Papers Published in Technical Journals and Conferences

High RF Output Power for H-terminated Diamond FETs

M. Kasu, K. Ueda, H. Ye, Y. Yamauchi, S. Sasaki, and T. Makimoto

Diamond and Related Materials, Elsevier, Vol. 15, No. 4-8, pp. 783–786, 2006.

We report great improvement of RF output power for H-terminated diamond field-effect transistors (FETs). For the FET device with a gate width of 1 mm and a gate length of 0.4 μm, the maximum output power (P_{out}) is 1.26 W, the maximum power gain is 23.2 dB, and the power added efficiency (PAE) is 56.3%. The increase in the device temperature when output power is 0.84 W is only–0.6°C. This is due to diamond having the highest thermal conductivity.

Influence of Impurity of MgO Substrates on Properties of Molecular Beam Epitaxy-grown Superconducting $NdBa_2Cu_3O_{7-\delta}$ Thin Films

S. Karimoto, H. Sato, and T. Makimoto

Jpn. J. Appl. Phys., Vol. 45, No. 15, pp. L419–L421, 2006.

We prepared various MgO substrates cut from various ingots with different impurity-Ca concentrations and deposited $NdBa_2Cu_3O_{7-\delta}$ (NBCO) thin-films on them by using molecular beam epitaxy (MBE). As a result, we found that the room temperature resistivity ($\rho_{(RT)}$) of NBCO thin-films and the Ca concentration in an MgO substrate are quantitatively correlated. Moreover we clarified the permissible impurity-Ca concentration in MgO substrates in terms of practical microwave applications.

Growth of Boron Nitride on 6H-SiC Substrate by Flow-rate Modulation Epitaxy

Y. Kobayashi and T. Makimoto

Jpn. J. Appl. Phys., Vol. 45, No. 4B, pp. 3519–3521, 2006.

Boron nitride (BN) layers on 6H-SiC substrate were grown by metalorganic vapor phase epitaxy (MOVPE) using triethylboron (TEB) and ammonia (NH_3). The growth rate of the BN decreased as the NH_3 flow rate increased, indicating that a strong parasitic reaction occurred between TEB and NH_3. Flow-rate modulation epitaxy (FME), which is based on alternating the gas supply, was applied to the BN growth for the first time and it was found that the parasitic reactions could be effectively reduced. The structural properties of BN grown by FME were also investigated by X-ray diffraction (XRD) and transmission electron microscopy. In contrast with amorphous BN layers grown by MOVPE, the BN structure grown by FME was turbostratic with a weakly preferred orientation to the *c*-axis.

Temperature Dependent DC and RF Performance of Diamond MESFET

H. Ye, M. Kasu, K. Ueda, Y. Yamauchi, N. Maeda, S. Sasaki, and T. Makimoto

Diamond and Related Materials, Elsevier, Vol. 15, No. 4-8, pp. 787–791, 2006.

This paper reports the first studies on temperature dependent DC and RF characteristics of diamond metal-semiconductor field-effect transistors along with circular-transmission-line-method measurements on hydrogen-terminated diamond surface. In general, the device under study is thermally stable up to 100°C as it does not deteriorate at higher temperatures with the cut-off frequency for current gain maintained at 8–9 GHz. It is found that the sheet resistance is almost totally independent of temperature, contact resistance is negligible, and channel conductance underneath the gate decreases with increasing temperature. The threshold voltage for the device is found to shift to the negative side with increasing temperature. A small-signal equivalent circuit analysis reveals that both transconductance and gate-source capacitance decrease with increasing temperature, which results in the almost constant cut-off frequency for current gain. The experimental results can be explained by the fact that with increasing temperature, the band near the Al/H-terminated diamond surface bends upward more weakly, which leads to a decrease of buffer capacitance. At the same time the mobility decreases and the transconductance therefore decreases.

The Highest Critical Electric Field among the Semiconductors – First Determination of the Critical Electric Field of AlGaN –

A. Nishikawa and T. Makimoto

NIKKEI NANO BUSINESS, Vol. 41, p. 21, July 2006.

We have succeeded in obtaining the high critical electric field exceeding 8 MV/cm measured using an AlGaN p-i-n vertical conducting diode on n-SiC substrate grown by low-pressure metal organic vapor phase epitaxy. The critical electric field of AlGaN with Al composition of 57% is as high as 8. 1 MV/cm, the highest among semiconductors with a doping concentration of less than 1017 cm-3, at which the avalanche multiplication process takes place.

Fidelity Estimation and Entanglement Verification for Experimentally Produced Four-qubit Cluster States

Y. Tokunaga, T. Yamamoto, M. Koashi, and N. Imoto

Phys. Rev., APS, Vol. 74, No. 2, p. 020301, 2006.

We propose methods of fidelity estimation and entanglement verification for experimentally produced four-qubit cluster states. We show that we can obtain a high lower bound of the fidelity using only four local projective measurement settings. The lower bound is close to the exact fidelity, which is determined only by at least nine local projective measurement settings. We also present witness operators for distinguishing entanglement around a four-qubit cluster state from specific classes of genuine four-qubit entanglement, e.g., a class including GHZ and *W* types of entanglement.

AlN Light-emitting Diodes with a Wavelength of 210 nm and Their Light Emission Mechanism

Y. Taniyasu, M. Kasu, and T. Makimoto

IWN, Kyoto, Jpn. J. Appl. Phys., p. 102, Oct. 2006.

Aluminum nitride (AlN) has a direct bandgap of 6 eV, the largest among semiconductors. Therefore, it has been expected that AlN light-emitting diodes (LEDs) would emit light at extremely short wavelengths. In this study, we demonstrated AlN LEDs with a wavelength of 210 nm, the shortest ever reported for any kind of LED, and compared vertical and lateral structures to understand the light emission mechanism.

Universally Composable Identity-based Encryption

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VietCrypt 2006, Hanoi, Vietnam, 2006 LNCS, Vol. 4341, pp. 337–353, 2006.

Identity-based encryption (IBE) is one of the most important primitives in cryptography, and various security notions of IBE (e.g., IND-ID-CCA2, NM-ID-CCA2, IND-sID-CPA etc.) have been introduced. The relations among them have been clarified recently. This paper, for the first time, investigates the security of IBE in the universally composable (UC) framework. This paper first defines the UC-security of IBE, i.e., we define the ideal functionality of IBE, F_{IBE}. We then show that UC-secure IBE is equivalent to conventionally-secure (IND-ID-CCA2-secure) IBE.

Multi-speaker Articulatory Trajectory Formation Based on Speaker-independent Articulatory HMMs

S. Hiroya and T. Mochida

Speech Commun, Elsevier, Vol. 48, No. 12, pp. 1677–1690, 2006.

Inter-speaker variability in the speech spectrum domain has been modeled using speaker-adaptive training (SAT), in which speaker-independent phoneme-specific hidden Markov models (HMMs) were used along with a speaker-adaptive matrix. In this paper, multi-speaker articulatory trajectory formation based on this method is presented. Both speaker-independent and speaker-specific features are statistically separated from a multi-speaker articulatory database, which consists of the mid-sagittal motion data of the lips, incisor, and tongue measured with an electro-magnetic articulographic (EMA) system. We evaluated the proposed method in terms of the RMS error between the measured and estimated articulatory parameters. When multi-speaker models of articulatory parameters with two speaker-adaptive matrices for each speaker were used, the average RMS error of articulatory parameters was 1.29 mm and showed no statistically significant difference from that for speaker-dependent models (1.22 mm). For comparison, multi-speaker models of the conventional speech spectrum were also constructed using a multi-speaker spectrum database, which consists of speech data simultaneously recorded during the articulatory measurements. The average spectral distance between the vocal-tract and estimated spectrum from two-matrix models was 4.19 dB and showed a statistically significant difference from that for speaker-dependent models (3.97 dB). These results indicate that modeling of inter-speaker variability in the articulatory parameter domain with a small number of matrices for each speaker almost perfectly approximates the speaker dependency of articulation and is better than that in the speech spectrum domain.

Wideband Speech Coding Robust against Packet Loss

T. Mori, H. Ohmuro, Y. Hiwasaki, S. Kurihara, and A. Kataoka

Electronics and Communications in Japan, Part3, Vol. 89, No. 12, pp. 20–30, 2006.

This paper describes a wideband speech coding method that is robust against packet loss and a packet transmission control method. The coding is based on 4-kHz-band CELP speech coding and consists mainly of multilevel coding using MDCT transform encoding, with a speech quality enhancement codec for the nonspeech portion and a higher subband enhancement codec for coding the higher subband at or above 4 kHz. This method can provide high-quality coding of nonspeech signals such as background music as well as wideband speech. If this coding method and packet transmission control are combined, speech transmission can continue without much deterioration even when the network becomes congested and packet loss occurs. Subjective and objective testing confirmed that, unlike conventional coding methods, high-quality speech transmission was possible even with 10% random packet loss when this method is used for speech transmission on an IP network.

Effective Perception Method for Directed Force When Holding a Nongrounding Force Display in the Air

T. Amemiya, H. Ando, and T. Maeda

TVRSJ, Vol. 11, No. 4, pp. 545–556, 2006.

We have proposed a novel translational force perception method for mobile and wearable displays. The method exploits the nonlinear relationship between perceived acceleration and physical acceleration to generate a force sensation. A prototype of the haptic display based on the method generates unidirectional force sensation using a crank-slider mechanism that physically generates bi-directional force. Two experiments were performed to clarify the perceptual characteristics when human held the force display in the air. The results indicate that the angular resolution with perceived force direction was significantly smaller with the force display that counteracted a swinging force generated by motion of linkages than with one that doubled it. In addition, the frequency, at which the force sensation was effectively induced when human held the display in the air, shift slightly lower than that when human held the display fixated on a linear slider. Our knowledge would be a criterion for designing smaller and lighter nongrounding force displays.

Improved Sensitivity of Optical Frequency Domain Reflectometry-optical Coherence Tomography Using a Semiconductor Optical Amplifier

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Jpn. J. Appl. Phys., Vol. 45, No. 49, pp. L1317–L1319, 2006.

We demonstrate an approach to enhance the optical frequency domain reflectometry (OFDR)-optical coherence tomography (OCT) sensitivity using a semiconductor optical amplifier (SOA) and a superstructure grating-distributed Bragg reflector (SSG-DBR) laser. We find that the sensitivity of the OCT images of an extracted canine tooth increases as a function of SOA injection current due to amplification through stimulated emission. At the injection current of 150 mA, the sensitivity of the OCT image is increased to a factor of 22.8 dB when compared to the unamplified OCT. Furthermore, an 18 μm axial resolution of the OCT in dental tissue is achieved using the discrete wavelength-swept SSG-DBR laser with an axial scan rate of 0.25 kHz. The observed results suggest that the optical amplification by SOA can significantly enhance the sensitivity of the OFDR-OCT system with a high-resolution.

Critical Electric Fields of AlGaN in AlGaN-based Vertical Conducting Diodes on *n*-SiC Substrates

A. Nishikawa, K. Kumakura, T. Akasaka, and T. Makimoto

Super lattices and Microstructures, Elsevier, Vol. 40, pp. 332–337, Dec. 2006.

We have succeeded in obtaining high critical electric fields from AlGaN layers using the p-InGaN/i-$Al_xGa_{1-x}N$/n-$Al_xGa_{1-x}N$ (x=0–0.22) vertical conducting diodes grown on n-SiC substrates by low-pressure metalorganic vapor phase epitaxy (MOVPE). The breakdown voltage (V_B) increases with increasing Al composition of the AlGaN layer. The corresponding critical electric fields are calculated to be 2.4 MV/cm for GaN and 3.5 MV/cm for $Al_{0.22}$ $Ga_{0.78}$ N. The critical electric field is proportional to the bandgap energy to a

power of 2.5. This bandgap energy dependence is much stronger than that in the empirical expression proposed by Sze and Gibbons. The figure of merit, $(V_B)^2/R_{on}$, increases with increasing Al composition, indicating the AlGaN-based *p-i-n* diodes are promising for high-power and high-temperature electronic device applications.

Japanese Native Speakers Discriminate English Vowel Formant Frequencies Better Than English Native Speakers

S. Hiroya, T. Mochida, and M. Kashino

Proc., the 7th ISSP, CEFALA of the Universidade Federal de Minas Gerais, Dec. 2006.

We have shown that thresholds for vowel formant frequency discrimination are significantly correlated with the constraints of directly measured articulatory parameters that produce the vowel, not with the predictions based on the auditory frequency resolution. These findings suggest that native speakers of different languages should have different speech production models and this should result in differences in vowel formant frequency discrimination thresholds. In this study, we examine whether thresholds for vowel formant frequency discrimination between Japanese and English speakers differ for eight English monophthongal vowels. Psychophysics experimental results show different discrimination capabilities for various English vowels in English and Japanese speakers. This indicates that vowel formant frequency discrimination is conducted on the basis of the articulatory constraints of native language.

Oxygen Self-diffusion in Silicon Dioxide: Effect of the Si/SiO_2 Interface

M. Uematsu, M. Gunji, and K. M. Itoh

Proc., DSL-2006 (Defect and Diffusion Forum), Vols. 258-260, No.1, pp. 554–561, 2006.

The effect of the SiO_2/Si interface on oxygen self-diffusion in SiO_2 during thermal oxidation was investigated using oxygen isotopes. A $Si^{18}O_2$ layer was first grown in $^{18}O_2$ and then the sample was reoxidized in $^{16}O_2$ at 900–1100°C. The O diffusion in SiO_2 during the $^{16}O_2$ oxidation was investigated by secondary ion mass spectrometry (SIMS) measurements. Near the SiO_2/Si-interface, a significant broadening of the ^{18}O profile toward the newly grown $Si^{16}O_2$ was observed. This ^{18}O diffusion became slower with oxidation time and hence with increasing distance between ^{18}O diffusion region and the interface. This distance-dependent ^{18}O self-diffusion was simulated taking into account the effect of SiO generated at the interface upon oxidation and diffusing into SiO_2 to enhance O self-diffusion. The simulation fits the SIMS profiles and shows that the SiO diffusion is greatly retarded by the oxidation with O_2 from the oxygen-containing atmosphere and that the O self-diffusion therefore becomes distance-dependent. In addition, near the SiO_2 surface, ^{16}O diffusion profiles develop with the $^{16}O_2$ oxidation time from the surface into the initially grown $Si^{18}O_2$. The integrated surface ^{16}O concentration increases with oxidation time and the SiO from the interface affects the O self-diffusion near the surface as well.

Long Retention of Gain-cell Dynamic Random Access Memory with Undoped Memory Node

K. Nishiguchi, A. Fujiwara, Y. Ono, H. Inokawa, and Y. Takahashi

IEEE Electron Device Lett., Vol. 28, No. 1, pp. 48–50, 2007.

Low current leakage characteristics of a novel silicon-on-insulator (SOI) device are investigated in view of application to a gain-cell dynamic random access memory (DRAM). The device consists of a two-layered poly-Si gate. Since, in this device, the memory node is electrically formed by the gate in undoped SOI wire, no p-n junction is required. The retention is found to be dominated by the subthreshold leakage, which leads to long data retention. The device also achieved a fast (10 ns) writing time and its fabrication process is compatible with those of SOI MOSFETs. The present results, thus, strongly suggest a way of conducting a gain-cell DRAM to be embedded into logic circuits.

ISSCC2007 Preview – Wireline –

Y. Ohtomo

NIKKEI ELECTRONICS, No. 943, p. 52, Jan. 2007.

The tendency to the wireline communication circuits of ISSCC 2007 which is a premium international conference on integrated circuits are speed-up and lowering cost with CMOS technology. The CMOS technology makes not only the transmission at 10-Gb/s or more but also integration of various functions possible. The tendency that analog circuits are replaced with digital circuits is settled to improve circuit characteristics at a very low supply voltage.

Error Estimation of Load Switching Signal from Contactless IC Card and a Proposal of Approximation Method for Discrete Fourier Transform

S. Nakano and Y. Ohtani

IEICE, Vol. J90-A, No. 1, pp. 13–26, 2007.

This paper analyses the theoretical and experimental measurement errors of the load switching signal spectrum from a contactless IC card which is complied with ISO/IEC 14443. We first show the measurement error estimation equation of load switching signal spectrum based on the inaccuracy of measurement apparatus. Secondly we propose the approximation method for the discrete Fourier transform. We can then get true values of the load switching signal spectrum. In the experiment of a contactless IC card, the evaluated measurement error by using conventional DFT method decreases significantly from 19% to 1%, by using the proposed approximation method of DFT.

Supported Lipid Bilayer Self-spreading on a Nanostructured Silicon Surface

K. Furukawa, K. Sumitomo, H. Nakashima, Y. Kashimura, and K. Torimitsu

Langmuir, ACS, Vol. 23, No. 2, pp. 367–371, 2007.

We report on the self-spreading behavior of a supported lipid bilayer (SLB) on a silicon surface with various 100 nm nanostructures. SLBs have been successfully grown from a small spot of a lipid molecule source both on a flat surface and uneven surfaces with 100 nm up-and-down nanostructures. After an hour, the self-spreading SLB forms a large circle or an ellipse depending on the nanostructure pattern. The results are explained by a model that shows that a single-layer SLB grows along the nanostructured surfaces. The model is further supported by a quantitative analyses of our data. We also discuss the stability of the SLB on nanostructured surfaces in terms of the balance between its bending and adhesion energies.

Self-assembly of Vesicle Nanoarrays on Si: A Potential Route to High-density Functional Protein Arrays

C. S. Ramanujan, K. Sumitomo, M. R. R. de Planque, H. Hibino, K. Torimitsu, and J. F. Ryan

Appl. Phys. Lett., AIP, Vol. 90, No. 3, p. 033901, 2007.

The authors show that 100 nm unilamellar thiol-tagged vesicles bind discretely and specifically to Au nanodots formed on a Si surface. An array of such dots, consisting of 20 nm Au–Si three-dimensional islands, is formed by self-assembly on terraces of small-angle-miscut Si (111) after Au deposition. Consequently, both the formation of the nanopattern and the subsequent attachment of the vesicles are self-organized and occur without the need for any "top-down" lithographic processes. This approach has the potential to provide the basis of a low-cost, high-density nanoarray for use in proteomics and drug discovery.

Threading Dislocations in Heteroepitaxial AlN Layer Grown by MOVPE on SiC (0001) Substrate

Y. Taniyasu, M. Kasu, and T. Makimoto

J. Cryst. Growth, Elsevier, Vol. 298, pp. 310–315, Jan. 2007.

To clarify the mechanisms governing the formation and reduction of threading dislocations (TDs) in aluminum nitride (AlN) layers grown on SiC (0001) substrates by metalorganic vapor phase epitaxy (MOVPE), we characterized the mosaicity and the growth mode. High-density (-10^{11}cm^{-2}) three-dimensional (3D) AlN islands nucleate on the substrate. Because the islands are slightly misoriented with respect to each other, dislocations are generated with a high density of 10^{10}–10^{11}cm^{-2} as the islands coalesce. However, most of the dislocations are annihilated because their propagation direction changes horizontally during the island growth. Thus, at the initial growth stage, the dislocation density is drastically decreased to 10^{8}–10^{9}cm^{-2}. Consequently, as the layer thickness increases, the defect-free region becomes larger and the misorientation becomes smaller. On the other hand, we found that the TDs induce a large tensile strain and that the residual strain decreases with decreasing dislocation density. From the relationship between *a*- and *c*-lattice strains, the Poisson ratio of AlN was determined to be 0.19.

Cathodoluminescence, Photoluminescence, and Reflectance of an Aluminum Nitride Layer Grown on Silicon Carbide Substrate

G.i M. Prinz, A. Ladenburger, M. Schirra, M. Feneberg, K. Thonke, R. Sauer, Y. Taniyasu, M. Kasu, and T. Makimoto

J. Appl. Phys., AIP, Vol. 101, p. 023511, Jan. 2007.

Aluminum nitride (AlN) has an ultrawide direct band gap of approximately 6.1 eV at low temperature and is fully miscible with gallium nitride. This makes AlN a promising material for ultraviolet optoelectronic applications. Here, we apply cathodoluminescence, photoluminescence, and reflectance spectroscopies to the *same* AlN layer grown by metalorganic vapor phase epitaxy on silicon carbide. In cathodoluminescence and photoluminescence, we observe strong near band edge emission at ≈6 eV. The contribution appearing at an energetic position of 5.983 eV could be identified as A free exciton recombination, strongly redshifted due to strain effects. The spectra obtained by reflectance measurements show features at 5.985 eV and ≈6.2 eV which we assign to the A exciton—in accordance to our luminescence measurements—and a combination of the B and C free excitons, respectively.

Terahertz Mixing in MgB_2 Microbolometers

S. Cherednichenko, V. Drakinskiy, K. Ueda, and M. Naito

Appl. Phys. Lett., AIP, Vol. 90, No. 2, pp. 023507-1–023507-3, 2007.

The authors report on a terahertz (600 GHz) mixing experiment with MgB_2 microbolometers in the resistive state. The authors observed that for a 20 nm film a mixer gain bandwidth of 2.3 GHz can be achieved, corresponding to an energy relaxation time of 70 ps. The experimental results were analyzed using a two-temperature model. As a result, the phonon escape time of –20 ps was deduced. At 1.6 THz the MgB_2 mixer uncorrected noise temperature was 11 000 K. The obtained results show that MgB_2 bolometers are good prospects for the terahertz range as both broadband mixers and fast direct detectors.

BGaN Micro-islands as Novel Buffers for Growth of High-quality GaN on Sapphire

T. Akasaka, Y. Kobayashi, and T. Makimoto

J. Cryst. Growth, Elsevier, Vol. 298, pp. 320–324, Jan. 2007.

We discuss the growth mechanism of GaN films and report very high two-dimensional electron gas (2DEG) mobility in AlGaN/AlN/GaN heterostructures fabricated on sapphire using BGaN micro-islands as novel buffers by metalorganic vapor phase epitaxy. The three-dimensional growth of BGaN (formation of BGaN micro-islands) occure due to the phase separation of BGaN. However, the surface of the overgrown GaN on the BGaN micro-islands becomes smooth and continuous through the epitaxial lateral overgrowth process. The threading dislocations (TDs) in GaN consist mainly of pure edge-type ones and are effectively annihilated using single and double layers of BGaN micro-islands from 2×10^{10} to 2×10^{9} and 2×10^{8} cm^{-2}, respectively. An n-type GaN film shallowly doped with Si exhibits an electron concentration and high Hall mobility of 3.0×10^{16} cm^{-3} and 669 cm^2/Vs at room temperature (RT). Very high Hall 2DEG mobility in an $Al_{0.10}Ga_{0.90}N$/AlN/GaN heterostructure is obtained: 1910 and 20,600 cm^2/Vs at RT and 77 K, respectively. The sheet carrier density had almost constant values of 6.9–5.7×10^{12} cm^{-2} in the temperature range from 77 to 500 K, indicating that the parallel conduction due to the residual electrons in the GaN underlying layer was negligible.

Low-resistance Graded $Al_xGa_{1-x}N$ Buffer Layers for Vertical Conducting Devices on n-SiC Substrates

A. Nishikawa, K. Kumakura, T. Akasaka, and T. Makimoto

J. Cryst. Growth, Elsevier, Vol. 298, pp. 819–821, Jan. 2007.

We investigated the Al composition and thickness dependence of the resistance of graded $Al_xGa_{1-x}N$ buffer layers for vertical conducting devices on n-type 6H-SiC substrates. To measure current-voltage characteristics, a Ti/Au ohmic contact was formed on the backside of the SiC substrate. The Al composition of the buffer layer was varied from 2% to 10%. We found that the optimal buffer layer thickness for the lowest resistance decreases with increasing Al composition because the nucleation seeds on SiC substrate coalesce faster. Since the optimal layer thickness depends on the Al composition, the sheet Al concentration, which is calculated from the Al composition and the thickness, should be considered as a critical parameter for low buffer resistance of vertical conducting devices on n-SiC substrates.

Characteristics of InP-InGaAs HPT-based Optically Injection-locked Self-oscillating Optoelectronic Mixers and Their Influence on Radio-over-fiber System Performance

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IEEE Photon. Technol. Lett., Vol. 19, No. 3, pp. 155–157, 2007.

A 30-GHz optically injection-locked self-oscillating optoelectronic mixer (OIL-SOM) is implemented with a high-performance InP-InGaAs heterojunction phototransistor. The subharmonic conversion efficiency and phase noise characteristics of OIL-SOM are investigated and used for analyzing OIL-SOM-based 60-GHz radio-over-fiber downlink data transmission performance. The OIL-SOM characteristics provide lower and upper boundaries for the input optical local oscillation (LO) power range within which the link performance does not significantly depend on input optical LO power.

Real-time Imaging of DNA–streptavidin Complex Formation in Solution Using a High-speed Atomic Force Microscope

M. Kobayashi, K. Sumitomo, and K. Torimitsu

Ultramicroscopy, Elsevier, Vol. 107, No. 2-3, pp. 184–190, 2007.

The direct observation of individual molecules in action is required for a better understanding of the mechanisms of biological reactions. We used a high-speed atomic force microscope (AFM) in solution to visualize short DNA fragments in motion. The technique represents a new approach in analyzing molecular interactions, and it allowed us to observe real-time images of biotinylated DNA binding to/dissociating from streptavidin protein. Our results show that high-speed AFMs have the potential to reveal the mechanisms of molecular interactions, which cannot be determined by analyzing the average value of mass reactions.