions at 0.786 - 0.808 eV were ascribed to β-FeSi$_2$. Similar features were obtained for β-FeSi$_2$ crystals prepared by horizontal gradient freeze and electron beam deposition (EBD) methods. p-type β-FeSi$_2$ layers were fabricated on n-type Si(100) substrates by Mn^+ ion-implantation into EBD-grown β-FeSi$_2$ layers and subsequent annealing.

Optical And Electrical Characterizations of Mn Doped P-Type β-FeSi$_2$

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Nuclear Instruments and Methods in Physics Research
B147 (1999) 337-342

β-FeSi^2 has attracted increasing attention as a promising material for optoelectronic and thermoelectronic devices due to a high optical absorption coefficient (a) of about 105 cm^{-1} near 1.0 eV and its chemical stability at higher temperatures. For the future practical use of this material as these devices, the control of each electrical conductivity type and the improvement of the material quality are highly required. Although unintentionally doped β-FeSi$_2$ layers formed on n-type Si(100) by the conventional electron-beam deposition (EBD) have typically shown n-type conductivity, the p-type β-FeSi$_2$ layers were formed by the introduction of Mn impurity using ion-implantation at room temperature (R.T.) and subsequent annealing procedures. In this study, we aimed to make p-type β-FeSi$_2$ by implantation of 55Mn$^+$ ions into EBD-grown n-type β-FeSi$_2$ layers/n-Si, where 55Mn$^+$ ions were implanted at two different temperatures (T_{sub}) of R.T. and 250 °C using an energy and a dose of 300 keV and 2.68×10^{15} cm^{-2}, respectively. Their optical and electrical properties, which ought to be affected by implantation and annealing temperatures (Ta_2), were investigated by Raman scattering, optical transmittance, reflectance and van der Pauw measurements. The results showed that the 55Mn$^+$ doping with T_{sub}= R.T. and higher thermal annealing at Ta_2= 900 °C produced p-type layers of good quality with maximum hole mobility of 454.5 cm^2/Vsec at about 65 K.

Carbon Doping into GaAs using Low-Energy Hydro-Carbon Ion

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Mat. Res. Soc. Symp. Proc. **510** (1998) 61-66

The role of hydrogen (H) in carbon (C)-doped GaAs was examined by co-doping of C and H atoms using low-energy hydrocarbon (CH_+ and CH_3^+) ions. Experiments were carried out using the combined ion beam and molecular beam epitaxy (CIBMBE) system. Samples were characterized by low-temperature photoluminescence at 2K and Hall effect measurements at room temperature. Results show that incorporated C atoms are optically and electrically activated as acceptors even by hydrocarbon ion impingement. The effect of H incorporation was found to be noticeable when impinged current density of CH_3^+ ion beam is high that produces equivqlent net hole carrier concentration greater than ~10^{18} cm^{-3}.

-Beta-FeSi$_2$ as a Environmentally Friendly Semiconductor

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Physical Society of Japan **53** 11 (1998) 858-859

The formation of new paradigm for the coming century semiconductor materials was discussed in terms of the abundunce of chemical elements on the earth's crust. Detailed descriptions were made on beta-FeSi$_2$ as optoelectronic and thermoelelctric devices that can be integrated on Si substrates.

Growth of dilute GaAsN alloys by Low-Energy Nitrogen Ion Beam Impinging during GaAs Molecular Beam Epitaxy

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Proc. of XIIth International Conf. on Ion Implantation Technology'98 (1998) 130

Dilute $GaAs_{1-x}N_x$ ($x= 4 \times 10^{-4}$) alloys were fabricated by impinging N ion beam (N^+ and N_2^+) during molecular beam epitaxy of GaAs. "x" was controlled by varying the GaAs growth rate in the range of 0.33~1.0 μm/h, while keeping the ion beam current density constant at 60~75 nA/cm^2. All samples were grown at the substrate temperature of 550 °C. Secondary ion mass spectrometry (SIMS) analysis showed that N atoms distributed uniformly in dilute GaAsN layers. In 2 K photoluminescence spectra of the samples furnace-annealed at 750 °C, peak-energy shift of band-to-carbon (C) acceptor emission, (e, C) towards lower energy side (red shift) was observed as x increases from zero. This is an evidence on the formation of GaAsN alloys since the red-shift was theoretically predicted owing to a large optical bowing parameter relevant to GaAsN system.

ENERGY TECHNOLOGY

Dependence of Deuterium Line-shape on the Insertion Depth of BN and C Limiters in the TPE-1RM20 Reversed Field Pinch Plasma

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Boron nitride (BN) and graphite limiters were placed in the edge region of deuterium plasma of the reversed-field-pinch machine TPE-1RM20. The limiters were attached on a linear motion feedthrough and were inserted into the edge plasma up to 40 mm beyond the plasma boundary defined by fixed limiters. The emission spectrum of deuterium atoms was measured in the vicinity of the limiters. The spectral line profile was analyzed by changing the insertion depth of the limiter. When the limiter was inserted a certain depth at the first time, the emission of hydrogen atoms was observed for both BN and carbon materials and the release of retained hydrogen was evident. The emission intensity of hydrogen was suddenly decreased within 3-5 shots for the case of BN limiter, and then, the peak was buried under noise. The broadened spectrum of deuterium was observed when the BN limiter was inserted up to approximately 30 mm. The amount of released hydrogen from the graphite limiter was 2-3 times larger than that from BN limiter and the release continued for 5-10 shots. The profile of deuterium line was changed with shot by shot compared to the BN limiter experiments. A broadened profile was observed when the insertion depth exceeded 30 mm.