

## ABSTRACTS OF PUBLISHED PAPERS

(Accepted April to May, 1999)

### CONDENSED MATTER AND MATERIAL

#### **Quantum-Size Effects on Radiative Lifetimes and Relaxation of Excitons in Semiconductor Nanostructures**

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*Phys. Rev. B* **58** 15 (1998) 9933-9940

A systematic study of exciton dynamics is presented in quantum boxes formed naturally along the axis of a V-shaped quantum wires, by means of time and spatially resolved resonant photoluminescence. The dependence of radiative lifetimes and relaxation mechanisms of excitons are determined versus the size of the boxes. The radiative recombination rate varies linearly with the length of the box, showing that the exciton has a coherence volume equal to the volume of the box. In a low excitation regime, emission from excited states has not been observed, which would be a consequence of relaxation bottleneck, but there is clear evidence that relaxation via emission of LA phonons depends strongly on the energy separation between the different quantum box levels.

#### **Optical Excitations in Fractal Antenna Supermolecules: Extended Dendrimers**

Kikuo HARIGAYA

*Proceedings of 4th Int. Symp. on Advanced Physical Fields* (1999) 311-313

A phenomenological coupled exciton model is proposed in order to characterize optical excitations in extended dendrimers. An onsite exciton state is assigned

at each phenyl rings and a nearest neighbor hopping integral which obeys the Gaussian distribution is considered between the exciton states. The decreasing optical excitation energy with respect to the dendrimer size indicates the presence of exciton funnels along the backbone of the dendrimers. Therefore, the extended dendrimers can work as artificial fractal antenna systems which capture energy of light. Dynamics of an exciton is also investigated by solving time development of a wave function of optical excitations. It is shown that a damping term with a certain magnitude is necessary in order that optical excitations captured at the outer edge of the supermolecule move to the central areas of the molecule.

#### **Oxygen Adsorption Site of Pd(110)c(2×4)O: Analysis of ARUPS Compared with STM Image**

Kazutoshi YAGI and Hirohito FUKUTANI<sup>1</sup>

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*Surface science* **412/413** (1998) 489-494

Surface band structures of Pd(110)c(2×4)-O are calculated for all possible models for which the substrate is reconstructed into the (1×2) missing-row structure and the oxygen adatoms are located in three-fold sites. These calculations were compared with the observed energy dispersions by angle-resolved photoemission study (ARUPS) to find out which structure model is the optimum one by means of tight-binding approximation.

#### **Wave Functions of Correlated-Electron State in the Periodic Anderson Model**

Takashi YANAGISAWA

*J. Phys. Soc. Jpn.* **68** 3 (1998) 893-902

We investigate the periodic Anderson model by a variational Monte Carlo method. A new wave function is proposed based on the well-known Gutzwiller wave function. We calculate the physical properties using the Monte Carlo algorithm to consider the strong correlation effects. The ground state energy is improved considerably by taking into account electron-hole excitation effects.

### **Off-Diagonal Wave Function Monte Carlo Method for the Hubbard Model**

Takashi YANAGISAWA, Soh KOIKE  
and Kunihiko YAMAJI  
*Physica B* **259** (1999) 742-744

We propose a Monte Carlo method to investigate the ground state of the two-dimensional Hubbard model with a sign problem. Our method is considered as a hybrid method of the variational Monte Carlo and projector quantum Monte Carlo methods. In the  $4 \times 4$  system, the results are favorably compared with exact results. An application is given to investigate the  $10 \times 10$  Hubbard model with next nearest-neighbor transfer  $t'$ . Our results suggest a possibility of superconductivity for a negative value of  $t'$ .

### **Hydrogen Effect on Solid Phase Epitaxy of Si on Si(001) Surface**

Masataka HASEGAWA, Yasunori TANAKA  
and Naoto KOBAYASHI  
*Nuclear Instrum and Methods in Physics Research B*  
**136-138** (1998) 209

Solid phase epitaxy (SPE) of amorphous Si layers of several tens of monolayers on hydrogen-adsorbed Si(001) substrates was studied in situ by low-energy time-of-flight Rutherford backscattering-ion channeling spectrometry using 25 keV hydrogen ions, and by reflection high energy electron diffraction. The SPE has not occurred at all for heating to 600°C heating even in the case of less than 1ML adsorption of hydrogen on the Si(001) surface. Although the SPE has occurred for heating to 700°C heating, polycrystalline, or {111} faceted surface were formed. We did not obtain pronounced differences

between the effects of the hydrogen adsorption of more or of less than 1 ML on the SPE of Si on Si(001). In the case of high density hydrogen-containing amorphous Si on a Si(001) clean surface the SPE has occurred at 600°C, and an {111} faceted surface was observed. Hydrogen adsorption obstructs the SPE of Si on Si(001) even if the coverage is less than 1ML. The rise of the SPE temperature of amorphous Si on a hydrogen-adsorbed Si(001) surface is attributed to the hydrogen adsorption on the surface.

### **Possibility of Determining Integration Boundaries of a Broad Peak Using Only the Shirley Method**

Masatoshi JO  
*Journal of Surface Analysis* **5** 1 (1999) 106

It is shown that the integration boundaries (end points) determined by background optimization are also suitable for the Shirley method. For a couple of end points that are deduced from an optimized background, the ratio of areas of the same peak calculated by the Shirley and the optimized background is constant for all analyzer resolutions. The relative intensity ratio of different peaks from the same solid is also constant if such a couple is chosen for each peak, irrespective of the resolution. This suggests a method of determining end points by using only the Shirley method.

### **Electronic Structure of the Superconducting Layered Perovskite Niobate**

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*Physical Review B* **58** 4 (1998) R1707-R1709

The electronic energy band structure for  $\text{RbLaNb}_2\text{O}_7$ , which is closely related to the layered perovskite niobate superconducting  $\text{KCa}_2\text{Nb}_3\text{O}_{10}$  and metallic  $\text{KLaNb}_2\text{O}_7$  with Li intercalation, has been calculated by using the scalar-relativistic full-potential linearized augmented plane wave (FLAPW) method within the local-density approximation. The result of the calculation shows that this compound is a band insulator with a small gap, and its conduction band is a typical two-dimensional one and

the valence band is rather three-dimensional. We can conclude that the layered perovskite niobate  $\text{KCa}_2\text{Nb}_3\text{O}_{10}$  is the first band insulator which can be superconducting with electron doping, and have the highly two-dimensional electronic structure.

### **Strong Excitonic Recombination Radiation from Homoepitaxial Diamond Thin Films at Room Temperature**

Hideyuki WATANABE<sup>1</sup>, Kazushi HAYASHI<sup>2</sup>,  
Daisuke TAKEUCHI, Sadanori YAMANAKA,<sup>3</sup>

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*Applied Physics Letter* **73** 7 (1998) 981-983

We have observed strong emission lines at 5.27 and 5.12 eV at room temperature in cathodoluminescence spectra from homoepitaxial diamond films grown by step-flow mode prepared with microwave plasma assisted chemical vapor deposition. The temperature dependence of integrated intensity of the emission lines indicates that they are attributed to free-exciton recombination radiation associated with a transverse optical phonon and its replica. These results have demonstrated the superior crystalline quality of the homoepitaxial diamond films grown by the step-flow mode.

### **High-Quality B-Doped Homoepitaxial Diamond Films using Trimethylboron**

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*Japanease Journal of Applied Physics* **37** Part2 10A  
(1998) L1129-L1131

High-quality B-doped homoepitaxial diamond films

have been synthesized by microwave plasma chemical-vapor-deposition (CVD) using a mixture consisting of  $\text{CH}_4$ ,  $\text{H}_2$ , and trimethylboron  $\text{B}(\text{CH}_3)_3$  diluted by  $\text{H}_2$  gas. These films have been obtained on the basis of the approach that high-quality diamond films should be grown in a clean CVD system. Hall-effect measurements of the film show that the Hall mobility exceeds about  $1800 \text{ cm}^2/\text{Vs}$  when the hole concentration is  $2.3 \times 10^{14} \text{ cm}^{-3}$  at room temperature (290K) and about  $3300 \text{ cm}^2/\text{Vs}$  at 170K. These results indicate that the quality of the present B-doped CVD films is comparable with or better than that of high-quality natural diamonds.

### **Junction Properties of Homoepitaxial Diamond Films Grown by Step-Flow Mode**

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*Journal of Applied Physics* **84** 11 (1998) 6095-6099

Homoepitaxial diamond films with atomically flat surface were reproducibly grown by step-flow mode under the condition of less than 0.1%  $\text{CH}_4/\text{H}_2$ . Using these diamond films, high-quality Schottky junctions between Al and high-conductivity layer near the surface of the films have been successfully made. At 400K, the ideality factor and the barrier height of the Schottky junctions, which are defined by the conventional junction theory, estimated from the current-voltage (I-V) characteristics are about 1.1 and 1.5-1.6 eV, respectively. Under the condition of more than 0.1%  $\text{CH}_4/\text{H}_2$ , however, many unepitaxial crystallites (UC) and pyramidal hillocks (PH) are often formed on the surface of the films which are even mainly grown by the step-flow mode. The Schottky junction properties become worse with an increase in the density of UC and PH. In particular, the increase in the saturation current, which was obtained by extrapolating the straight line to  $V=0$  in a plot of  $\ln I$  against  $V$ , correlated with Schottky Barrier height is more sensitive than that of the ideality factor to the density of UC and

PH. It is concluded that diamond films grown by the step-flow mode without UC and PH is essential to obtain an ideal Schottky junction.

### Spatial Resolved Cathodoluminescence Study on CVD Homoepitaxial Diamond Film

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*Solid State Phenomena* **63-64** (1998) 489-496

We have investigated the correlation between macroscopic imperfections and luminescence centers in homoepitaxial diamond films by field emission scanning electron microscope (FE-SEM) and spatially resolved cathodoluminescence (CL) spectroscopy. Diamond films were grown by microwave plasma assisted chemical vapor deposition using mixed gas of 0.5% CH<sub>4</sub> in H<sub>2</sub>. It was found that the CL spectra of the films consist of four luminescence lines related to band-A, V-N-V (575) center, N-V-N (H3) center and free-exciton. The spatial distributions of these luminescence lines were strongly correlated with the position of macroscopic imperfections such as unepitaxial crystallite (UC) and pyramidal hillock (PH) formed on the surface of the films. At the UC, the band-A luminescence was observed but the free-exciton recombination radiation was not. On the other hand, at the PH, the luminescence intensity of V-N-V center was strong, while that of N-V-N center was weak.

### Effect of CH<sub>4</sub> Concentration Control during Synthesis of Homoepitaxial Diamond Thin Films

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*Diamond Films and Technology* **8** 5 (1998) 317-322

Recently, we found that homoepitaxial diamond films synthesized in the presence of a CH<sub>4</sub> concentration lower than 0.15% in an end-launch-type microwave plasma CVD system had excellent electrical and optical properties without any unepitaxial crystallites. In the presence of such low concentrations of CH<sub>4</sub>, however, the growth rate becomes too low to obtain the thickness desired for practical use. In order to solve this problem, we attempted to use a two-step growth method. In the first step of this method, the substrate surface was treated by homoepitaxial diamond growth in the presence of 0.05% CH<sub>4</sub> in H<sub>2</sub>, and in the second one, the CH<sub>4</sub> concentration was increased. We found that by using this method, high-quality films with high growth rate and reproducibility were obtained.

### Positron-Annihilation Studies of Stable Al-Based Icosahedral Quasicrystals

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*Phys. Rev. B* **59** 10 (1999) 6712-6716

The positron-annihilation lifetime spectra in the Al-Pd-Re alloy system, the positron-annihilation Doppler-broadening spectra by slow variable monoenergetic positron beam in Al<sub>70.7</sub>Pd<sub>21.34</sub>Re<sub>7.96</sub> and Al<sub>71.5</sub>Pd<sub>20.3</sub>Mn<sub>8.2</sub> alloys, and positron-annihilation lifetime spectra by slow positron beam in Al<sub>71.5</sub>Pd<sub>20.3</sub>Mn<sub>8.2</sub> were measured. These measurements indicate that every sample contains a dense distribution of structural vacancy-type sites. This result is consistent with our previous expectation of the relationship between the presence of vacant centers in clusters and the stability of icosahedral quasicrystals.

### Investigation of Vacancy-Type Defects in P<sup>+</sup>-Implanted 6H-SiC Using Monoenergetic Positron Beams

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*Jpn. J. Appl. Phys.* **37** 5A (1998) 2422-2429

Vacancy-type defects and their annealing properties for 200 keV P<sup>+</sup> implanted 6H-SiC were studied using monoenergetic positron beams. For the specimen with a dose of  $1 \times 10^{13} \text{cm}^{-2}$ , the mean size of the open volume of defects was estimated to be close to that of divacancies. Based on the annealing behavior of the S parameter corresponding to the annihilation of positrons trapped by vacancy-type defects, the temperature range for the annealing of vacancy-type defects was divided into three stages. The annealing behavior of the amorphous region introduced by ion implantation was also discussed.

### Defects in Ion Implanted Hg<sub>0.78</sub>Cd<sub>0.22</sub>Te Probed by Monoenergetic Positron Beams

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*Jpn. J. Appl. Phys.* **37** 7 (1998) 3910-3914

Defects and their annealing properties in ion implanted Hg<sub>0.78</sub>Cd<sub>0.22</sub>Te were studied using monoenergetic positron beams. Vacancy-type defects introduced by B<sup>+</sup> implantation were identified as open spaces associated with extended defects such as dislocation loops and stacking faults. For an Ar<sup>+</sup> implanted specimen, the mean size of the open volume of defects in the damaged region was estimated to be that of divacancies. The observed difference between the species or defects in the B<sup>+</sup> and the Ar<sup>+</sup> implanted specimens was attributed to the suppression of the recombination between vacancies and interstitials in the damaged region introduced by Ar<sup>+</sup> implantation. The

annealing temperature of the vacancy-type defects introduced by Ar<sup>+</sup> implantation was determined to be 300 degrees C.

### Open Spaces in the Subsurface Region of Polyethylene Probed by Monoenergetic Positron Beams

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*J. Polymer Science Part B* **36** (1998) 2597-2605

Open spaces in the subsurface region (<10 μ m) of very low density polyethylene were probed by a monoenergetic positron beam. From measurements of Doppler broadening spectra measurements of the annihilation radiation and the lifetime spectra of positrons as a function of incident positron energy, the size of the open spaces in the region of 0-3 μ m was found to be larger than that in the deeper region. This was attributed to the cooperative motion of large segments of molecules which is activated near the surface. After the freezing in of such motions (below 230 K), although the lineshape parameter S in the bulk was almost constant, S in the region of 0-3 μ m decreased with decreasing temperature. This discrepancy was associated with the presence of the open spaces with an excess content and the resultant contraction of amorphous structure near the surface.

### Vacancy Defects in Solid-Phase Epitaxial Grown Layers of Self-Implanted Si

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*Appl. Phys. Lett.* **74** 7 (1998) 997-999

A method for preparing shallow dopant distributions via solid-phase epitaxial growth (SPEG) following amorphization by low-energy Si self-ion implantation leaves defects that can lead to unwanted dopant impurity diffusion. The double implant method for SPEG uses both

low- and high-energy Si self-ion implantation to remove most of the interstitials. Nevertheless, we find that measurable crystalline imperfections remain following the SPEG annealing step. Measurements of defect profiles using variable-energy positron spectroscopy show that there are divacancy-impurity complexes in the SPEG layer and  $V_6$  and larger vacancy clusters near the SPEG-crystalline interface. These measurements should be useful for modeling the diffusion of dopant atoms and for fine tuning the double implant parameters.

### Thermal Evolution of Defects in H-Implanted Si Studied by Monoenergetic Positrons

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*Phys. Rev. B* **58** 19 (1998) 12559-12562

The behavior of hydrogen-vacancy defects in silicon implanted with H ions ( $1 \times 10^{16} \text{cm}^{-2}$ , 60 keV) has been investigated by means of a slow positron beam, in which both the positron lifetime and the Doppler broadening have been measured. It has been found that the positron-trapping defect associated with H is formed within the H implantation profile. Upon annealing at up to 400C, the defects located within 350 nm of the surface are agglomerated and also hydrogenated, whereas the H-decorated defects within the H implantation profile are unchanged. Annealing at 500C leads to the agglomeration of the H-decorated defects and annealing at 600C leads to hydrogen release from these agglomerates. It has been found that a high density of hydrogen-stabilized defects is present within the implantation profile upon annealing at 400C.

### Investigation of Positron Moderator Materials for Electron-Linac-Based Slow Positron Beamlines

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*Jpn. J. Appl. Phys.* part 1 **37** 8 (1998) 4636-4643

Positron re-emission properties were studied on moderator materials in order to improve the positron moderation system of electron-linac-based intense slow positron beamlines. The re-emitted positron fraction was measured on tungsten, SiC, GaN, SrTiO<sub>3</sub>, and hydrogen-terminated Si with a variable-energy pulsed positron beam. The results suggested that tungsten is the best material for the primary moderator of the positron beamlines while epitaxially grown n-type 6H-SiC is the best material for the secondary moderator. The characterization experiments on degraded tungsten films revealed that the degradation is due to both radiation-induced vacancy clusters and surface carbon impurities. For the restoration of degraded tungsten moderators, oxygen treatment at 900 degrees C is effective.

### Magnetic Properties of Organic Ferromagnetic TDAE-C<sub>60</sub> Single Crystals and Thin Films

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*Mat. Res. Soc. Proc.* **488** (1998) 477-482

Recent progress in the study on magnetic properties of molecular soft ferromagnet TDAE-C<sub>60</sub> (where TDAE is tetrakis(dimethylamino) ethylene) is reported. Both crystalline and thin film samples are prepared by the diffusion method and the temperature and field dependence of magnetization are studied by SQUID magnetometer. The magnetic behaviors of single crystals were found to vary from sample to sample. In best single crystals, the saturation magnetization as high as  $1.0 \mu_B/C_{60}$  has been observed. Spontaneous magnetization and its temperature dependence was evaluated from the Arrott plot. The ferromagnetic phase transition was also observed in TDAE-C<sub>60</sub> thin films.

### Superconductivity of $\kappa$ -(BEDT-TTF)<sub>2</sub>Cu[N(CN)<sub>2</sub>]Br: Isotope Effect Revisited

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*Mat. Res. Soc. Proc.* **488** (1998) 903-908

In 1991, we reported a normal isotope effect in organic superconductor  $\kappa$ -(BEDT-TTF)<sub>2</sub>Cu[N(CN)<sub>2</sub>]Br, when all the hydrogen atoms of BEDT-TTF were replaced with deuterium. In other words,  $T_c$  was depressed by as much as 0.9 K, in contrast to the "inverse isotope effect" commonly observed in 10K-class organic superconductors. Recently, it was reported that the deuterated  $\kappa$ -(BEDT-TTF)<sub>2</sub>Cu[N(CN)<sub>2</sub>]Br shows an insulating nature when cooled very rapidly. Therefore, it is necessary for us to reexamine the superconducting transition of both deuterated and undeuterated  $\kappa$ -(BEDT-TTF)<sub>2</sub>Cu[N(CN)<sub>2</sub>]Br by SQUID measurements with special attention to the cooling speed. We studied the effect of cooling rate ranging from 10K/min down to as slow as 0.02 K/min, and observed a significant effect not only on the superconducting transition temperature  $T_c$  but also on the superconducting volume fraction.

### Near Quantum Limit SdH and dHvA Wave Forms in Low-Dimensional Metals

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*Physica B* **246-247** (1998) 307-310

We describe experiments in steady magnetic fields up to 33 T at low-temperatures on low-dimensional organic metals where the Landau level separation becomes greater than either the thermal or the impurity broadening. High precision simultaneous Shubnikov-de Haas and de Haas-van Alphen measurements allow direct correlation of the oscillations of the magnetization with the dissipation as the Landau levels cross the Fermi level. From these results, we can determine with reasonable certainty the functional form of the density of states, and their relative values in the open- and closed-orbit bands.

### Structural and Magnetic Properties of M(mnt)<sub>2</sub> Salts (M=Ni, Pt, Cu) with a Ferrocene-Based Cation, [FcCH<sub>2</sub>N(CH<sub>3</sub>)<sub>3</sub>]<sup>+</sup>. Interplay between M...M and M...S Intermolecular Interactions

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*Inorg. Chem.* **37** 26 (1998) 6714-6720

A series of metal bis-mnt complexes (mnt = 1,2-dithiolatomaleonitrile) with the trimethylammonium methyl-ferrocene cation have been synthesized and characterized using X-ray diffraction, magnetic susceptibility, and differential scanning calorimetry measurements. The complexes have the formulas (FcCH<sub>2</sub>NMe<sub>3</sub>)[Ni(mnt)<sub>2</sub>] (2), (FcCH<sub>2</sub>NMe<sub>3</sub>)[Pt(mnt)<sub>2</sub>] (3), and (FcCH<sub>2</sub>NMe<sub>3</sub>)<sub>2</sub>[Cu(mnt)<sub>2</sub>] (4) (where Fc = ferrocene). At 300 K, the crystal structures of 1 : 1 complexes 2 and 3 are very similar. They consist of pairs of [M(mnt)<sub>2</sub>]<sup>-</sup> in a slipped configuration packed in stacks. Each [M(mnt)<sub>2</sub>]<sup>-</sup> stack is separated from adjacent stacks by two columns of cations. Within the pairs, the [M(mnt)<sub>2</sub>]<sup>-</sup> anions interact via short M...S contacts, while there are no short contacts between the pairs. Complex 4, which has a 2:1 stoichiometry, exhibits a markedly different packing arrangement of the anionic units. Due to the special position of the Cu atom in the asymmetric unit cell, [Cu(mnt)<sub>2</sub>]<sup>2-</sup> dianions are completely isolated from each other. The magnetic susceptibility behavior of the nickel complex is consistent with the presence of magnetically isolated, antiferromagnetically (AF) coupled [Ni(mnt)<sub>2</sub>]<sup>-</sup> pairs with the AF exchange parameter,  $J = -840 \text{ cm}^{-1}$ . The platinum complex undergoes an endothermic structural phase transition ( $T_p$ ) at 247 K. Below  $T_p$  its structure is characterized by the formation of magnetically isolated [Pt(mnt)<sub>2</sub>]<sup>2-</sup> dimers in an eclipsed configuration with short Pt...Pt and S...S contacts between monomers. In the magnetic properties, the structural changes reveal themselves as an abrupt susceptibility drop implying a substantial increase of the AF exchange parameter. A mechanism of the phase transition in the platinum compound is proposed. For compound 4, paramagnetic behavior is observed.

### Atomic Structure and Electronic Properties of Single-Wall Carbon Nanotubes Probed by Scanning Tunneling Microscope at Room Temperature

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*Appl. Phys. Lett.* **73** 26 (1998) 3839-3841

A detailed three-dimensional structural analysis of single-walled carbon nanotubes was carried out using a scanning tunneling microscope (STM) operated at room temperature in ambient conditions. On a microscopic scale, the images show tubes condensed in ropes as well as tubes which are separated from each other. For a single-wall nanotube rope, the outer portion is composed of highly oriented nanotubes with nearly uniform diameter and chirality. On separated nanotubes, atomically resolved images show variable chirality ranges between 0°-30°, and variable diameter (1-3 nm), with no one type dominant. From STM and scanning tunneling spectroscopy measurements we confirmed the correlation between chirality and the electronic properties, namely the tuning from metallic to semiconducting. We also observed a rectifying behavior correlated with the chiral angle of 25°, an important observation for nanodevices application.

## ELECTRONIC DEVICES

### Electrical Properties of Nanoscale Si Clusters Embedded in an Ultrathin Oxide

Tatsuro MAEDA, Eiichi SUZUKI, Kenichi ISHII,  
Isao SAKATA and Mitsuyuki YAMANAKA

*IEEE Silicon Nanoelectronics Workshop Abstracts*  
(1998) 7-8

We have investigated Si nanocrystals fabricated by the rapid thermal oxidation (RTO) of an ultrathin chemical vapor deposition (CVD) amorphous Si (a-Si:H) film. It is found from the transmission electron microscope (TEM) observation that the ultrathin RTO film contains the Si nanocrystals of less than 5nm in diameter. The dynamic electrical conduction measurement of the RTO

diode structure including Si nanocrystals reveals novel features such as the current peak and valley and the hysteresis in the tunnel current vs. voltage characteristics. These findings can be explained by the electron charging effect in the Si nanocrystals and the consequent screening effect on the tunnel current. We regard that this is the first observation of the dynamic modulation of the tunnel current.

### Bismuth-Induced Structures on Si(001) Surfaces

K. MIKI, J.H.G. OWEN<sup>1</sup>, D.R. BOWLER<sup>1</sup>,  
G.A.D. BRIGGS<sup>1</sup> and K. SAKAMOTO

<sup>1</sup>Oxford University

*Surface Science* **421** 3 (1999) 397-418

We have examined Bi-induced surface structures of Si(001), formed in the vicinity of its desorption temperature, by means of scanning tunnelling microscopy (STM) and reflection high-energy electron diffraction (RHEED). Below the desorption temperature, adsorption of bismuth results in a (2 × n) Bi/Si(001) reconstruction with second-layer Bi dimers either parallel or perpendicular to the underlying dimers. Even after the desorption of the bismuth epitaxial layer, some bismuth remains on the surface with characteristic structures which depend upon the formation pathway. Perfectly straight Bi lines 1 nm wide and hundreds of nm long can be formed either by annealing of the saturated Bi epitaxial layer, or by exposure to a large flux of bismuth around the desorption temperature. Exposure to a smaller flux of Bi at the desorption temperature generates a (4 × 4) reconstruction. The stability of the (4 × 4) reconstruction is thought to be due to a strain effect resulting from incorporated Bi. Both the Bi line and the (4 × 4) structures disappear after further annealing and the remaining Bi concentration was below the detection limit of secondary ion mass spectroscopy (SIMS).

### Observation of an Electron Charging Effect in Si Nanocrystals Embedded in an Ultrathin GateOxide

Tatsuro MAEDA, Eiichi SUZUKI, Isao SAKATA, Mitsuyuki YAMANAKA and Kenichi ISHII

*Meeting Abst. 194th Meeting of the Electrochemical Society* **98-2** 388 (1998)

We have investigated the electrical characteristics of Si nanocrystals fabricated by the rapid thermal oxidation (RTO) of an ultrathin chemical vapor deposition (CVD) amorphous Si (a-Si:H) film (<10nm). It is found from the transmission electron microscope (TEM) observation that the ultrathin RTO film contains Si nanocrystals of less than 5nm in diameter. The dynamic measurement of the electrical conduction through the ultrathin RTO film reveals novel features indicating a tunnel current modulation such as the current peak and valley and the hysteresis. The electron charging effect in Si nanocrystals and the consequent screening effect on reducing the tunnel current can explain these experimental results. We also fabricated the 3-terminal device with Si nanocrystals, which shows the similar charging effect, modulated by the gate voltage.

### Pulsed Lased Deposition and Ferroelectric Properties of SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub>

S.B. XIONG, S. MIGITA, H. OTA and S. SAKAI

*Materials Letters* **38** (1999) 406-412

Ferroelectric SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> (SBTO) thin films were successfully produced on Nb-doped SrTiO<sub>3</sub> and Pt-coated SrTiO<sub>3</sub> substrates by pulsed laser ablation of SrBi<sub>2.5</sub>Ta<sub>2</sub>O<sub>9</sub> ceramic targets (25 mol% bismuth excess) and a KrF excimer laser. Very weak spontaneous polarization was observed for c-axis oriented SBTO thin films on Nb-doped SrTiO<sub>3</sub> substrates. For films deposited at 705°C on Pt/Ti/STO (100) substrates, the small signal dielectric constant and dissipation loss factor at 1 kHz were 370 and 0.020, the remnant polarization and coercive field were 4.2 mC/cm<sup>2</sup> and 30 kV/cm at 9 V and 1kHz, and the decay of remnant polarization at a fatigue measurement was less than 6% up to 10<sup>10</sup> cycles. The effects of film microstructure on the degradation of spontaneous polarization are also

discussed.

### Molecular Beam Epitaxial Growth of BSCCO and Bi-Based Oxides: Self-limiting Growth of the Bi Element

S. SAKAI, S. MIGITA, H. OTA, H. FUJINO, T. OOHIRA, H. MATSUHATA and K. KAJIMURA

*Proceedings of SPIE* **3481** (1998) 161-171

Self-limiting function of Bi element in connection with experimental results of sticking coefficients of constituent atoms of BSCCO is described. Molecular beam epitaxial growth of Bi<sub>2</sub>Sr<sub>2</sub>CuO<sub>x</sub> (Bi2201) and Bi<sub>4</sub>Ti<sub>3</sub>O<sub>12</sub> (BIT) is demonstrated using this function. A further advanced method and its growth results for Bi<sub>2</sub>Sr<sub>2</sub>CaCu<sub>2</sub>O<sub>x</sub> (Bi2212) and Bi<sub>2</sub>Sr<sub>2</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>x</sub> (Bi2223) growth are shown, where a chemical reaction between Bi2201 molecular layer and one or two monolayers of Ca and Cu deposited on Bi2201 is used. Estimation by means of X-ray diffraction, reflection high-energy electron diffraction, and atomic force microscopy shows excellent quality of the films obtained. Heteroepitaxial growth of BIT/Bi2201 using the self-limiting function of Bi is also done.

### Dynamics of Multiple-Junction Stacked Flux-Flow Oscillators: Comparison between Theory and Experiment

S. SAKAI, A.V. USTINOV, N. THYSSEN and H. KOHLSTEDT

*Physical Review B* **58** 9 (1998) 5777-5782

Flux-flow dynamics in long N-layered Nb/Al-AlO<sub>x</sub>/Nb Josephson tunnel junctions is investigated experimentally and by numerical simulations. Magnetic-field-dependent current-voltage characteristics show the collective flow of Josephson vortices in the experiments with N=7 and N=9. In order to interpret the observed characteristics we performed numerical analysis using a finite difference method. The structure of cavitylike resonances displayed in the I-V characteristics is accounted for by the characteristic frequencies calculated using the coupled sine-Gordon equation model. A static I-V curve obtained numerically for a seven-junction stack

shows voltage-locked flux-flow motion among the inner five junctions. The numbers of vortices in the top and bottom junction is found to be larger than those of the inner junctions because of the thicker top and bottom Nb electrodes. Numerical data show very good overall agreement with the experiment.

### **Josephson Plasma Resonance in Superconducting Multilayers**

N.F. PEDERSEN and S. SAKAI

*Physical Review B* **58** 5 (1998) 2820-2826

We derive an analytical solution for the Josephson plasma resonance of superconducting multilayers. This analytical solution is derived mainly for low  $T_c$  systems with magnetic coupling between the superconducting layers, but many features of our results are more general, and thus an application to the recently derived plasma resonance phenomena for high  $T_c$  superconductors of the BSCCO type is discussed. Our approach allows us to give full details of the different plasma resonance excitations, and we also predict the existence of new non-linear effects, so far only identified in single junctions.

### **Submillimeter-Band High-Power Generation using Multilayered Josephson Junctions**

A.V. USTINOV and S. SAKAI

*Applied Physics Letters* **73** 5 (1998) 686-688

We report on numerical simulations of 10- and 19-layer stacked Josephson junctions. Simulations are performed using the experimentally feasible parameters for Nb/Al-AIO<sub>x</sub>/Nb junctions. With an appropriate choice of parameters such as magnetic field and coupling, the current-voltage curves of N layer stacks systematically indicate in-phase locking among the inner N-2 junctions. The simulation results suggest that multilayer Josephson junctions are very promising as submillimeter-band high power oscillators.

### **Maximum Supercurrent in Two Josephson-Junction Stacks: Theory and Experiment**

G. CARAPPELLA, G. COSTABILE, S. SAKAI and N.F. PEDERSEN

*Physical Review B* **58** 10 (1998) 6497-6505

The interaction between two long Josephson junctions in a stack is investigated experimentally in the absence of applied magnetic field. Mutual interaction is observed when both junction or only one junctions in the stack is in the zero voltage state. To account for the observed phenomena we propose a model that takes into account the nonuniform self-fields generated by the bias currents.

## **INFORMATION SCIENCE**

### **RMCP: Musical Information Processing Based on Remote Music Control Protocol**

Masataka GOTO, Ryo NEYAMA<sup>1</sup>  
and Yoichi MURAOKA<sup>1</sup>

<sup>1</sup>*Waseda Univ.*

*Transactions of Information Processing Society of Japan* **40** 3 (1999) 1335-1345

This paper describes a communication protocol, called RMCP (Remote Music Control Protocol), which is designed for sharing symbolic musical information through computer networks. The purpose of this research is to design a network protocol which is suitable for musical information processing and facilitates distributed implementation of music-related applications. Although efficient musical information sharing is desirable for such a purpose, most previous music-related protocols were connection-oriented and did not emphasize efficient information sharing among multiple processes. Since the RMCP is a connection-less protocol, it supports broadcast-based efficient information sharing without the overhead of multiple transmission. It also supports time scheduling using time stamps for real-time musical information processing and reliable bidirectional packet relay for remote sessions. This paper also proposes an innovative remote session over the Internet that has a long delay. RMCP has been utilized in various applications and we found that the communication delay of RMCP was enough

small and RMCP facilitated system implementation and expansion because of good reusability.

### **Estimating the Possible Omission Number for Groups in Go by the Number of n-th Dame**

Morihiko TAJIMA and Noriaki SANECHIKA  
*Lecture Notes in Computer Science* **1558** (1999)  
265-281

This paper describes a new method for estimating the strength of a group in the game of Go. Although position evaluation is very important in Computer Go, the task is very complex, so good evaluation methods have not yet been developed. One of the major factors in evaluation is the strength of groups. In general, this evaluation is a difficult problem, so it is desirable to have a simple method for making a rough estimate. We define PON (Possible Omission Number) as a precise measure for the strength of groups, and present a simple method for the rough estimation of PON by calculating n-th dame (liberties). We report some experiments indicating the effectiveness of the method.

### **A Market in the Computer: Construction and Evaluation of an Artificial Market with Agents Having the Cognitive Mechanisms**

Kiyoshi IZUMI and Kazuhiro UEDA<sup>1</sup>  
<sup>1</sup>*University of Tokyo*

*Cognitive Studies: Bulletin of Japanese Cognitive Science Society* **6** 1 (1999) 31-43

In this study, an artificial market approach, which is a new agent-based approach to investigate foreign exchange markets, is proposed. Using this approach, three emergent phenomena of markets were explained. First, in order to investigate the learning patterns of actual dealers, we held an interview with a dealer. Second, based on the field data acquired, we constructed a multiagent model of a market using genetic algorithms. Finally, the emergent phenomena of markets were analyzed using the simulation results of the model. The results showed that the interaction between the agents' forecasts and the relationship of demand and supply caused the phase

transition of forecast variety. The three emergent phenomena were explained by the phase transition. This approach, therefore, integrates the fieldwork and the multiagent model, and provide quantitative explanation of the micro-macro relation in markets.

### **Analysis of Dealers' Processing Financial News Based on an Artificial Market Approach**

Kiyoshi IZIMI and Kazuhiro UEDA<sup>1</sup>  
<sup>1</sup>*University of Tokyo*

*Journal of Computational Intelligence in Finance* **7** 2  
(1999) 23-33

In this study we used a new agent-based approach, an artificial market approach, to analyze the ways that dealers in a foreign exchange market process the information in financial news. We first interviewed a dealer and found that the features of dealer interaction in learning were similar to features of genetic operations in biology. We then constructed an artificial market model using a Genetic Algorithm, which is a computer algorithm based on population biology, by regarding the market as a multi-agent system. Using the simulation results obtained with our model, we classified, according to the ways that agents regard the news, three categories of news data. We then identified three emergent phenomena of the market: the peaked and long-tailed distribution of rate changes, the negative correlation between trading amounts and rate fluctuation, and the contrary opinions phenomenon. As a result, we concluded that these emergent phenomena could be explained by the phase transition of forecast variety, which transition is due to the interaction of agent forecasts and the demand-supply balance. The analysis based on the categorization acquired from the simulation results could thus reveal the mechanisms of the emergent phenomena in markets.

### **Optoelectronic Fuzzy Inference Architecture using Beam-Steering Vertical Cavity Surface-Emitting Laser Diodes**

Hideo ITOH, Mitsuaki SHIMIZU, Mutsuo OGURA,  
Seiji MUKAI and Masanobu WATANABE  
*Journal of The European Optical Society, Journal of*

*Optics A, Pure and Applied Optics* 1 2 (1999) 338-340

Novel optoelectronic fuzzy inference architecture using beam-steering vertical cavity surface-emitting laser diodes is described. Antecedent fuzzy operation using the laser is demonstrated.

### **AI as Complex Information Processing**

Hideyuki NAKASHIMA

*Mind and Machines* 9 1(1999) 57-80

In this article, I present a software architecture for intelligent agents. The essence of AI is complex information processing. It is impossible, in principle, to process complex information as a whole. We need some partial processing strategy that is still somehow connected to the whole. We also need flexible processing that can adapt to changes in the environment. One of the candidates for both of these is situated reasoning, which makes use of the fact that an agent is in a situation, so it only processes some of the information -- the part that is relevant to that situation. The combination of situated reasoning and context reflection leads to the idea of organic programming, which introduces a new building block of programs called a cell. Cells contain situated programs and the combination of cells is controlled by those programs.

### **Automatic Text Summarization Based on the Global Document Annotation**

Katashi NAGAO<sup>1</sup> and Koiti HASIDA

<sup>1</sup>*Sony Computer Science Laboratory*

*Proceedings of the 17th International Conference on Computational Linguistics* (1998)

The GDA (Global Document Annotation) project proposes a tag set which allows machines to automatically infer the underlying semantic/pragmatic structure of documents. Its objectives are to promote development and spread of NLP/AI applications to render GDA-tagged documents versatile and intelligent contents, which should motivate WWW (World Wide Web) users to tag their documents as part of content authoring. This paper

discusses automatic text summarization based on GDA. Its main features are a domain/style-free algorithm and personalization on summarization which reflects readers' interests and preferences. Our solution naturally outperforms the traditional summarization methods, which just pick out sentences highly scored on the basis of superficial clues such as word count, etc. In order to calculate the importance score of a text element, the algorithm uses spreading activation on an intra-document network which connects text elements via thematic, rhetorical, and coreferential relations. The proposed method is flexible enough to dynamically generate summaries of various sizes. A summary browser supporting personalization is reported as well.

### **Emergence and Categorization of Coordinated Visual Behavior Through Embodied Interaction**

Luc BERTHOUBE and Yasuo KUNIYOSHI

*Autonomous Robots* 5 3/4 (1998) 369-379

This paper discusses the emergence of sensorimotor coordination for ESCHeR, a 4DOF redundant foveated robot-head, by interaction with its environment. A feedback-error-learning(FEL)-based distributed control provides the system with explorative abilities with reflexes constraining the learning space. A Kohonen network, trained at run-time, categorizes the sensorimotor patterns obtained over ESCHeR's interaction with its environment, enables the reinforcement of frequently executed actions, thus stabilizing the learning activity over time. We explain how the development of ESCHeR's visual abilities (namely gaze fixation and saccadic motion), from a context-free reflex-based control process to a context-dependent, pattern-based sensorimotor coordination can be related to the Piagetian 'stage theory'.

### **Dynamic Categorization of Explorative Behaviors for Emergence of Stable Sensorimotor Configurations**

Luc BERTHOUBE, Yukifumi SHIGEMATSU and Yasuo KUNIYOSHI

*Proc. of Fifth International Conference of the Society for Adaptive Behavior (SAB'98)* 67-72

A prerequisite for autonomous acquisition of novel behaviors would be the ability to evolve internal representation of embodied interaction structures, in other words, sensory-motor categorization. It requires a unified approach to categorical learning of spatio-temporal information. This paper proposes a novel artificial neural architecture for such processing. It is based on a "spiking neuron" model and a temporal learning rule, and is capable of spatio-temporal association and categorization. The architecture has been applied to an example of visuo-ocular interaction with its surrounding by a binocular active vision system. Its sensory-motor interactions are triggered by a set of a priori reflexes and the neural architecture successfully categorized resulting structure of the interaction. Results from simulation experiments are presented.

### **Emergence and Categorization of Coordinated Visual Behavior Through Embodied Interaction**

Luc BERTHOUBE and Yasuo KUNIYOSHI  
*Machine Learning* **31** 1/2/3 (1998) 187-200

This paper discusses the emergence of sensorimotor coordination for ESCHeR, a 4DOF redundant foveated robot-head, by interaction with its environment. A feedback-error-learning(FEL)-based distributed control provides the system with explorative abilities with reflexes constraining the learning space. A Kohonen network, trained at run-time, categorizes the sensorimotor patterns obtained over ESCHeR's interaction with its environment, enables the reinforcement of frequently executed actions, thus stabilizing the learning activity over time. We explain how the development of ESCHeR's visual abilities (namely gaze fixation and saccadic motion), from a context-free reflex-based control process to a context-dependent, pattern-based sensorimotor coordination can be related to the Piagetian 'stage theory'.

### **Towards a Comprehensive Integration of Subjective Parameters in Database Browsing**

Nadia Bianchi BERTHOUBE<sup>1</sup>, Luc BERTHOUBE and  
Toshikazu KATO<sup>2</sup>  
<sup>1</sup>*Univ. of Milano*

<sup>2</sup>*Chuo Univ.*

*Advanced Database Systems for Integration of Media and User Environments '98* **9** 227-232

Today, the cyberspace provides the user with quantities of distributed multimedia information. Whereas adequate technical tools were developed that enable the user to actually access this database, information technology still lacks of plasticity to handle requests based on subjective parameters, i.e. non explicit requests. In human-human communication however, such complex and variable information can be transmitted by words, even if the meaning associated varies from one actor to the other one. In this paper, we propose an experimental framework in which, through intensive interaction, the machine and the user develop a common language through which they can establish mutual understanding over visual perceptions. We describe the mechanisms underlying the development of this language and which allow the user to have full control, both functionally and structurally of the system.

### **Three Dimensional Bipedal Stepping Motion using Neural Oscillators - Towards Humanoid Motion in the Real World**

Seiichi MIYAKOSHI, Gentaro TAGA<sup>1</sup>,  
Yasuo KUNIYOSHI and Akihiko NAGAKUBO  
<sup>1</sup>*University of Tokyo*

*Proceeding of IEEE/RSJ International Conference on Intelligent Robots and Systems(IROS98)* **1** 84-89

CPG (central pattern generator) and entrainment dynamics together form a promising framework for robust and adaptive behavior generation for a high degree of freedom system in unstructured environment. This paper investigates its possibility in the domain of biped robotic locomotion. We extend a previous work on 2D biped locomotion using neural oscillators to 3D, introducing many more degrees of freedom and complexity in control. While the complexity of the problem has been increased, we have simplified the internal neural mechanism compared to the original 2D work. Our fully dynamic 3D simulation experiments showed that our mechanism can generate 3D stable biped stepping motion as well as tolerance against external perturbations.

## Robust Tracking by A Humanoid Vision System

Sebastien ROUGEAUX<sup>1</sup> and Yasuo KUNIYOSHI

<sup>1</sup>*Univ. of Evry*

*Proceeding of IARP First International Workshop on  
Humanoid and Friendly Robotics (1998)*

Achieving the first step of a framework for human-robot interaction, we have designed a binocular tracking system which uses disparity and velocity information for the detection and pursuit of moving objects in cluttered environments without a-priori knowledge of the target shape or texture. The implemented system robustly tracks in real-time deformable objects such as human hands and faces, taking advantage of the mechanical and optical properties of ESCHeR, a high performances active vision head equipped with foveated wide-angle lenses. We also present a system which learns hand-eye coordination based on the above vision system and a neural net.

## Neural Learning of Embodied Interaction Dynamics

Yasuo KUNIYOSHI and Luc BERTHOUBE

*Neural Networks 11 (1998 Special Issue) 7-8  
1259-1276*

This paper presents our approach towards realizing a robot which can bootstrap itself towards higher complexity through embodied interaction dynamics with the environment including other agents. First, the elements of interaction dynamics are extracted from conceptual analysis of embodied interaction and its emergence, especially, of behavioral imitation. Then three case studies are made, presenting our neural architecture and the robotic experiments on some of the important elements discussed above: Self exploration and entrainment, emergent coordination, and categorizing self behavior. Finally we propose that integrating all these elements will be the important step towards realizing the bootstrapping agent envisaged above.

## Embedded Neural Networks: Exploiting Constraints

Christian SCHEIER<sup>1</sup>, Rolf PFEIFER<sup>1</sup> and

Yasuo KUNIYOSHI

<sup>1</sup>*University of Zurich*

*Neural Networks 11 (1998 Special Issue) 7-8  
1551-1569*

Using concepts and tools of embodied cognitive science, we investigate the implications of embedding neural networks in a physical structure, the body of a robot. Through this embedding the loop from a network's outputs to its subsequent inputs is closed. This closure enables an embedded network to actively generate its own input data instead of only passively processing predesigned input patterns. We argue that this simplifies some of the hard problems faced by disembodied neural networks. It can also help to deepen our understanding of biological neural networks, which are likewise embedded in a physical structure, the animals' body. The main arguments are illustrated with a series of case studies with simulated and physical mobile robots that are controlled by hand-designed as well as evolved neural networks.

## BIOSCIENCE

### Molecular Dynamics Simulation of the Hin-Recombinase -DNA Complex

Yuto KOMIJI and Masami UEBAYASHI<sup>1</sup>

<sup>1</sup>*NIBH*

*Molecular Simulation 21 (1999) 303-324*

Molecular dynamics simulation was performed for 1 ns for a peptide:DNA complex formed by Hin recombinase 52mer peptide and a 13 base-pair synthetic hixL half-site. The Ewald summation method was employed to treat the electrostatic interaction without the cutoff. Comparison with the results of the conventional cutoff method revealed that proper treatment of the electrostatic interaction was required to produce a stable trajectory. The trajectory thus obtained was used to analyze the interaction between the peptide and the DNA. Both N- and C-terminal regions reside within two regions of the minor groove. The N-terminus-DNA interaction was fairly

stable in the current simulation, but the C-terminus-DNA interaction was only marginally stable. These simulation results were consistent with reported experimental data that the N-terminal residues were required for the DNA recognition, while the C-terminal ones were supportive but not necessary.

### Combinatorial Receptor Codes for Odors

Bettina MALNIC<sup>1</sup>, Junzo HIRONO, Takaaki SATO  
and Linda BUCK<sup>1</sup>

<sup>1</sup>*Harvard Medical School*  
*Cell* **96** 5 (1999) 713-723

The discriminatory capacity of the mammalian olfactory system is such that thousands of volatile chemicals are perceived as having distinct odors. Here we used a combination of calcium imaging and single cell RT-PCR to identify odorant receptors (ORs) for odorants with related structures but varied odors. We found that one OR recognizes multiple odorants and that one odorant is recognized by multiple ORs, but that different odorants are recognized by different combinations of ORs. Thus the olfactory system uses a combinatorial receptor coding scheme to encode odor identities. Our studies also indicate that a slight alteration in an odorant, or a change in its concentration, can change its "code", potentially explaining how such changes can alter perceived odor quality.

### Functional Identification and Reconstitution of an Odorant Receptor in Single Olfactory Neurons

Kazushige TOUHARA<sup>1</sup>, Shintaro SENGOKU<sup>2</sup>,  
Koichiro INAKI<sup>1</sup>, Junzo HORONO, Takaaki SATO,  
Hitoshi SAKANO<sup>2</sup> and Tatsuya HAGA<sup>1</sup>

<sup>1</sup>*Dept. of Neurochem. Faculty of Medicine, Univ. of Tokyo*

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*Proc. Natl. Acad. Sci. USA* **96** **30** March (1999) 4040-4045

The olfactory system is remarkable in its capacity to discriminate a wide range of odorants through a series of

transduction events initiated in olfactory receptor neurons. Each olfactory receptor neuron is expected to express only a single odorant receptor gene that belongs to the G protein coupled receptor family. The ligand-receptor interaction, however, has not been clearly characterized. This study demonstrates the functional identification of olfactory receptor(s) for specific odorant(s) from single olfactory neurons by a combination of Ca<sup>2+</sup>-imaging and reverse transcription-coupled PCR analysis. First, a candidate odorant receptor was cloned from a single tissue-printed olfactory neuron that displayed odorant-induced Ca<sup>2+</sup> increase. Next, recombination adenovirus-mediated expression of the isolated receptor gene was established in the olfactory epithelium by using green fluorescent protein as a marker. The infected neurons elicited external Ca<sup>2+</sup> entry when exposed to the odorants that was originally to identify the receptor gene. Experiments performed to determine ligand specificity revealed that the odorant receptor recognized specific structural motifs within odorant molecules. The odorant receptor-mediated signal transduction appears to be reconstituted by this two-step approach: the receptor screening for given odorant(s) from single neurons and the functional expression of the receptor via recombinant adenovirus. The present approach should enable us to examine not only ligand specificity of an odorant receptor but also receptor specificity and diversity for a particular odorant of interest.

### OPTICS AND RADIATION

#### X-Ray Microfocusing by Ti/Al Multilayer Zone Plate and Bragg-Fresnel Lens

Masaki KOIKE, Isao H. SUZUKI and  
Satoshi KOMIYA<sup>1</sup>

<sup>1</sup>*Fujitsu Laboratories Ltd.*

*Proceedings of SPIE* **3449** (1999) 129-132

A one-dimensional Bragg-Fresnel lens for monochromatizing and focusing hard X-rays has been developed using a multilayer zone plate and a crystal. Ti and Al have been chosen as material for phase modulation type zone plate. About 400 layers of Ti and Al were alternately deposited on a plane substrate according to the Fresnel's formula using a helicon plasma sputtering

technique, in which Ar gas pressure was less than 1 mTorr. The total thickness of the layers is about 128  $\mu\text{m}$ . The multilayered plane was sliced vertically and glued onto Ge(211) crystal, and thinned to about 10  $\mu\text{m}$ . The synchrotron light source was focused one dimensionally, and the focal line width was measured by a knife edge scan technique.

### Characteristics of the NIJI-IV FEL at the Electron-Beam Energy of 263 MeV

Norihiro SEI, Tetsuo YAMAZAKI,

Kawakatsu YAMADA, Suguru SUGIYAMA,

Tomohisa MIKADO and Hideaki OHGAKI

*Nuclear Instruments and Methods in Physics Research*

**A407** (1998) 187-192

Electron-beam qualities and characteristics of the FEL oscillation with the NIJI-IV FEL system were investigated at the low electron-beam energy of 263 MeV. The peak electron density at 263 MeV was suppressed due to instabilities in high electron-beam current, but it was about 40% higher than that at the normal electron-beam energy of 310 MeV below 4 mA. The maximum gain estimated from the measurements of the electron-beam qualities was about 1.5% at 4 mA. The measurement of the detuning curve suggests that the practical gain was about 0.8 times as low as the estimated value. Moreover, variation of the average FEL power versus the electron-beam current and the transverse profile was observed with a CCD camera system. The typical average power of the FEL was about 53  $\mu\text{W}$  at 3.2 mA and we were able to observe up to the TEM<sub>03</sub> mode.

### Free-Volume Hole Model for Positronium Formation in Polymers: Surface Studies

H. CAO<sup>1</sup>, R. ZHANG<sup>1</sup>, J-P YUAN<sup>1</sup>, C-M HUANG<sup>1</sup>,  
Y.C. JEAN<sup>1</sup>, Ryoichi SUZUKI, Toshiyuki OHDAIRA  
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*J. Phys. Condens. Matter* **10** (1998) 10429-10422

Positron annihilation lifetime and Doppler broadening

of annihilation radiation experiments are performed in a polyurethane film using the mono-energetic slow positron probe as a function of positron energies. Significant variations of positron annihilation signals are observed at a short distance from the surface (<100 nm). The ortho-positronium lifetime in the polymer increases near the surface, while its intensity decreases. The intensity results are consistent with the description of a free-volume hole model for positronium formation proposed by Brandt, Berko and Wilker.

### Free Electron Laser Oscillation down to the Deep UV Range Using a Small-Scale Storage Ring

Kawakatsu YAMADA, Norihiro SEI,

Tetsuo YAMAZAKI<sup>1</sup>, Hideaki OHGAKI,

Tomohisa MIKADO, Suguru SUGIYAMA,

Masayuki KAWAI<sup>2</sup> and Minoru YOKOYAMA<sup>2</sup>

<sup>1</sup>*Kyoto University*

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*Jpn. J. Appl. Phys.* **37** Part 2 10A (1998) L1151-L1153

Free electron laser (FEL) based on the small-scale storage-ring NIJI-IV at the Electrotechnical laboratory (ETL) was operated at wavelengths down to the deep ultraviolet (UV) range. The laser oscillation was obtained at both regions from 315 to 287 nm and from 253 to 228 nm using low-loss dielectric multilayer mirrors optimized at 300 and 240 nm, respectively, for the laser cavity. The wavelength of 228 nm is shorter than the former record for FELs by more than 10 nm. Suppression of the beam instability led to a drastic enhancement of the laser gain which enabled us to achieve the FEL oscillation at such short wavelengths even in a small-scale storage ring.

### Observation of Higher Harmonics in the NIJI-IV FEL

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Characteristics of higher harmonics from the optical klystron have been investigated to study the feasibility of the coherent harmonic generation (CHG) as a useful method to shorten the FEL wavelength down to the vacuum ultraviolet (VUV) in a small-scale storage ring like the NIJI-IV. Obvious modulation was observed on the 3rd harmonic line at 117 nm with a VUV monochromator. The 5th and 7th harmonics with reasonable intensity were also observed by using a real-time spectrum measurement system. These facts suggest that coherent photons are obtainable at the VUV wavelength down to ~50 nm through the CHG process by introducing a high power external laser or utilizing the intense intra-cavity optical field in the visible FEL as a source for electron bunching in the optical klystron.

### **Development of the Deep UV and VUV FELs on the Compact Storage Ring NIJI-IV**

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Processing with Advanced Energy Sources (ECOMAP-  
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Characteristics of free electron lasers (FELs) were investigated at the wavelengths down to the deep ultraviolet (UV) range on the compact storage ring NIJI-IV at the Electrotechnical Laboratory (ETL), aiming at further wavelength shortening to the vacuum ultraviolet (VUV) region. Recent improvement of the optical cavity as well as a successful enhancement of the FEL gain enabled us to achieve lasing in the deep UV around 212 nm. Coherent harmonic generation (CHG) was also tried as a promising method to reach the wavelength much shorter than 150 nm.

## **MEASUREMENT AND STANDARD**

### **Measurement of Outgassing Characteristics from a Vacuum Chamber Fabricated for Pressure Calibration in UHV/XHV Region**

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*Vacuum* **53** (1999) 291-294

The construction of a new vacuum system fabricated for pressure calibration in UHV/XHV region is explained together with the measurement of outgassing rate from an XHV chamber used in the system. The outgassing rate was measured using a test chamber by a throughput method after each treatment of the chamber surface such as electrolytic polishing, pre-baking in vacuum, and TiN coating. It was found that the outgassing rate of  $3.7 \times 10^{-9}$  Pams-1 after electrolytical polishing could be reduced to  $1.0 \times 10^{-13}$  Pams-1 after pre-baking twice followed by TiN coating. The outgassing rate was also measured by the pressure rise method using the whole XHV chamber, and the result was compared with that obtained with the test chamber.

## **ENERGY TECHNOLOGY**

### **An Estimation of Environmental Impacts of the Trade of Industrial Products: A Case of Japan**

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*Intl.J. of Global Energy Issues* **11** 1-4 (1998) 139-145

In this paper, some impacts of trade on regional energy demand, air pollutants emissions, and carbon dioxide emission are estimated in the case of the trade of industrial products between Asia and Japan in 1985. Quantity avoided by the import of industrial products and quantity induced owing to the export of the same products are evaluated with respect to regional demand for primary energy and the emissions of air pollutants and carbon dioxide, and they are compared across regions. This paper

also discusses the implication of the result for the global environment and regional environment strategy preliminarily.

### **Development of the Oxygenated Thermionic Energy Converters Utilizing the Sputtered Metal Oxides as a Collector**

Ryuzo FUKUDA, Ken KATO, Sadaaki Shimizu and Yasuhiro KASUGA

*AIP Conference Proceedings 458 Proc. Space Technology & International Forum 1999 1444*

Refractory metal oxides such as  $\text{NbO}_x$ ,  $\text{WO}_x$ ,  $\text{MoO}_x$ ,  $\text{TaO}_x$ ,  $\text{PtO}_x$  and Silver oxide ( $\text{AgO}_x$ ) have been studied for an oxygenated thermionic converter and a low work function collector. The metal oxide materials were deposited on metal substrates by RF sputtering in the  $\text{Ar}/\text{O}_2$  gas mixture to fabricate collector electrodes. Work function values of the collector electrodes were evaluated by cesium plasma immersion technique. Very low work function values were obtained, for instance 1.25V as  $\phi_c$  of  $\text{AgO}_x$ . A research thermionic energy converter with a plane parallel type of a polycrystalline W emitter and the metal oxide collectors ( $\text{AgO}_x$ ,  $\text{NbO}_x$  and  $\text{PtO}_x$ ), was set up and the power generation experiments were conducted. In the case of the W- $\text{AgO}_x$  thermionic converter, the barrier index VB was 2.05V. The oxygen supply ability of the  $\text{AgO}_x$ ,  $\text{NbO}_x$ ,  $\text{PtO}_x$  collectors were evaluated by the bare work function values  $\phi_c$  of the W emitter, for instance,  $\phi_c=5.4\text{V}$  for the W- $\text{PtO}_x$  converter.

#### **SPACE AND OCEAN TECHNOLOGY**

### **Observation of Vapor Bubble of Non-Azeotropic Binary Mixture in Microgravity with a Two-Wavelength Interferometer**

Yoshiyuki ABE and Akira IWASAKI

*Proceedings of 5th ASME/JSME Joint Thermal Engineering Conference (1999)*

The present study attempts at understanding fundamental heat and mass transfer mechanisms in nucleate pool boiling of non-azeotropic binary mixtures,

and with the knowledge to develop a passive boiling heat transfer enhancement eventually. To this end, the authors have employed microgravity environment for rather detailed observation around vapor bubbles in the course of boiling inception and bubble growth. A two-wavelength Mach-Zehnder interferometer has been developed, which withstands mechanical shock caused by gravity change from very low gravity of the order of 10<sup>-5</sup> g to relatively high gravity of approximately 8 g exposed during deceleration period. A series of experiments on single vapor bubbles for CFC113 single component and CFC12/CFC112 non-azeotropic binary mixture have been conducted under a high quality microgravity conditions available in 10-second free-fall facility of Japan Microgravity Center (JAMIC). The results for single component liquid showed a strong influence due to Marangoni effect caused by the temperature profile around the bubble. The results for non-azeotropic binary mixture showed, however, considerably different behavior from single component liquid. Both temperature and concentration profiles around a single vapor bubble were evaluated from the interferograms. The temperature and concentration layers established around the bubbles were nearly one order of magnitude larger than those predicted by thermal diffusion and mass diffusion. The temperature and concentration profiles evaluated from the present experiments suggest the role of Marangoni effects due to both concentration profile and temperature profile around the bubble interface.

### **Design and Testing of an Underwater Microscopy for the Study of Zooplankton Distribution**

Tatsuro AKIBA and Yoshimi KAKUI

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A method that can monitor zooplankton density at adequate spatio/temporal resolution is desired in the field of oceanic ecosystem studies.

We have developed a submersible microscopes equipped with a non-interlace CCD camera. As target plankton, plover, cladocera, calanoida, cyclopoida, ciliata are selected those are dominant species in coastal sea in Japan. Requirements of an system for an underwater imaging of

zooplankton are discussed. Selections of lens, camera and illumination are key issues, as they may influence on performance of the system.

Second order auto-correlational masks are used to extract features from images. The combination of local auto-correlational masks and multivariate analysis, which is a two-step feature extraction, is a powerful tool as a general information extracting method from images. In our procedures, a set of these masks is 33 dimensional vector. To identify and count zooplankton, canonical correlation analysis is performed. Therefore, we can count and classify zooplankton into its taxonomic unit. Through another multiple regression, sizing of plankton can also be performed. Proof of principle experiment was also performed with images of living copepoda.

taxonomic unit. Through a multiple regression, sizing of plankton can also be performed. As far as we tested, accuracies of identifications were more than 90% when discrimination analysis was performed between any two taxa of preserved plankton.

### **On Development of a Submersible Microscopes and Image Processing System**

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Yoshimi KAKUI

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We have developed a submersible microscopes equipped with a non-interlace CCD cameras. As target plankton to be counted automatically, pteropoda, cladocera, calanoida, cyclopoida, ciliata are selected those are dominant species in coastal sea in Japan. The range of size of target plankton is a few ten microns to several mm. Requirements of an submersible microscope for an imaging of zooplankton are discussed. Selections of lens, camera and illumination are key issues, as they may influence on performance of the system. As a light source, xenon flash lamp is employed. Three objective lens with different magnification (as x0.83, x3.3, x13.3) are used to take images of plankton. Acquired image is processed with a image processing system that extract 33 dimensional second order auto-correlational features from each image. To identify and count zooplankton, multivariate analysis is performed on a personal computer. Transformed features have properties similar to a vector. The direction of a vector represents a species, and the length of it matches the number of the species. When more than two plankton is observed in one image, transformed features are the linear combination of vectors of each plankton. Therefore, we can count and classify zooplankton into its