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Oxygen Vacancy Induced Substantial Threshold Voltage Shifts in the Hf-based High-*K* MISFET with p+poly-Si Gates -A Theoretical Approach

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A theoretical investigation has been made of the origin of substantial threshold voltage (V_{th}) shifts observed in p+poly-Si gate Hf-based metal insulator semiconductor field effect transistors (MISFETs), by focusing on the effect of oxygen vacancy (V_O) formation in HfO_2. It has been found that V_O formation and subsequent electron transfer across the interface definitely causes substantial V_{th} shifts, especially in p+poly-Si gate MISFETs. Moreover, the theory also systematically reproduces recent experimental reports that large flat band (V_{fb}) shifts are observed, even in intrinsic poly-Si gates, and that the V_{fb} shifts exhibit a high dependence on $HfSiO_x$ thickness. [DOI : 10.1143/JJAP.43.L1413]

Keywords: high-*k* dielectrics, poly-Si-gate electrode, Fermi level pinning, theory, oxygen vacancy, HfO_2, flatband shift, threshold voltage shift

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Theoretical Prediction of Curie Temperature in (Zn,Cr)S, (Zn,Cr)Se and (Zn,Cr)Te by First Principles Calculations

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(Received September 10, 2004; accepted September 14, 2004; published October 8, 2004)

The electronic structure and the magnetic properties of (Zn,Cr)S, (Zn,Cr)Se and (Zn,Cr)Te are calculated by using the Korringa-Kohn-Rostoker method combined with the coherent potential approximation (KKR-CPA) within the local density approximation. Curie temperatures are calculated by the mean field approximation (MFA) and by Monte Carlo simulation. It is found that the MFA strongly overestimates the Curie temperatures for low concentrations due to shortrangeness of interactions in (Zn,Cr)S, (Zn,Cr)Se and (Zn,Cr)Te. The Curie temperatures of (Zn,Cr)Te calculated by Monte Carlo simulation agree very well with recent experimental values. [DOI : 10.1143/JJAP.43.L1416]

Keywords: *ab initio* calculation, dilute magnetic semiconductor, ferromagnetism, Curie temperature, zinc sulfur, zinc selenide, zinc telluride, exchange coupling constant, Monte Carlo simulation

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Continuous Wave Milliwatt Power AlGaN Light Emitting Diodes at 280 nm

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We report on deep ultraviolet light emitting diodes using AlGaN multiple quantum well active regions and with peak emission at 280 nm. A new buffer layer and active region design resulted in flip-chip devices with continuous wave powers as high as 0.85 mW for a pump current of 20 mA and a record external quantum efficiency over 1%. The power saturated at 5 mW for a dc pump current of 200 mA.
[DOI : 10.1143/JJAP.43.L1419]
Keywords: AlGaN, quantum well, ultraviolet, light emitting diode

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A Promising Evaluation Method of Ultra-Low-Expansion Glasses for the Extreme Ultra-Violet Lithography System by the Line-Focus-Beam Ultrasonic Material Characterization System

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A super-precise method of evaluating the coefficient of thermal expansion (CTE) of ultra-low-expansion glasses was developed using the line-focus-beam ultrasonic material characterization (LFB-UMC) system and was demonstrated for TiO_2-doped SiO_2 glass. The sensitivity and resolution in the velocity measurement of leaky surface acoustic waves (LSAWs) in CTE were estimated to be 4.40 (ppb/K)/(m/s) and ± 0.77 ppb/K for ± 2σ (σ: standard deviation) at 225 MHz. LSAW velocity differences caused by different TiO_2 concentrations and distributions or striae in the specimens were successfully detected and evaluated, providing two-dimensional information. This ultrasonic method is effective for evaluating ultra-low-expansion glasses needed for extreme ultraviolet lithography (EUVL) systems. [DOI : 10.1143/JJAP.43.L1455]
Keywords: line-focus-beam ultrasonic material characterization system, velocity measurement, leaky surface acoustic waves, ultra-low-expansion glasses, TiO_2-doped SiO_2 glass, CTE evaluation, EUVL system

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New Electron-Doped Superconducting Cuprate $Li_xSr_2CuO_2Br_2$

Tetsuya Kajita, Masatsune Kato*, Takashi Suzuki, Takashi Itoh[1], Takashi Noji and Yoji Koike
(Received September 22, 2004; accepted September 24, 2004; published October 22, 2004)

A new electron-doped superconductor $Li_xSr_2CuO_2Br_2$ with x = 0.15 has successfully been synthesized by an electrochemical Li-intercalation technique. The magnetic susceptibility shows superconductivity of bulk with the superconducting transition temperature T_c = 8K. This compound is the first electron-doped superconducting cuprate with the K_2NiF_4 structure. [DOI : 10.1143/JJAP.43.L1480]
Keywords: superconductivity, Li-intercalation, layered perovskite, cuprate, electron-doping

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Low Microwave Surface Resistance in $NdBa_2Cu_3O_{7-\delta}$ Films Grown by Molecular Beam Epitaxy

Jose Kurian* and Michio Naito
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We report the growth of $NdBa_2Cu_3O_{7-\delta}$ films on (100) MgO substrate by Molecular Beam Epitaxy (MBE). Large area $NdBa_2Cu_3O_{7-\delta}$ films with homogeneous superconducting properties were grown by precise control of stoichiometry and the optimisation of growth parameters. The stoichiometric ratio of Nd:Ba:Cu close to 1:2:3 yields films with T_C of 94K and J_C values above 3.5 MA/cm^2 at 77 K on bare MgO substrate. The $NdBa_2Cu_3O_{7-\delta}$ films grown under optimised conditions had excellent in-plane texture and good metallicity. The most significant characteristic of our MBE grown $NdBa_2Cu_3O_{7-\delta}$ films is the very low microwave surface resistance values at all temperature range compared to its $YBa_2Cu_3O_{7-\delta}$ counterpart with typical value of ~870 μΩ at 77 K & 22 GHz. Our results on the MBE grown $NdBa_2Cu_3O_{7-\delta}$ films suggests that $NdBa_2Cu_3O_{7-\delta}$ is a superior choice for the realisation of commercial microwave applications. [DOI : 10.1143/JJAP.43.L1502]
Keywords: $NdBa_2Cu_3O_{7-\delta}$, MgO, surface resistance, superconducting thin film, molecular beam epitaxy

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InGaN/GaN Multiple Quantum Disk Nanocolumn Light-Emitting Diodes Grown on (111) Si Substrate

Akihiko Kikuchi, Mizue Kawai, Makoto Tada and Katsumi Kishino
(Received October 5, 2004; accepted October 8, 2004; published November 5, 2004)

GaN-nanocolumn-based InGaN/GaN multiple quantum disk (MQD) light-emitting diodes (LEDs) with a novel columnar structure were fabricated on n-type (111) Si substrates. The n-GaN and InGaN/GaN MQD active region had isolated columnar structures, while the diameters were gradually increased in the p-GaN region by controlling the growth conditions. Consequently, the nanocolumn LED had a continuous surface without chasms. This novel structure enables p-type electrodes to be fabricated by the conventional method on top of nanocolumn devices while keeping the superior optical properties of the isolated nanocolumn active region. The nanocolumn LED showed clear rectifying behavior with a typical turn-on voltage of 2.5–3.0 V at room temperature. Electroluminescence was observed through semitransparent electrodes with various emission colors from green (530 nm) to red (645 nm).
[DOI : 10.1143/JJAP.43.L1524]

Keywords: nanocolumn, nanorod, GaN, InGaN, light-emitting diodes, molecular beam epitaxy

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Ultrasensitive Detection of DNA Hybridization Using Carbon Nanotube Field-Effect Transistors

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(Received October 4, 2004; accepted October 13, 2004; published November 12, 2004)

We have sensitively detected DNA hybridization using carbon nanotube field-effect transistors (CNTFETs) in real time. Amino modified peptide nucleic acid (PNA) oligonucleotides at 5' end were covalently immobilized onto the Au surface of the back gate. For 11-mer PNA oligonucletide probe, full-complementary DNA with concentration as low as 6.8 fM solution could be effectively detected. Our CNTFET-based biochip is a promising candidate for the development of an integrated, high-throughput, multiplexed DNA biosensor for medical, forensic and environmental diagnostics. [DOI : 10.1143/JJAP.43.L1558]
Keywords: carbon nanotube field-effect transistors, DNA hybridization, PNA probe, ultrasensitivity, real time, label free

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First Demonstration of TE Mode Nonreciprocal Propagation in an InGaAsP/InP Active Waveguide for an Integratable Optical Isolator

Hiromasa Shimizu* and Yoshiaki Nakano
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We have proposed and fabricated a TE mode semiconductor-waveguide-type optical isolator based on the nonreciprocal loss shift at a wavelength λ = 1560 nm. Furthermore, we demonstrate, for the first time, a TE mode nonreciprocal loss shift of 9.3 dB/mm under a magnetic field of +/–1 kG in the facricated InGaAsP active waveguide with Fe on an InP substrate. This result opens a way to the monolithic integration of semiconductor waveguide-type optical isolators with edge emitting semiconductor lasers. [DOI : 10.1143/JJAP.43.L1561]
Keywords: nonreciprocal loss shift, semiconductor optical amplifier, waveguide-type optical isolator, TE mode, InGaAsP, Fe

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Nanosecond Time-Resolved Stimulated Raman Spectra of Benzene under Shock Compression up to 4.2 GPa: Observation of Liquid-Solid Phase Transition

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(Received October 7, 2004; accepted October 27, 2004; published November 26, 2004)

Nanosecond time-resolved stimulated Raman spectroscopy is used to investigate the shock-induced phase transition of liquid benzene. A supercooled state and a liquid-solid phase transition are observed at shock pressures above 2.8 GPa. Time-resolved Raman spectra reveal that the liquid state is initially preserved and rapidly transforms to the solid state under shock compression at 4.2 GPa. Rapid nucleation and growth on a micrometer scale occurs within 20 ns. [DOI : 10.1143/JJAP.43.L1614]
Keywords: benzene, shock compression, stimulated Raman spectroscopy, time-resolved spectroscopy, phase transition

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Dilution Effects on Chemical and Magnetic Clusters of α-$LiFeO_2$

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We have synthesized α-$LiFe_{1-x}In_xO_2$ (x = 0, 0.001, 0.01, 0.05, and 0.1) powders by calcination of Li_2CO_3, Fe_2O_3 and In_2O_3 mixtures. In X-ray diffraction, the sample with larger x value showed larger lattice constant of the cubic NaCl-type structure. Aside from electron diffraction patterns of the cubic unit cell with diffuse scattering for both the samples, the x = 0 sample demonstrated a doubled structure of the cubic unit cell with wavy diffuse scattering, though the x = 0.1 sample exhibited the doubled structure with less intensive diffuse scattering. In cooling history-dependent dc susceptibilities, the bifurcation point of the x = 0 sample was \approx90 K, and it lowered from 87 to 44 K with increasing the x value from 0.001 to 0.1. Dilution of α-$LiFeO_2$ with nonmagnetic In^{3+} ions suppressed chemical cluster formation at room temperature and reduced temperature of ferromagnetic cluster formation.
[DOI : 10.1143/JJAP.43.L1620]

Keywords: α-$LiFeO_2$, chemical cluster, magnetic cluster, short-range order, dilution

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Reduction of Surface Resistance of $ErBa_2Cu_3O_{7-\delta}$ Films by $BaZrO_3$ Nano-Particle Inclusion

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Low surface resistance is achieved by introducing $BaZrO_3$ nano-particles in high crystalline quality $ErBa_2Cu_3O_{7-\delta}$ films. The surface resistance of a $ErBa_2Cu_3O_{7-\delta}$ film with $BaZrO_3$ nano-particles grown by pulsed laser deposition is 55% of that without $BaZrO_3$ nano-particles near 65 K. This result suggests that the $ErBa_2Cu_3O_{7-\delta}$ films with $BaZrO_3$ nano-particles have potential as high power microwave emitting devices. A new direction is shown for reducing the surface resistance of superconducting films. [DOI : 10.1143/JJAP.43.L1623]

Keywords: $ErBa_2Cu_3O_{7-\delta}$, $BaZrO_3$ nano-particles, surface resistance, pinning center

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Synthesis of GaN Crystal Using Gallium Hydride

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A new method for synthesizing a large area of c-axis GaN film was developed. The gallium hydride which was formed by the reaction between metal-Ga and hydrogen gas was used as the Ga source, and reacted with NH_3 gas to grow GaN crystals on the sapphire (0001) substrate. 2.7 μm-thick GaN film with c-axis orientation could be grown on the substrate. Stable conditions for the synthesis of gallium hydride by the reaction of H_2 gas with metal-Ga were examined. As a result, gallium hydride is stable at about 1000°C which is a temperature commonly used for the growth of GaN. These results show that the use of gallium hydride as the predominant species of the Ga source can provide a relatively inexpensive method of growing GaN crystals at a high level of purity. [DOI : 10.1143/JJAP.44.L1]

Keywords: GaN, single crystal, gallium hydride, bulk, growth mechanism

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$Zn_{1-x}Cd_xO$/ZnO Heterostructures for Visible Light Emitting Devices

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(Received October 26, 2004; accepted November 8, 2004; published December 10, 2004)

Wurtzite $Zn_{1-x}Cd_xO$/ZnO heterostructures were successfully grown by remote plasma enhanced metalorganic chemical vapor deposition (RPE-MOCVD) and were investigated by photoluminescence (PL) spectroscopy. The flatness of $Zn_{1-x}Cd_xO$ films was investigated by an atomic force microscope (AFM), indicating the typical RMS value of 0.5 nm. The optical properties of the $Zn_{0.96}Cd_{0.04}O$ film were characterized by micro-PL at 4 K, exhibiting micro-structural and positional uniformities in the films. In the double heterostructure consisting of ZnO/$Zn_{0.92}Cd_{0.08}O$/ZnO, temperature and excitation intensity dependencies of PL spectra were examined. The PL emission is characterized as localized and free exciton emission. A dependence with a slope near unity is obtained from the excitation dependence of the PL intensity. Blue-green emission (2.78 eV) was demonstrated from the double-heterostructure at room temperature.
[DOI : 10.1143/JJAP.44.L4]

Keywords: ZnO, ZnCdO, heterostructure, remote plasma-enhanced MOCVD, photoluminescence, light-emitting device

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Epitaxial Growth of GaN on (1 0 0) β-Ga_2O_3 Substrates by Metalorganic Vapor Phase Epitaxy

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Epitaxial growth of nitride compounds by the metalorganic vapor phase epitaxy (MOVPE) technique is demonstrated for the first time on β-Ga_2O_3 single crystal substrates, which are near-UV transparent and n-type conductive. High-quality (0 0 0 1) GaN epi-layer with a narrow bandedge luminescence was obtained using a low temperature conductive buffer layer. InGaN multi-quantum well (MQW) structure was also successfully grown. The first blue light-emitting diode (LED) on β-Ga_2O_3 with vertical current injection is demonstrated.
[DOI : 10.1143/JJAP.44.L7]

Keywords: β-Ga_2O_3, GaN, substrate, transparent conductive oxide, MOVPE, LED

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X-ray Absorption and X-ray Magnetic Circular Dichroism Studies of a Monatomic Fe(001) Layer Facing a Single-Crystalline MgO(001) Tunnel Barrier

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(Received October 29, 2004; accepted November 6, 2004; published December 10, 2004)

We studied the electronic and magnetic states of a monatomic bcc Fe(001) layer facing a single crystalline MgO(001) tunnel barrier by using X-ray absorption spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD) at the Fe $L_{2,3}$ core edges in order to clarify the origin of the huge tunnel magnetoresistance (TMR) effect observed in Fe/MgO/Fe magnetic tunnel junctions. Both the XAS and XMCD revealed that the 1 ML-Fe is not oxidized, which is crucial to the huge TMR effect. A sum-rule analysis of the XMCD shows that the 1 ML-Fe(001) has an enhanced total magnetic moment of about 2.6 μB per Fe atom compared with that of bulk Fe. [DOI : 10.1143/JJAP.44.L9]
Keywords: monatomic bcc Fe(001) layer, MgO(001) tunnel barrier, Fe/MgO/Fe magnetic tunnel junctions, X-ray absorption spectroscopy (XAS), X-ray magnetic circular dichroism (XMCD), epitaxial growth

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Peltier Effect in Sub-micron-Size Metallic Junctions

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Resistance (*R*)-current (*I*) curves in trilayer CPP-GMR (current perpendicular to plane-giant magnetoresistance) elements show a parabolic baseline because of Joule heating, and abrupt jumps due to magnetization reversals. The bottom of the parabolic baseline shifts in one current direction for reasons that were previously unclear. Our study of the *R-I* characteristics of CPP elements with various structures showed (i) the shift in the *R-I* curve originates from Peltier cooling in the CPP elements; (ii) the cooling power per unit area of the CPP elements (~10^5 W/cm^2) is much greater than that of conventional thermoelectric materials (~5 W/cm^2). [DOI : 10.1143/JJAP.44.L12]
Keywords: Peltier effect, CPP-GMR, CPP structure, metallic junctions, current induced magnetization reversal

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Materials Design of Ferromagnetic Diamond

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We propose materials design of ferromagnetic diamond without any transition metal elements based on first principles calculations. The electronic structure and the magnetic properties of impurities-doped diamond are calculated by using the Korringa-Kohn-Rostoker method within the local spin density approximation with taking into account disorder using coherent potential approximation. It is found that H atoms which are doped into tetrahedral interstitial sites show finite local magnetic moments. Moreover, the impurities-doped diamond show ferromagnetism with half-metallic density of states. [DOI : 10.1143/JJAP.44.L51]
Keywords: diamond, ferromagnetism without transition metal elements, materials design, *ab initio* calculation

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Protein Cryocrystallography Using Laser-Processed Crystal

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We propose a new procedure in biological cryocrystallography, using the laser-ablation technique. This is the first report on the successful processing of cryo-cooled crystals to create a "protein crystal ball" that is conducive to X-ray diffraction (XRD) data collection. Pulsed UV laser soft ablation (PULSA) modifies protein crystals into a spherical shape and removes surrounding materials, but does not negatively affect crystallinity and may improve diffraction data quality. Additionally, we demonstrate treatment of problematic samples to make them serviceable for XRD analysis. Isolation of single crystals can be performed after flash cooling with the PULSA technique. [DOI : 10.1143/JJAP.44.L54]

Keywords: protein crystal, cryocrystallography, laser ablation, UV laser, X-ray diffraction, structural analysis

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Spin Polarization Effects on O_2 Dissociation from Heme-O_2 Adduct

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(Received November 14, 2004; accepted December 1, 2004; published December 17, 2004)

We consider singlet and triplet iron-porphyrin-O_2 (FeP-O_2) adducts to investigate spin polarization effects on the FeP-O_2 interaction using *ab initio* calculations based on density functional theory (DFT). The presence of the imidazole (Im) ligand induces spin polarization from O_2 to Fe in the triplet (Im)FeP-O_2 adduct. The O-O bond of the triplet (Im)FeP-O_2 is weaker than that of the triplet FeP-O_2 because of this spin polarization effects. Our results suggest that magnetization of heme or heme-based nanomaterials may be utilized as cathode electrode catalysts in polymer electrolyte fuel cells (PEFCs). [DOI : 10.1143/JJAP.44.L57]

Keywords: polymer electrolyte fuel cell, cathode electrode, hemoglobin, heme, Fe, porphyrin, imidazole, O_2, spin polarization, density functional theory

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Sensitivity Characteristics of Positive and Negative Resists at 200 kV Electron-Beam Lithography

Byung-Sung Kim, Hyo-Sung Lee, Jung-Sub Wi, Kyung-Bae Jin and Ki-Bum Kim*
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The contrast curve of positive and negative electron-beam resists such as polymethylmethacrylate (PMMA), ZEP520A, and hydrogen silsesquioxane (HSQ) at 200 kV electron-beam was estimated by using continuous slow down approximation (CSDA) model with both non-relativistic and relativistic Bethe stopping power. Experimental results show that simple CSDA model well explains the overall response of these various electron-beam resists to high energy electron-beam only if we use the relativistic Bethe stopping power. The difference between non-relativistic and relativistic Bethe stopping power is discussed.
[DOI : 10.1143/JJAP.44.L95]

Keywords: sensitivity characteristics, electron-beam energy, 200 kV electron-beam lithography, relativistic Bethe stopping power, PMMA, ZEP520A, HSQ

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10 Milliwatt Pulse Operation of 265 nm AlGaN Light Emitting Diodes

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We report on the development of solid-state deep ultraviolet light sources optimized for the germicidal applications. Pulsed power levels in excess of 10 mW were achieved for AlGaN based 265 nm light emitting diodes by improving the material quality using Migration-Enhanced Metal Organic Chemical Vapor Deposition. Packaged devices reached the continuous-wave power of 237 μW at 30 mA and a pulse power exceeding 10 mW for 1.2 A driving current. [DOI : 10.1143/JJAP.44.L98]

Keywords: deep UV light emitting diodes, AlGaN, multiple-quantum-well, MEMOCVD

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1.1 mW Single-Mode Output Power of All-Monolithic 1.3 μm InAlGaAs/InP Vertical Cavity Surface Emitting Lasers Grown by Metal Organic Chemical Vapor Deposition

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(Received November 24, 2004; accepted December 1, 2004; published December 24, 2004)

We present all-monolithic InAlGaAs/InP vertical cavity surface emitting lasers (VCSELs) emitting wavelength of 1.3 μm grown by metal organic chemical vapor deposition (MOCVD). The devices with tunnel junction (TJ) and the air-gap aperture showed the performances as high as output power of 1.1 mW and as low as threshold current of 1.9 mA operating in single-mode at room temperature. We obtained the emitting transverse wavelength of 1333.1 nm with side mode suppression ratio (SMSR) of 40 dB, the continuous wave (CW) operation of temperature over 80°C, and modulation bandwidth exceeding 2.5 Gbit/s.
[DOI : 10.1143/JJAP.44.L101]

Keywords: vertical cavity surface emitting laser (VCSEL), InP, InAlGaAs, metal organic chemical vapor deposition (MOCVD), monolithic, long wavelength

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Piezoelectric Windmill: A Novel Solution to Remote Sensing

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This study demonstrates a technology, "Piezoelectric Windmill", for generating the electrical power from wind energy. The electric power-generation from wind energy is based on piezoelectric effect and utilizes the bimorph actuators. Piezoelectric Windmill consists of piezoelectric actuators arranged along the circumference of the mill in the cantilever form. Using the camshaft gear mechanism an oscillating torque is generated through the flowing wind and applied on the actuators. A working prototype was fabricated utilizing 12 bimorphs (60 × 20 × 0.5 mm^3) having a preload of 23.5 gm. Under a nominal torque level corresponding to normal wind flow and oscillating frequency of 6 Hz, a power of 10.2 mW was successfully measured across a load of 4.6 kΩ after rectification. Combined with the wireless transmission, this technology provides a practical solution to the remote powering of sensors and communication devices. [DOI : 10.1143/JJAP.44.L104]

Keywords: piezoelectric, energy harvesting, bimorph, windmill, transducer, remote sensing

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High-Critical-Current-Density Epitaxial Films of $SmBa_2Cu_3O_{7-x}$ in High Fields

Yutaka Yoshida[1,6], Kaname Matsumoto[2,6], Yusuke Ichino[1,6], Masakazu Itoh[1,6], Ataru Ichinose[3,6], Shigeru Horii[4,6], Masashi Mukaida[5,6] and Yoshiaki Takai[1]
(Received November 8, 2004; accepted December 3, 2004; published January 7, 2005)

The critical current density (J_c) and irreversibility field (B_{irr}) of epitaxial $SmBa_2Cu_3O_{7-x}$ (SmBCO) films are reported. The B_{irr} and J_c of these films deposited on MgO(100) substrates by pulsed-laser deposition depend critically on the substrate temperature. The use of a thin SmBCO seed layer grown at a high substrate temperature enabled us to obtain fully *c*-axis-oriented SmBCO films at relatively low temperatures, resulting in a high J_c of 1.7 × 10^5 A/cm^2 of B // c at 5 T and 77 K. This value is as high as that of the optimized NbTi superconducting wires achieved at 5 T and 4.2 K. [DOI : 10.1143/JJAP.44.L129]

Keywords: $SmBa_2Cu_3O_y$, thin film, pulsed laser deposition, low-temperature growth, superconducting properties, microstructure

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Selective Removal of Carbon Nanotubes Utilizing Low-Acceleration-Voltage Electron Irradiation Damage

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(Received December 6, 2004; accepted December 20, 2004; published January 7, 2005)

A simple method for spatially selective removal of single-walled carbon nanotubes is demonstrated. This method is based on low-acceleration-voltage electron irradiation damage and consists of local electron irradiation of nanotubes and annealing in air. The irradiation damage seems to follow excitation of valence electrons.
[DOI : 10.1143/JJAP.44.L133]

Keywords: nanotube, low-acceleration-voltage electron, electron irradiation damage, selective removal

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Demonstration of Nonpolar *m*-Plane InGaN/GaN Light-Emitting Diodes on Free-Standing *m*-Plane GaN Substrates

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(Received November 24, 2004; accepted December 27, 2004; published January 14, 2005)

We report the fabrication of nonpolar *m*-plane InGaN/GaN multiple-quantum well light-emitting diodes (LEDs) on free-standing *m*-plane GaN substrates. On-wafer continuous wave output power of 240 μW was measured at 20 mA for a 300× 300 μm^2 device, and output power as high as 2.95 mW was measured at 300 mA. There was no sign of saturation of the output power at high drive currents. An emission peak at 450 nm was obtained on electroluminescence measurements with high drive currents. The current-voltage characteristics of these LEDs showed rectifying behavior with a turn-on voltage of 3-4 V.
[DOI : 10.1143/JJAP.44.L173]

Keywords: Nonpolar, *m*-plane, InGaN, light-emitting diode, free-standing, electroluminescence

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Etching a Micro-Trench with a Maximum Aspect Ratio of 60 on Silica Glass by *Laser-Induced Backside Wet Etching* (LIBWE)

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(Received December 8, 2004; accepted December 22, 2004; published January 14, 2005)

We have successfully fabricated a deep micro-trench about 7 μm wide and 420 μm deep on silica glass with a maximum aspect ratio of 60 by *laser induced backside wet etching* (LIBWE) via KrF laser ablation of a saturated pyrene/acetone solution. The processing time for the microetching was as short as 5 min at a repetition rate of 80 Hz and a fluence of F = 1.0 J·cm^{-2}·pulse^{-1}. The etch rate was calculated to be approximately 17 nm·pulse^{-1}. The LIBWE method is shown to be very useful for surface microstructuring of silica glass with high aspect ratio and high throughput. [DOI : 10.1143/JJAP.44.L176]
Keywords: laser-induced backside wet etching, LIBWE, microetching, microfabrication, silica glass, high aspect ratio, microtrench, pyrene/acetone solution, KrF excimer laser

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Subwavelength-Resolution Raman Microscopy of Si Structures Using Metal-Particle-Topped AFM Probe

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Using depolarization of the 364 nm light scattered by a small particle on the (100)Si surface, one can obtain allowed 520 cm^{-1} Raman signal from the localized area of Si around the particle, while the ordinary Raman signal is forbidden by the polarization selection rules. We have realized this scheme using Ag-particle-topped quartz atomic force microscope (AFM) probe immersed into glycerol droplet on Si surface and applied to local stress measurement. Lateral resolution in the range of 100 nm was demonstrated, and stress variation in a strained Si film was investigated. [DOI : 10.1143/JJAP.44.L202]
Keywords: silicon, stress, Raman microscopy, subwavelength resolution, atomic force microscopy, polarization of light

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Supercritical Improvement of Resist Patterns by Introducing Functional Molecules

Hideo Namatsu and Mitsuru Sato[1]
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A new performance enhancement technique for resists has been developed that involves the use of supercritical fluid and functional molecules. Because it is an excellent solvent, the supercritical fluid dissolves the molecules, which provide functions originally lacking in the resist material; and the good diffusivity of supercritical fluid distributes the molecules throughout the resist. Thus, functions can be added to a resist without degrading its sensitivity or development characteristics because the process is performed after exposure and development. Furthermore, since the molecules are dispersed uniformly, there is no change in the line width of resist patterns. This advanced technique for improving resists using supercritical fluid has great potential to change the current concept of resist processes.
Keywords: supercritical fluid, resist improvement, functional molecule, ArF resist

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Fabrication and Characterization of InN-Based Quantum Well Structures Grown by Radio-Frequency Plasma-Assisted Molecular-Beam Epitaxy

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(Received January 4, 2005; accepted January 14, 2005; published January 28, 2005)

InN/$In_xGa_{1-x}N$ quantum well structures have been successfully fabricated on InN templates grown on (0 0 0 1) sapphire substrates by RF plasma assisted molecular beam epitaxy for the first time. The structure was confirmed by observing the 1st and 2nd satellite peaks of X-ray diffraction. From InN/$In_{0.8}Ga_{0.2}N$ single quantum well structures with the different well widths of 2.3, 3.4 and 5.7 nm, photoluminescence (PL) emission from the well layers was observed at 77 K, and the PL peak energy slightly lowered with increasing well width. This dependence can be explained by combined effects of the quantum size effect, quantum confinement Stark effect, and band filling effect.
[DOI : 10.1143/JJAP.44.L230]

Keywords: InN, In-rich $In_xGa_{1-x}N$, quantum well, optical property, X-ray diffraction, RF-MBE

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A Pd-Cu-Ni Ternary Alloyed Membrane on Porous Nickel Support Prepared by Sputtering and Copper Reflow

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(Received December 8, 2004; accepted January 11, 2005; published January 28, 2005)

We propose a ternary, Pd-Cu-Ni, alloyed membrane on porous nickel support that dramatically enhances the hydrogen selectivity by using sputtering and copper reflow. Porous nickel support made by sintering shows strong resistance to hydrogen embrittlement and thermal fatigue. To improve the hydrogen selectivity of the membrane, fabricated the layer sequence of Cu/Pd/Ni on porous nickel support replaced that of conventional Pd/Cu/Ni and then reflow was performed at 700°C. Consequently, copper was reflowed unilaterally into Pd/Ni layer, thereby avoiding delamination by the interlayered copper and enabling infinite hydrogen selectivity because of extremely dense coatings.
[DOI : 10.1143/JJAP.44.L233]

Keywords: porous nickel support, hydrogen selectivity, Pd alloyed coatings, Pd-Cu-Ni ternary alloyed membrane, copper reflow, plasma surface modification

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Center-Wavelength-Shifted Passively Mode-Locked Diode-Pumped Ytterbium(Yb): Yttrium Aluminum Garnet(YAG) Laser

Sadao Uemura and Kenji Torizuka
(Received February 3, 2005; accepted February 18, 2005; published March 4, 2005)

We generate 136-fs pulses from a passively mode-locked diode-pumped ytterbium(Yb):yttrium aluminum garnet(YAG) laser. This is to our knowledge the shortest pulse from a Yb:YAG laser. We shift the laser center wavelength from the commonly used 1030 nm to around 1050 nm to utilize the Yb:YAG spectrum broader.
[DOI : 10.1143/JJAP.44.L361]

Keywords: Yb:YAG, passively mode-locked, diode-pumped, SESAM

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Si Nano-Photodiode with a Surface Plasmon Antenna

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Nano-photodiodes with a subwavelength active area using the optical near-field enhanced by surface plasmon resonance are proposed. We fabricated a Si Schottky photodiode that consists of an active area of 300 nm in diameter and a surface plasmon antenna to generate the carrier within the active area efficiently. The fabricated photodiode shows an increase of the photocurrent by several tenfold compared to that without a surface plasmon antenna. This result suggests an enhanced photogeneration of carriers in a semiconductor via surface plasmon resonance. Such a Si nano-photodiode is a potential high-speed optical signal detector because the opto-electronic conversion process occurs within a subwavelength scale. [DOI : 10.1143/JJAP.44.L364]

Keywords: photodiode, subwavelength aperture, optical near-field, surface plasmon

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Epitaxial Lateral Overgrowth of High Al Composition AlGaN Alloys on Deep Grooved SiC Substrates

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(Received February 19, 2005; accepted February 27, 2005; published March 11, 2005)

Fully coalesced $Al_{0.93}Ga_{0.07}N$ films were demonstrated by metalorganic chemical vapor deposition on deep grooved SiC substrates. Lateral $Al_{0.93}Ga_{0.07}N$ growth was achieved at low V/III ratios during growth. The deep grooves enabled coalescence despite of parasitic growth in the trenches. Dislocation reduction in the overgrown regions of the films was observed by transition electron microscopy and atomic force microscopy. [DOI : 10.1143/JJAP.44.L405]

Keywords: aluminum nitride, aluminum gallium nitride, metalorganic chemical vapor deposition, epitaxial lateral overgrowth, transmission electron microscopy, threading dislocations

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355-nm UV Light Generation in High-Quality CsB_3O_5 Fabricated by Post-Growth Heat Treatment

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(Received March 2, 2005; accepted March 7, 2005; published March 18, 2005)

Cesium triborate (CsB_3O_5) is expected to be an efficient harmonic generator in the UV region. However, as-grown single crystals of CsB_3O_5 often contain a high density of optical scattering centers that significantly reduce device performance. We found that these can be removed by a post-growth heat treatment with quenching. Treated crystals were employed for the third harmonic generation of a high-power Nd:YAG laser operating at 1064 nm. We generated high-power 355-nm output power of 14 W, which is three times higher than that obtained by a commercial LiB_3O_5 crystal under the same experimental conditions.
[DOI : 10.1143/JJAP.44.L422]

Keywords: cesium borate, CsB_3O_5 (CBO), nonlinear optics, crystal growth, scattering center, heat treatment, quenching, third harmonic generation (THG)

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Production of Short-Lived Positron-Emitting Radioactive Nuclei Using a 2.4 TW, 50 fs Tabletop Laser

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We produced a short-lived positron-emitting radioisotope ^{13}N by using MeV-order deuterons emitted from relativistic laser plasma generated by a tabletop laser. For generation of the plasma, laser pulses with a peak power of 2.4 TW and a pulse duration of 50 fs were focused with a 10 Hz repetition rate onto a microporous polytetrafluoroethylene film loaded with deuterated polystyrene, where the maximum intensity at the focal point was 3×10^{18} W/cm^2. The irradiation of melamine resins by deuterons for 55 s produced ^{13}N of 1.00 ± 014 Bq through a nuclear reaction of $^{12}C(d,n)^{13}N$. This is the first report on an actual activation using a table-sized femtosecond laser. [DOI : 10.1143/JJAP.44.L425]

Keywords: terawatt laser, femtosecond laser pulse, nuclear reaction, positron-emitting radioisotope, energetic deuteron generation, relativistic laser plasma, microporous polytetrafluoroethylene film, deuterated polystyrene, melamine resin

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Nanoholes in InP and C_{60} Layers on GaAs Substrates by Using AlGaAs Nanowire Templates

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As one of the nano-scale fabrication techniques, free-standing nanowires are promising. We have developed a new method for nanohole fabrication using nanowire templates; that is, etching the exposed wires selectively after the layer growth. We have demonstrated nanoholed array in InP and C_{60} layers on GaAs substrates. For the metalorganic vapor phase epitaxy of InP, (111)B facets tend to form so that the AlGaAs nanowires are easily removed. Tilted nanowires and nanoholes are possible by using (311)B substrates. As another holed layer case, a C_{60} layer was tried. We found that this method can also be applied to the fragile material like C_{60}. [DOI : 10.1143/JJAP.44.L428]

Keywords: nanowire, nanohole, AlGaAs, InP, C_{60}, scanning electron microscope

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MoO_2 Hollow Fiber with Rectangular Cross Sections

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Molybdenum oxide hollow fiber with rectangular cross sections has been discovered. The fibers grow on a Mo substrate heated with an acetylene-oxygen combustion flame from the backside. The edge length of the cross-sectional rectangle ranges from ~0.1 to 10 μm. The material, as determined from the X-ray photoelectron spectroscopy and X-ray diffraction, is of monoclinic MoO_2. [DOI : 10.1143/JJAP.44.L449]

Keywords: monoclinic molybdenum dioxide, molybdenum oxide, hollow fiber, rectangular cross section, metallic metal oxide, acetylene-oxygen combustion flame

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AlGaN/GaN Heterostructure Field-Effect Transistors with Current Gain Cut-off Frequency of 152 GHz on Sapphire Substrates

Masataka Higashiwaki* and Toshiaki Matsui
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AlGaN/GaN heterostructure field-effect transistors (HFETs) with a gate length (L_G) of 60-250 nm were fabricated on a sapphire substrate. The HFET structure was grown by plasma-assisted molecular-beam epitaxy, and a 2-nm-thick SiN film was formed on the device surface by catalytic chemical vapor deposition. All of the HFETs showed outstanding DC device performance. They exhibited maximum drain current densities of 1.50-1.55 A/mm and extrinsic transconductances of 340-400 mS/mm. The 60-nm-gate HFET had a current gain cut-off frequency (f_T) of 152 GHz and a maximum oscillation frequency (f_{max}) of 173 GHz. To our knowledge, the f_T and f_{max} are the highest ever reported for GaN-based transistors. These superior high-frequency characteristics were achieved with a process using a thin and high-Al-content barrier layer, high-quality catalytic chemical vapor deposition (Cat-CVD) SiN passivation, and sub-0.1-μm gates defined by electron-beam lithography.
[DOI : 10.1143/JJAP.44.L475]

Keywords: AlGaN, GaN, heterostructure field-effect transistor (HFET), sapphire, plasma-assisted molecular-beam epitaxy (PAMBE), catalytic chemical vapor deposition (Cat-CVD), current gain cut-off frequency (f_T), maximum oscillation frequency (f_{max})

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Alignment-Free Top-Contact Formation for Organic Thin Film Transistors with Submicron-Length Channel

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(Received March 4, 2005; accepted March 17, 2005; published April 1, 2005)

We propose a simple fabrication method for self-aligned top contacts for an organic thin film transistor (TFT) that can be miniaturized. The self-aligned top electrodes are formed without any break in the vacuum condition after the formation of an organic channel on the substrate with a prefabricated insulating structure. As a demonstration of this method, pentacene TFTs with submicron-length channels have been fabricated and successfully operated. Scanning electron microscopy of TFTs reveals well-defined TFT structures as expected.
[DOI : 10.1143/JJAP.44.L479]

Keywords: organic thin film transistor, pentacene, top-contact, alignment-free fabrication, submicron-length channel

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Single-Walled Carbon Nanotube Thin-Film Sensor for Ultrasensitive Gas Detectio

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We demonstrated a gas sensor fabricated by growing a single-walled carbon nanotube (SWNT) thin film directly on a conventional sensor substrate. NO_2 and Cl_2 were detected down to the ppb level under room-temperature operation with a fast response. Using an electrical breakdown technique, gas response sensitivity was improved by an order of magnitude. The relationship between gas concentration and sensor response was derived based on the Langmuir adsorption isotherm, predicting a detection limit of 8 ppb for NO_2. The SWNT thin-film gas sensor exhibits merits over other types of sensors by virtue of its simplicity in fabrication and feasible application. [DOI : 10.1143/JJAP.44.L482]

Keywords: single-walled carbon nanotube, gas sensor, chemical vapour deposition, electrical breakdown, Langmuir adsorption isotherm

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Milliwatt Power Deep Ultraviolet Light Emitting Diodes Grown on Silicon Carbide

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Deep ultraviolet light emitting diode structures with a peak wavelength of 275 nm were grown by metalorganic chemical vapor deposition on (0001) silicon carbide. Despite its strong ultraviolet light absorption, silicon carbide was chosen as a substrate rather than sapphire for its improved thermal conductivity and the potential for vertically conducting devices. An output power of 0.11 mW was observed at 300 mA DC during single device on-wafer testing, and output powers of 2.09 mW at 1.3 A were obtained from a packaged, silicone encapsulated array of five devices. Forward voltages as low as 4.9 V at 20 mA were obtained. The injection profile of Cp2Mg during the p-AlGaN blocking layer was instrumental in the suppression of emission at undesired wavelengths and the realization of peak-to-defect level ratios greater than 100. [DOI : 10.1143/JJAP.44.L502]

Keywords: metalorganic chemical vapor deposition, aluminum nitride, light emitting diodes, deep ultraviolet, silicon carbide

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Growth of Thick AlN Layer by Hydride Vapor Phase Epitaxy

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(Received March 10, 2005; accepted March 23, 2005; published April 8, 2005)

Thick AlN crystals were grown by conventional hydride vapor phase epitaxy (HVPE) on AlN/sapphire templates under low pressure (~15 Torr) at high temperature (1100°C–1200°C). Colorless, mirror-like AlN films were obtained at the growth rates of up to 20.6 μm/h. The best root mean square (RMS) value of atomic force microscope (AFM) observations for the AlN surface was 2.34 nm. The typical values of full width half maximum (FWHM) of X-ray rocking curves for (0002) and (10\bar12) diffraction of AlN films were 173-314 arcsec and 1574-1905 arcsec, respectively. We also investigated the influences of carrier gas, growth temperature and growth rate on the crystal quality.
[DOI : 10.1143/JJAP.44.L505]

Keywords: AlN, hydride vapor phase epitaxy, HVPE, carrier gas, growth temperature

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High Gain and High Sensitive Blue-Ultraviolet Avalanche Photodiodes (APDs) of ZnSSe n$^+$-i-p Structure Molecular Beam Epitaxy (MBE) Grown on p-type GaAs Substrates

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(Received March 16, 2005; accepted March 23, 2005; published April 8, 2005)

High gain and high sensitive blue-ultraviolet avalanche photodiodes (APDs) are developed using high quality ZnSSe n$^+$-i-p hetero-structure grown on p-type GaAs substrates by molecular beam epitaxy (MBE). The short wavelength APDs have been realized by a new technique of interface superlattice buffers between p-GaAs and p-ZnSe hetero-interfaces, by which we have overcome large interface energy barriers (>1 eV: for hole-conduction) and unstable dark leakage currents. Utilizing a benefit of the n$^+$-i-p structure on p-GaAs, the short wavelength APDs have been designed with an thin transparent n$^+$ window layer (< 300 Å), demonstrating large APD gains (G>90) and high sensitivities of 5-3 A/W in blue-ultraviolet optical region under very low reverse bias condition of 33 V. [DOI : 10.1143/JJAP.44.L508]

Keywords: Short wavelength avalanche photodiode, Blue-Ultraviolet APD, ZnSSe n$^+$-i-p Structured APDs on p-GaAs, Interface superlattice buffer

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Preparation of Atomically Smooth TiO_2 Single Crystal Surfaces and Their Photochemical Property

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(Received February 22, 2005; accepted March 23, 2005; published April 8, 2005)

Atomically smooth rutile TiO_2(110), (100), (001), (111) and (101) surfaces were obtained for the first time by an appropriate cleaning and subsequent thermal treatment of commercially available single crystals. The annealing temperature for obtaining the ultra-smooth surface varied between 400 and 900°C depending on the crystallographic planes. The key point to the successful preparation of the regularly stepped TiO_2 surface was an HF treatment for the removal of surface impurities. By using these well-defined TiO_2 surfaces, the photochemical property was found to depend on the surface orientation; the photo-reduction of Ag$^+$ to Ag metal from an aqueous solution proceeded in the order of (101) > (100) > (001) > (111) > (110) on the TiO_2 surfaces.
[DOI : 10.1143/JJAP.44.L511]

Keywords: rutile, TiO_2, surface orientation, step and terrace, ultra-smooth surface, photochemical activity

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Hard X-ray Diffraction-Limited Nanofocusing with Kirkpatrick-Baez Mirrors

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Nanofocused X-ray beams are necessary for nanometer-scale spatial microscopy analysis. X-ray focusing using a Kirkpatrick-Baez setup with two total reflection mirrors is a promising method, allowing highly efficient and energy-tuneable focusing. In this paper, we report the development of ultraprecise mirror optics and the realization of a nanofocused hard-X-ray beam. Fabricated mirrors having a figure accuracy of 2 nm peak to valley height give ideal diffraction-limited focusing at the hard X-ray region. The focal size, defined as the full width at half maximum in the intensity profile, was 36 nm × 48 nm at an X-ray energy of 15 keV.
[DOI : 10.1143/JJAP.44.L539]

Keywords: hard X-ray, nanofocusing, focusing mirror, Kirkpatrick-Baez mirrors, diffraction limited focusing, plasma CVM, EEM, MSI, RADSI

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Impact of Defect Control on the Polarization Properties in $Bi_4Ti_3O_{12}$ Ferroelectric Single Crystals

Yuji Noguchi[1,2], Takahiro Matsumoto[1] and Masaru Miyayama[1]
(Received March 29, 2005; accepted April 7, 2005; published April 22, 2005)

We have investigated the defect structure in bismuth titanate ($Bi_4Ti_3O_{12}$) through high-temperature neutron powder diffraction analysis and *ab-initio* electronic structure calculations. It is shown that the vacancies of Bi and oxide ions are created preferentially in the perovskite layers rather than in the Bi_2O_2 layers. Measurements of the leakage-current properties of the single crystals demonstrate that electron holes arising from the incorporation of oxygen at the vacancies of oxide ions act as detrimental carriers for electrical conduction at room temperature. A crystal growth under high oxygen pressure is proposed to be advantageous for suppressing the vacancy formation and for attaining a large remanent polarization as well as a high insulating property of the $Bi_4Ti_3O_{12}$ system.
[DOI : 10.1143/JJAP.44.L570]

Keywords: bismuth titanate, single crystal, defect, oxygen vacancy, *ab-initio*

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Pulsed Laser Deposition of Ferroelectric $(Na_{0.5}K_{0.5})NbO_3$-Based Thin Films

Takehisa Saito, Harumi Adachi and Takahiro Wada
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Ferroelectric $(Na_{0.52}K_{0.44}Li_{0.04})(Nb_{0.84}Ta_{0.10}Sb_{0.06})O_3$ thin films were epitaxially grown on a (100)$SrRuO_3$//(100)$SrTiO_3$ substrate by pulsed laser deposition. Crystallographic analysis of the film was performed using conventional X-ray diffraction analysis and rocking curve measurements. High resolution X-ray diffraction reciprocal space map was also measured to analyze the crystallographic relationship between the grown film and the $SrTiO_3$ substrate and to determine the strain state of the film. The full width at half maximum of the rocking curve was as small as 0.19° and the determined pseudo-tetragonal lattice parameters were a=3.947Å and c=3.955Å. The *P-E* hysteresis loop of the film was characteristic of ferroelectric behavior.
[DOI : 10.1143/JJAP.44.L573]

Keywords: ferroelectric, sodium niobate, potassium niobate, thin film, pulsed laser deposition, epitaxial film

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