

## Abstracts of Express Letters

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### Room-Temperature Epitaxial Growth of GaN on Atomically Flat $\text{MgAl}_2\text{O}_4$ Substrates by Pulsed-Laser Deposition

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We have grown GaN films on  $\text{MgAl}_2\text{O}_4(111)$  substrates at room temperature (RT) and investigated the structural properties of the films. The atomically flat surfaces of  $\text{MgAl}_2\text{O}_4$  with a step and terrace structure are obtained by annealing at 1000°C in a box made of ceramic  $\text{MgAl}_2\text{O}_4$ . It is found that GaN(0001) grows epitaxially on atomically flat  $\text{MgAl}_2\text{O}_4(111)$  surfaces even at RT. The epitaxial relationship between the GaN epilayer and the  $\text{MgAl}_2\text{O}_4$  substrate is  $\text{GaN}[11\bar{2}0]/\text{MgAl}_2\text{O}_4[0\bar{1}1]$ . GaN films have a clear six fold symmetry without 30° rotational domains. The interfacial reaction between GaN and  $\text{MgAl}_2\text{O}_4$  is completely suppressed in the case of RT growth.

[DOI : 10.1143/JJAP.45.L457]

**Keywords:**  $\text{MgAl}_2\text{O}_4$ , GaN, atomically flat surface, pulsed laser deposition

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### Atmospheric Pressure Fluorocarbon-Particle Plasma Chemical Vapor Deposition for Hydrophobic Film Coating

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We have realized a fluorocarbon-particle plasma chemical vapor deposition employing an atmospheric pressure plasma with continuous-wave microwave excitation. Spherical fluorocarbon particles 50–100 nm in diameter were formed in the atmospheric pressure plasma. The gas temperature in the plasma was controlled to be 480 K, as estimated using numerical calculations from  $\text{N}_2$  emission spectra. It was found that the gas temperature was an important factor for the synthesis of the fluorocarbon particles. The particles were negatively charged downstream from the plasma and were transported efficiently to the substrate by an electric field. A hydrophobic coating with a contact angle of 140° was achieved at room temperature. [DOI : 10.1143/JJAP.45.L460]

**Keywords:** hydrophobic, atmospheric, plasma, gas temperature, fluorocarbon

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### Stress Characterization of Si by a Scanning Near-Field Optical Raman Microscope with Spatial Resolution and with Penetration Depth at the Nanometer Level, using Resonant Raman Scattering

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(Received April 11, 2006; accepted April 20, 2006; published online May 12, 2006)

We have developed a new tapping mode-scanning near-field optical Raman microscope (SNORM) with a caved and pyramidal probe, using resonant Raman scattering and measured the stress distribution of very-large-scale integration (VLSI) standards made of the silicon dioxide film and Si. It has been found that compressive stresses of about 0.69 GPa/cm<sup>2</sup> are concentrated on the corner of the area uncovered by silicon dioxide. The SNORM we developed has at least the spatial resolution of less than 250 nm and is a useful tool to measure image of stresses in Si devices within a short time and with a penetration depth of 5 nm.

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**Keywords:** near-field, Raman, resonant Raman, stress, silicon

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### Optical Stark Effect of Exciton in Semiconducting Single-Walled Carbon Nanotubes

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An instantaneous blue shift of exciton absorption due to the optical Stark effect was observed in isolated semiconducting single-walled carbon nanotubes (SWNTs) by using a femtosecond (fs) pump-probe spectroscopy. From the analysis of time profiles of transient absorption changes, the photoinduced shift and the dipole moment of the exciton transition were evaluated as ~1.1 meV for the pump fluence of 34  $\mu\text{J}/\text{cm}^2$  and ~6 eÅ, respectively. Such a large dipole moment as well as ultrafast recovery of real carrier excitations suggests high potential of SWNTs for an ultrafast optical-switching material. [DOI : 10.1143/JJAP.45.L513]

**Keywords:** carbon nanotube, optical Stark effect, nonlinear optical response, femtosecond spectroscopy, exciton

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## Misfit Dislocation Generation in InGaN Epilayers on Free-Standing GaN

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We have found that, in the absence of threading dislocations in  $\text{In}_x\text{Ga}_{1-x}\text{N}/\text{GaN}$  heterostructures, coherent generation of misfit dislocations occurs for  $x > 0.11$  in  $\sim 100$ -nm-thick epilayers. We focus this report on  $\text{In}_{0.17}\text{Ga}_{0.83}\text{N}$  grown on a low-defect-density GaN free-standing substrate (with 1.9% lattice mismatch). A diffraction contrast analysis carried out in the transmission electron microscope showed straight line defects with Burgers vectors  $2/3 \langle 11\bar{2}0 \rangle$  (i.e.,  $2\mathbf{a}$ , where  $\mathbf{a}$  is the hexagonal plane lattice parameter), which extended many micrometers approximately along  $\langle 1\bar{1}00 \rangle$  directions and with an average lateral spacing of 90 nm. Although these defects were complex and mostly sessile, evidence was found that they can dissociate into glissile misfit dislocations with Burgers vectors of  $1/3 \langle 11\bar{2}0 \rangle$ . It is proposed that the defects are generated by a punch-out mechanism involving slip on inclined prismatic planes. The properties of these defects and their role in relieving misfit strains are discussed. [DOI: 10.1143/JJAP.45.L549]

**Keywords:** misfit dislocations, InGaN epilayers, epitaxy on bulk GaN, plastic relaxation, punch-out relaxation process

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## Effect of a Generalized Particle Momentum Distribution on Plasma Nuclear Fusion Rates

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 (Received December 19, 2005; accepted May 13, 2006; published online June 2, 2006)

We investigate the effect of a generalized particle momentum distribution derived by Galitskii and Yakimets (GY) on nuclear reaction rates in plasma. We derive an approximate semi-analytical formula for nuclear fusion reaction rate between nuclei in a plasma (quantum plasma nuclear fusion; or QPNF). The QPNF formula is applied to calculate deuteron–deuteron fusion rate in a plasma, and the results are compared with the results calculated with the conventional Maxwell–Boltzmann velocity distribution. As an application, we investigate the deuteron–deuteron fusion rate for mobile deuterons in a deuterated metal/alloy. The calculated deuteron–deuteron fusion rates at low energies are enormously enhanced due to the modified tail of the GY's generalized momentum distribution. Our preliminary estimates indicate also that the deuteron–lithium (D+Li) fusion rate and the proton–lithium (p+Li) fusion rate in a metal/alloy at ambient temperatures are also substantially enhanced. [DOI: 10.1143/JJAP.45.L552]

**Keywords:** generalized particle momentum distribution, quantum plasma nuclear fusion

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## Characteristics of InGaN with High In Concentrations Grown on ZnO at Low Temperatures

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 (Received May 7, 2006; accepted May 28, 2006; published online June 16, 2006)

We have investigated the effect of substrate temperature on the structural properties of InGaN with high In concentrations grown on atomically flat ZnO substrates by pulsed laser deposition using an  $\text{In}_{0.65}\text{Ga}_{0.35}$  alloy target. Although the InGaN film grown at 650°C shows poor crystalline quality and has a rough surface, those grown at temperatures below 420°C have surfaces with stepped and terraced structures. We found that the epitaxial growth of InGaN at low temperatures proceeds by the layer-by-layer mode, which is consistent with the atomically flat surfaces of InGaN. We also found that phase separation of InGaN is suppressed by reducing the growth temperature. [DOI: 10.1143/JJAP.45.L611]

**Keywords:** InGaN, ZnO, pulsed laser deposition, low temperature growth, phase separation

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## Dye-Sensitized Solar Cells with Conversion Efficiency of 11.1%

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 (Received June 7, 2006; accepted June 9, 2006; published online June 23, 2006)

Dye-sensitized solar cells (DSCs) using titanium dioxide ( $\text{TiO}_2$ ) electrodes with different haze were investigated. It was found that the incident photon to current efficiency (IPCE) of DSCs increases with increase in the haze of the  $\text{TiO}_2$  electrodes, especially in the near infrared wavelength region. Conversion efficiency of 11.1%, measured by a public test center, was achieved using high haze  $\text{TiO}_2$  electrodes. This indicates that raising the haze of  $\text{TiO}_2$  electrodes is an effective technique for improvement of conversion efficiency. [DOI: 10.1143/JJAP.45.L638]

**Keywords:** dye-sensitized solar cells, haze, internal resistance,  $\text{TiO}_2$  electrode, IPCE

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## Blue, Green, and Amber InGaN/GaN Light-Emitting Diodes on Semipolar {11-22} GaN Bulk Substrates

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We demonstrate the fabrication of blue, green, and amber InGaN/GaN light-emitting diodes (LEDs) on semipolar {11-22} bulk GaN substrates. The {11-22}GaN substrates used in this study are produced by cutting out from a c-oriented GaN bulk crystal grown by hydride vapor epitaxy. The LEDs have a dimension of  $320 \times 320 \mu\text{m}^2$  and are packed in an epoxide resin. The output power and external quantum efficiency (EQE) at a driving current of 20mA are 1.76mW and 3.0%, respectively, for the blue LED, 1.91mW and 4.1% for the green LED, and 0.54mW and 1.3% for the amber LED. The maximum output powers obtained with a maximum current of 200mA are 19.0mW (blue), 13.4mW (green), and 1.9mW (amber), while the maximum EQEs are 4.0% at 140mA (blue), 4.9% at 0.2mA (green), and 1.6% at 1mA (amber). It is confirmed that the emission light is polarized along the [1-100] direction, reflecting the low crystal symmetry of the {11-22} plane.

[DOI : 10.1143/JJAP.45.L659]

**Keywords:** {11-22} plane, semipolar, GaN bulk substrate, InGaN/GaN quantum well, light-emitting diode, polarized light

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## Investigation of Spin Voltaic Effect in a $p$ - $n$ Heterojunction

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(Received May 25, 2006; accepted June 17, 2006; published online June 30, 2006)

Model calculation and experimental data of circularly-polarized-light-dependent photocurrent in a  $n$ -GaAlAs/ $p$ -GaInAs/ $p$ -GaAs heterostructure are reported. It is found that, with appropriate heterojunction parameters, spin voltaic effect may survive across the heterojunction and give rise to detectable polarization-dependent photocurrent signals which are greater than those due to the magnetic-circular-dichroism background. [DOI : 10.1143/JJAP.45.L663]

**Keywords:** III-V semiconductors, heterostructure, spintronics,  $g$ -factor, spin voltaic effect, photodiode

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## Electro-Luminescence from Ultra-Thin Silicon

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Ultra-thin single crystal silicon with the (100) surface formed by the local-oxidation-of-silicon (LOCOS) on a silicon-on-insulator (SOI) substrate becomes a quasi-direct band-gap semiconductor due to the quantum mechanical confinement effect. The device is a simple pn diode in a planar structure. Electro-luminescence (EL) has been observed by the lateral carrier injections into the two-dimensional quantum well.

[DOI : 10.1143/JJAP.45.L679]

**Keywords:** quantum mechanical confinement, silicon, photoluminescence, electroluminescence, diode, quantum well

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## Current-Excited Magnetization Dynamics in Narrow Ferromagnetic Wires

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We investigate the current-excited magnetization dynamics in a narrow ferromagnetic Permalloy wire by means of Lorentz microscopy, together with the results of simultaneous transport measurements. A detailed structural evolution of the magnetization is presented as a function of the applied current density. Local structural deformation, bidirectional displacement, and magnetization reversal are found below the Curie temperature with increasing the current density. We discuss probable mechanisms of observed features of the current-excited magnetization dynamics. [DOI : 10.1143/JJAP.45.L683]

**Keywords:** current-driven magnetization dynamics, magnetic domain wall, spin torque, Permalloy wire, Lorentz microscopy, electron holography

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## Investigation of Current on the Conducting Target Biased with a Large Negative Potential in the Non-Uniform Plasma

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It was investigated the current on a biased target in the non-uniform plasma. The argon plasma was generated at the low pressure of 0.5–5 mTorr and the stainless steel target was biased with 0.2–6 kV negatively. The target current increases with increasing the target voltage due to the non-uniform plasma distributed near the target, which follows the Child law. The secondary emission current, following the square root of target voltage, is superposed to the ion current. For the higher pressures of larger than 1.5 mTorr, the target current is larger than the expected current of Bohm current plus the secondary emission current. The deviation increases drastically with increasing the operating pressure, which may due to the local ionization near the target. This phenomenon is important to understand more accurately the high voltage sheath formation in practices. [DOI : 10.1143/JJAP.45.L686]

**Keywords:** target current, negative bias, sheath, non-uniform plasma, secondary electron emission

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## Spin-Dependent Transport in C<sub>60</sub>-Co Nano-Composites

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C<sub>60</sub>-Co nano-composites, in which Co nano-particles are embedded in C<sub>60</sub> molecules, have been fabricated and a magnetoresistance (MR) ratio of 8% has been observed at  $T = 4.2$  K. In addition, we have succeeded in observing a clear MR curve even at room temperature (RT). The MR effect is ascribed to magnetization of the Co nano-particles and spin-dependent transport in C<sub>60</sub> molecules. This study directly indicates that RT operation of molecular spin devices can be realized.

[DOI : 10.1143/JJAP.45.L717]

**Keywords:** magnetoresistance, spin-dependent transport, fullerene, molecular spintronics

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## Growth of Super Long Aligned Brush-Like Carbon Nanotubes

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Efficient chemical vapor deposition (CVD) synthesis of super long (7 mm) aligned carbon nanotubes (CNTs) with high-density is reported here. Activity of catalyst nanoparticles has been achieved for very long time periods (ca. 12 h) by optimization of experimental parameters. The relative levels of ethylene and water, as well as those of ethylene and H<sub>2</sub>, were found to be most important for achieving extended-time activity of the catalyst. Transmission electron microscope (TEM) images revealed that the nanotubes were mainly double-walled, but very few single-walled and multi-walled nanotubes were also present in the sample.

[DOI : 10.1143/JJAP.45.L720]

**Keywords:** carbon nanotube, super long, vertically aligned, thermal chemical vapor deposition, double-walled nanotubes

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## First-Order AlInGaN 405 nm Distributed Feedback Laser Diodes by Current Injection

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The first-order AlInGaN 405 nm distributed feed-back (DFB) laser diodes were grown on the c-face sapphire substrates by a metal-organic chemical vapor deposition method. The diffractive grating, which was shaped by 108 nm deep grating of an 85.7 nm period with a side-wall angle 89°, was formed into a p-type waveguiding layer. As a result, we succeeded in demonstrating the first-order AlInGaN based 405 nm DFB laser diodes by pulsed current injection. The threshold current and the peak lasing wavelength of the DFB laser diode were 190 mA and 403.7 nm under pulsed current operation at 25°C, respectively. The lasing spectrum was kept the single longitudinal mode emission up to an output power of 30 mW. [DOI : 10.1143/JJAP.45.L749]

**Keywords:** AlInGaN, laser diode, first-order, 80 nm, DFB, 405 nm, EB

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## Electron Emission Tip at Extremely Low Bias Voltage

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We report the invention of a modification technique of tungsten tip, which results modified tip apex capable of emitting electrons at extremely low bias voltage. Field-ion microscope induces the structural switching of the oxidized apex at room temperature, which is frozen out at low temperature. Thus modified tips exhibit an extraordinary decrease in applied bias needed for electron emission (typically from -300 to -3.8V). Electron emission shows good angular confinement with an opening angle of less than  $2^\circ$ . Such special tip is repeatedly reproducible and stable for several hours at low temperature. [DOI : 10.1143/JJAP.45.L752]

**Keywords:** field emission (FE), tungsten tip, field ion microscopy (FIM)

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## *In Situ* Scanning Tunneling Microscope Observation of InAs Wetting Layer Formation on GaAs(001) during Molecular Beam Epitaxy Growth at 500°C

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(Received June 20, 2006; accepted July 10, 2006; published online July 28, 2006)

The evolution of InAs wetting layer growth on GaAs(001) was observed at 500°C using scanning tunneling microscope within a molecular beam epitaxy growth chamber. In a series of island nucleation and step flow growth of InAs are clearly observed in the same region with each snapshot. The step density was increased with increasing of InAs growth due to island nucleation and recovered within one monolayer (ML) growth with coalescent with two-dimensional islands. Actual step flow growth was stopped beyond 1ML and then InAs quantum dots (QDs) were appeared at 1.72ML. It is found that the excess amount of  $3.9 \times 10^{14} \text{cm}^{-2}$  In adatom independent from chemical bonding might be participate the formation of QDs induced with drastically around 1.7ML.

[DOI : 10.1143/JJAP.45.L777]

**Keywords:** *in situ*, molecular beam epitaxy, InAs, GaAs, scanning tunneling microscope, wetting layer, quantum dots, RHEED

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## High-Performance Short-Gate InAlN/GaN Heterostructure Field-Effect Transistors

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We fabricated 60-nm-gate InAlN/GaN heterostructure field-effect transistors (HFETs), which had a 6-nm-thick InAlN barrier with an Al composition of 0.86. The devices had a maximum drain current density of 1.34 A/mm and a maximum extrinsic transconductance of 389 mS/mm. The small-signal performance of the devices showed a current-gain cutoff frequency of 172 GHz and a maximum oscillation frequency of 206 GHz. These DC and RF device characteristics were superior to the best values reported for AlGaIn (8 nm)/GaN HFETs with the same gate length. [DOI : 10.1143/JJAP.45.L843]

**Keywords:** InAlN, GaN, heterostructure field-effect transistor (HFET), catalytic chemical vapor deposition (Cat-CVD), current-gain cutoff frequency ( $f_T$ ), maximum oscillation frequency ( $f_{\text{max}}$ )

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## Continuous-Wave Diode-Pumped Yb:YAG Laser with High Beam Quality

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We have developed a continuous-wave diode-pumped Yb:YAG laser with high beam quality applying only a highly doped Yb:YAG crystal that is pumped directly into the upper lasing level. The laser produces a practically diffraction-limited Gaussian beam, whose  $M^2$  factor is 1.36.

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**Keywords:** Yb:YAG, quasi-three-level laser, direct pumping, diode pumped, beam quality, highly doped,  $M^2$  factor

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## Availability of Liquid Crystalline Molecules for Polycrystalline Organic Semiconductor Thin Films

Hiroaki Iino and Jun-ichi Hanna\*

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We have characterized the crystallographic features and charge carrier transport properties of polycrystalline films of both triphenylene and terthiophene derivatives, which are representative materials of discotic (disc-like) and calamitic (rod-like) liquid crystals, respectively. Because of the enhanced anisotropy with the hydrocarbon chains in their molecular structure and the pre-ordered molecular alignment in the mesophase, polycrystalline films of liquid crystals, which exhibit a particular texture indicating that the molecular alignment in the liquid-crystalline phase is well preserved, suppresses the formation of grain boundaries across conduction channels and exhibit clear hole transport even in several- $\mu\text{m}$ -thick films. The present results indicate that liquid-crystalline molecules are good candidates for preparing quality organic polycrystalline semiconductor thin films for optoelectronic applications.

[DOI : 10.1143/JJAP.45.L867]

**Keywords:** organic polycrystal, discotic liquid crystal, smectic liquid crystal, grain boundaries, mobility, time-of-flight

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## Optical Buffer Memory Using Polarization-Bistable Vertical-Cavity Surface-Emitting Lasers

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(Received July 28, 2006; accepted August 9, 2006; published online August 25, 2006)

A novel optical buffer memory with shift register function is proposed. The buffer consists of a two-dimensional array of polarization-bistable vertical-cavity surface-emitting lasers (VCSELs), in which the bit state of the optical signal, "0" or "1" is stored as a lasing linear polarization state of 0 or 90°. One-bit optical buffering which is an essential part of the memory, is experimentally demonstrated for the first time using a 980 nm polarization-bistable VCSEL having a mesa structure.

[DOI : 10.1143/JJAP.45.L894]

**Keywords:** optical buffer, optical flip-flop, bistability, polarization, vertical-cavity surface-emitting laser (VCSEL)

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## Monolithic Implementation of Elemental Devices for Optoelectronic Integrated Circuit in Lattice-Matched Si/III-V-N Alloy Layers

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(Received July 22, 2006; accepted August 13, 2006; published online September 1, 2006)

Light emitting diodes (LEDs) and Si-based metal oxide semiconductor field effect transistors (MOSFETs) were monolithically merged in a single chip which consisted of a Si layer and an InGaPN/GaPN double heterostructure layer lattice-matched to Si grown on a Si substrate by dislocation-free growth process for the first time. The developed fabrication process was conformed to a conventional planar MOSFET process. All LEDs and MOSFETs operated normally. Light emission from the LED was modulated by switching the MOSFET. The growth and fabrication technologies could be effective for realizing monolithic optoelectronic integrated circuits for massively parallel processing and optical interconnections. [DOI : 10.1143/JJAP.45.L920]

**Keywords:** optoelectronic integrated circuit, MOSFET, light emitting diode, Si, III-V-N alloy, lattice-matching, device process

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## Terahertz Plasma Waves in Gated Graphene Heterostructures

Victor Ryzhii

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Plasma waves in graphene-based heterostructures with massless (neutrino-like) two-dimensional electron gas and with a highly conducting substrate ( $n^+\text{-Si}$ ) serving as a gate and an isolating gate layer ( $\text{SiO}_2$ ) are studied. Using the developed model, we show that the sufficiently long plasma waves exhibit a linear (sound-like) dispersion with the wave velocity determined by the gate layer thickness and the gate voltage. The plasma wave velocity in graphene heterostructures can significantly exceed the plasma wave velocity in the commonly employed semiconductor gated heterostructures. The gated graphene heterostructures can be used in different novel voltage tunable THz devices which utilize the plasma waves. [DOI : 10.1143/JJAP.45.L923]

**Keywords:** graphene, two-dimensional electron gas, plasma wave, terahertz range

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## Microanalysis of Brownian Particles and Real-Time Nanometer Vibrometry with a Laser-Diode-Pumped Self-Mixing Thin-Slice Solid-State Laser

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(Received August 8, 2006; accepted August 17, 2006; published online September 1, 2006)

Doppler particle sizing by self-mixing laser was demonstrated by using a laser-diode-pumped thin-slice Nd:GdVO<sub>4</sub> laser with extreme optical sensitivity. A substantial improvement of optical frequency shifters led to quick and accurate sizing of Brownian particles with concentration as low as 50 parts per billion (ppb) for 262-nm polystyren latex spheres in water. A successful real-time measurement of sub-nanometer vibrations was also demonstrated with the present self-mixing laser.

[DOI : 10.1143/JJAP.45.L926]

**Keywords:** laser-diode-pumped, thin-slice Nd:GdVO<sub>4</sub> laser, self-mixing laser, particle sizing, microanalysis, real-time vibrometry

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## Quenching Mechanism of Mechanically Compressed Green Fluorescent Protein Studied by CASSCF/AM1

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"Atomic force microscopy (AFM) compression simulation" approach together with "CASSCF/AM1 ONIOM" model calculation method is used for investigating the quenching mechanism of the luminescence in green fluorescent protein (GFP). Our results show that the electronic properties and steric conformations of the chromophore's neighboring residues strongly influence the photo decay behaviors in GFP.

[DOI : 10.1143/JJAP.45.L929]

**Keywords:** afm, gfp, quenching, CASSCF, ONIOM

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## Ferromagnetism in Transparent Thin Films of Fe-Doped Indium Tin Oxide

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(Received August 17, 2006; accepted August 24, 2006; published online September 8, 2006)

Transparent films of Fe-doped indium tin oxide (ITO) were grown at oxygen pressures of 5, 1, 10<sup>-1</sup>, 10<sup>-2</sup>, and 10<sup>-3</sup>Pa on yttria-stabilized zirconia (001) substrates by a pulsed-laser deposition method. We observed X-ray diffraction peaks from (00*h*) planes of In<sub>2</sub>O<sub>3</sub> crystalline phase for the films. The films grown at 5 and 1Pa were paramagnetic and semiconducting, that at 10<sup>-1</sup>Pa was ferromagnetic and semiconducting, and those at 10<sup>-2</sup> and 10<sup>-3</sup>Pa were ferromagnetic and metallic. The Fe-ITO films grown below 10<sup>-1</sup>Pa exhibited room-temperature (RT) ferromagnetism. Nanoscale Fe clusters in the highest oxidation state such as γ-Fe<sub>2</sub>O<sub>3</sub> resulted in the RT ferromagnetism.

[DOI : 10.1143/JJAP.45.L957]

**Keywords:** Fe-doped ITO, ITO, thin film, PLD, ferromagnetism, Fe<sub>2</sub>O<sub>3</sub>, cluster

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## Nonlinear Optical Properties of Hydrogenated Amorphous Si Films Probed by a Novel Z-Scan Technique

Naoki Minamikawa and Keiji Tanaka

(Received July 25, 2006; accepted August 22, 2006; published online September 8, 2006)

Two-photon absorption coefficient β and intensity-dependent refractive-index *n*<sub>2</sub> at a wavelength of 1.06μm in hydrogenated amorphous Si films have been evaluated using an imaging-type Z-scan technique. Obtained β and *n*<sub>2</sub> are 3000cm/GW and 0.006cm<sup>2</sup>/GW, which are compared with others and discussed in light of a relation proposed by Sheik-Bahae *et al.* for crystalline semiconductors. Potential of the film to optical communication devices is pointed out.

[DOI : 10.1143/JJAP.45.L960]

**Keywords:** amorphous Si, nonlinear optics, Z-scan, optical device

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## Phonon Wavepacket Scattering Dynamics in Defective Carbon Nanotubes

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(Received August 11, 2006; accepted August 24, 2006; published online September 8, 2006)

Phonon wavepacket propagation in defective carbon nanotubes has been investigated through molecular dynamics simulations. We have demonstrated that the wavepacket scattering method enable the phonon transmission function of carbon nanotubes to be determined with high accuracy. We have also found that the influence of phonon-defect scattering increases with decreasing tube diameter, especially in the case of high-frequency phonons. These results are in excellent agreement with those obtained by Green's function calculations.

[DOI : 10.1143/JJAP.45.L963]

**Keywords:** phonon wavepacket, molecular dynamics, carbon nanotube, phonon-defect scattering

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## Implantation of Perylene Molecules into Glass Plates through a Water Layer Using a Laser Induced Molecular Micro-Jet

Masahiro Goto, Yuriy Pihosh, Akira Kasahara and Masahiro Tosa  
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Perylene molecules have been successfully implanted onto borosilicate glass plates, forming fluorescent features of 420 nm in diameter, using a method involving laser induced molecular micro-jet ejection through a water layer. The technique utilizes a polymer source film in which perylene molecules are dispersed, a borosilicate glass substrate as a target and a pulsed laser. The space gap between the source film and the target is filled with liquid water. Perylene molecules dispersed in the polymer source films are photo-excited using 4-ns laser pulses resulting in the ejection of the molecules from the source matrix after which they become implanted into the target after passing through the water layer. This new advanced implantation method, using a laser induced molecular micro-jet through water, gives fine spatial control for fixing functional organic molecules in a designated region on hard dielectric materials and will have application in the fabrication of molecular devices, molecular sensors, and opto-electronics. [DOI : 10.1143/JJAP.45.L966]

**Keywords:** perylene, water, pulsed laser, molecular implantation, molecular jet

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## Lowering the Switching Current of Resistance Random Access Memory Using a Hetero Junction Structure Consisting of Transition Metal Oxides

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Both lowering the "reset" current of resistance random access memory (ReRAM) and raising the resistance in the low resistance state are crucial for practical use of ReRAM. These requirements have been satisfied by using a hetero junction structure consisting of transition metal oxides,  $\text{NiO}_y/\text{TiO}_x/\text{Pt}$ , combining direct contact with the  $\text{NiO}_y$  using a W-probe. It is considered that this configuration brought about extreme downsizing of the effective area of both the top and bottom electrodes for  $\text{NiO}_y$  and thus decreased the number of filaments formed in "forming" process. Reducing the number of filaments is essential to these issues. [DOI : 10.1143/JJAP.45.L991]

**Keywords:** ReRAM,  $\text{NiO}$ ,  $\text{TiO}_2$ , forming, reset

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## Realization of Large Open-Circuit Photovoltage in Organic Thin-Film Solar Cells by Controlling Measurement Environment

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(Received August 21, 2006; accepted September 4, 2006; published online September 15, 2006)

To obtain large open-circuit photovoltage ( $V_{oc}$ ), we introduced a p-type semiconductor 5,6,11,12-tetraphenylnaphthacene (rubrene), which has a highest occupied molecular orbital (HOMO) level of 5.4 eV. Owing to an adsorption of  $\text{O}_2$  and  $\text{H}_2\text{O}$  into rubrene film, optical absorption peaks were markedly decreased after exposure in air. By controlling the measurement environment to prevent the adsorption of  $\text{O}_2$  and  $\text{H}_2\text{O}$  into rubrene films, we could obtain a high-performance organic thin-film solar cell with a large  $V_{oc}$  of 0.91 V. [DOI : 10.1143/JJAP.45.L995]

**Keywords:** organic thin-film solar cell, organic photovoltaic cell, organic semiconductor, open-circuit photovoltage, rubrene, C60

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## Negative Ion Transfer Model of Low-Temperature Oxidation of Silicon Surface by High-Density Microwave Plasma

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High-quality thin SiO<sub>2</sub> layer is rapidly formed at low temperature (~400°C) by oxidation of silicon wafer using high-density microwave plasma in argon containing a few % O<sub>2</sub>. The oxidation rate is proportional to the square root of electron density but hardly correlates with the measured O radical density. Secondary ion mass spectrometry (SIMS) depth analysis of SiO<sub>2</sub> layer with <sup>18</sup>O as an isotope tracer suggests that predominant mobile species in the oxide layer is not neutral oxygen atom but oxygen negative ion, possibly O<sup>2-</sup>, as proposed by Jorgensen and Mott. The time evolution of oxidation process calculated in a negative ion transfer model well explains the experimental observation and accounts for the square root dependence on the electron density.

[DOI : 10.1143/JJAP.45.L1022]

**Keywords:** plasma oxidation, microwave plasma, radical, silicon oxidation, negative ion, Jorgensen–Mott model

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## High-Brightness Narrow-Bandwidth Operation of a Broad-Area Laser Diode with a Rear External Cavity

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We demonstrate a high-brightness, narrow-bandwidth, broad-area laser diode with a rear external cavity that consists of a micro-cylindrical lens and a volume Bragg grating in the rear facet of the diode. Using this external-cavity technique, a broad-area laser diode achieved a bandwidth's full width at half-maximum (FWHM) of 0.22 nm and a divergence angle (FWHM) of 1.1° with an output power of 446 mW.

[DOI : 10.1143/JJAP.45.L1025]

**Keywords:** broad-area laser diode, volume Bragg grating, external cavity, bandwidth, divergence angle

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## High-Efficiency Excitonic Emission with Deep-Ultraviolet Light from (001)-Oriented Diamond *p-i-n* Junction

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We have realized high-efficiency excitonic emission with deep-UV light at room temperature for a (001)-oriented diamond light-emitting diode with an intrinsic diamond layer as an active region. The boron-doped *p*-type, non-doped intrinsic, and phosphorus-doped *n*-type (*p-i-n*) junction diode structure was formed by applying an optimized homoepitaxial growth technique based on microwave plasma-enhanced chemical vapor deposition. High-performance *p-i-n* junction characteristics were confirmed from current–voltage and capacitance–voltage properties. A strong UV light emission at around 240 nm due to free exciton recombination was observed at a forward current of over 6 mA, while the broad visible light emission from deep levels was significantly suppressed compared to that of reported electroluminescence in diamond *p-n* junctions. [DOI : 10.1143/JJAP.45.L1042]

**Keywords:** diamond, chemical vapor deposition, *p-i-n* junction, light-emitting diode, exciton

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