

Nanometer-scale Science and Technology

Room: 4C - Session NS-ThP

Nanometer-Scale Science & Technology Poster Session II

NS-ThP1 Aligned Growth of Carbon Nanotube using Protein Supramolecule. *S. Kumagai*, ATRL, Matsushita Electric Industrial Co., Ltd., Japan, *T. Ono*, Tohoku University, Japan, *R. Tsukamoto*, CREST, Japan Science and Technology Agency, Japan, *S. Yoshii*, *I. Yamashita*, ATRL, Matsushita Electric Industrial Co., Ltd., Japan

Carbon nanotubes (CNTs) have remarkable electrical, mechanical and chemical properties and are expected for broad applications in nanoelectronics. For practical applications, it is desirable to be able to synthesize a CNT in a particular location. In this study, we present novel catalytic nanoparticle (NP) positioning technique for CNT growth, which is one application of the Bio Nano Process (BNP)¹. We used cage-shaped protein, apoferritin ($\phi 12\text{nm}$) to synthesize homogenous catalytic $\phi 7\text{nm}$ Co NPs within the cavity and the negatively charged outer surface of the apoferritin was used for electrostatic placement of the inner Co NP on Si substrate. We modified Si substrate with positively charged aminosilane molecule (3-aminopropyltriethoxysilane: APTES) and made electrostatic interaction between the ferritin and a surface-modified Si substrate place the ferritins with Co core on a Si substrate. Under appropriate ionic strength around neutral pH, negatively charged ferritins were adsorbed selectively on positively charged APTES-modified area that was fabricated on negatively charged SiO₂ surface. This electrostatic adsorption method successfully worked to place the ferritins on the APTES patterns. Heat treatment under O₂ gas removed outer protein shells selectively and left only Co NPs on the substrate. The substrate with NPs placed at the designed positions was set in a DC plasma chamber and heated. Firstly, the substrate was treated by H₂ plasma to reduce the NPs. After the treatment, CNT growth was conducted under C₂H₂/H₂ plasma. The SEM observation revealed that CNTs grew not on the Si substrate surface but on the NP patterned area. This indicated that the patterned Co NPs, which were synthesized through the BNP, worked as catalyst and determined CNT growth position. Here, we demonstrated novel technique for the CNT growth at the designed positions. We also have succeeded in the single NP placement by analyzing the electrostatic interaction precisely. Individual CNT growth from arranged single NPs will be realized for nanoelectronic devices such as field emission and vertical FET. Part of the experiment was done in Micro/Nanomachining Research and Education Center, Tohoku University. This study is partially supported by Leading Project of MEXT, Japan.

¹I. Yamashita, "Bio Nano Process: Fabrication of Nanoelectronic Devices Using Protein Supramolecules" Tech. Dig. 2006 International Electron Devices Meeting p.447.

NS-ThP2 Fabrication of TiN Nanopillar Field Emitters Templated by Porous Anodic Aluminum Oxide. *T.-M. Chen*, *J.-Y. Hung*, *F.-M. Pan*, *L. Chang*, National Chiao-Tung University, Taiwan, *S.-C. Wu*, National Nano Device Laboratories, Taiwan

Anodic aluminum oxide (AAO) has been widely used as a template for fabrication of nanostructured materials. In this study, we fabricated highly ordered TiN nanopillars on the Si substrate as electron field emitters using the AAO as the template. The nanopillars showed satisfactory field emission properties because of the high aspect ratio of the nanostructure and a low work function of TiN. To prepare the AAO template, an Al film 2 μm thick was first thermally evaporated on a sputter-deposited TiN layer of 500 nm in thickness. The Al film was anodically oxidized in an oxalic acid electrolyte at room temperature, and the as-prepared AAO pore channels had a pore diameter about 60 nm. During the preparation of the AAO pore channels, the underlying TiN layer was anodically oxidized as well in the late stage of the AAO anodization, forming titanium oxide nanodots. The TiOx nanodots were then used as the hardmask for dry-etching the underlying TiN layer, thereby transferring the AAO hexagonal arrangement pattern to the TiN layer leading to the formation of the well-ordered TiN nanopillar array. The nanopillars were ~ 200 nm in height and ~ 50 nm in diameter. The TiN nanopillar field emitter had a turn-on voltage of $< 5\text{V}/\mu\text{m}$, which was defined as the voltage at which the field-emission began to exhibit linear Fowler-Nordheim field emission characteristics.

NS-ThP3 Growth and Characterization of Carbon Nanotubes on Biaxially Textured Ni Alloy Metallic Substrates without Additional Catalysts. *C. Varanasi*, University of Dayton Research Institute, *J. Bulmer*, *M. Mullins*, AFRL/PRPG, WPAFB, *J. Burke*, University of Dayton Research Institute, *J. Baca*, AFRL/PRPG, WPAFB, *L. Brunke*, University of Dayton Research Institute, *K. Yost*, *P. Barnes*, AFRL/PRPG, WPAFB

One of the common methods used to grow aligned CNTs on various substrates is chemical vapor deposition (CVD) using C₂H₂ or CH₄ as precursors. In this process, the substrates are processed prior to CVD such that metallic nanoparticles such as Fe, Ni etc. are formed on the surfaces to act as catalysts during the CVD process. However, the adhesion of CNTs to the substrates has been a problem in this approach as the nanoparticles are not integrated in to the substrate. In this study, biaxially textured Ni based alloy substrates were investigated as an alternate choice of substrates where the catalyst forms an integral part of the substrate to reduce the problem of adhesion of CNTs to the substrate. A biaxially textured Ni based substrate offers a surface with a well oriented grain structure (offering uniform growth) and the defects, grain boundaries, and the precipitates of the alloying additions etc., in the materials provide the necessary nucleation sites for the CNT growth. In the present work, several biaxially textured Ni alloy based metallic substrates were investigated to grow CNTs without giving any prior catalyst treatment to the substrates. A very high density of the CNT growth was observed on these substrates when suitable conditions were used using a CVD process with C₂H₂ as a carbon source. In the present talk, the experimental details to prepare the textured metallic substrates and CVD growth conditions used to grow the CNTs will be discussed. In addition, the characterization of textured substrates and CNTs grown on these substrates by using various characterization tools such as orientation image microscopy, Raman spectroscopy, TEM, and SEM will be presented.

NS-ThP4 Synthesis and Characterization of LaPO₄:Eu Nanotubes Prepared by the Sol-Gel Template Method. *M.J. Fisher*, *W. Wang*, *P.K. Dorhout*, *E.R. Fisher*, Colorado State University

Flat electroluminescent, plasma, and field emission devices demand materials with better stability, brightness, and industrial processing ability. Lanthanide ions (e.g. Eu⁺³) have sharp and intense emission lines, and exhibit high luminescence yields. Synthesis technique, particle size and heating process strongly affect the physico-chemical properties of lanthanide ion containing oxide materials. We have synthesized pure phase LaPO₄:Eu bulk-powders and nanoparticles via the sol-gel template method, which has a high industrial processing ability for pure-phase submicron scale materials. Materials were dried at 70 °C, and sintered at 650 °C. Powder X-ray diffraction indicates that at 70 °C the bulk powder is a mix of hexagonal and monazite phases, whereas at 650 °C the bulk-powder is a pure monazite phase. SEM showed the morphology of the nanoparticles is tubular. Luminescence spectra of both the bulk-powder and the nanotubes contain the typical Eu⁺³ peaks.¹ As the nanotubes diameter decreases from 200 nm to 20 nm, the luminescence spectrum developed a broad background. The temperature and particle size are major factors in the observed phase and luminescence properties of the materials synthesized. Site-selected excitation, energy dispersive spectroscopy, and x-ray photoelectron spectroscopy results will also be discussed.

¹ J. Dexpert-Ghys, R. Maurioct, and M. D. Fauxher, Journal of Luminescence 69, 203 (1996).

NS-ThP5 Carbon Nanotubes Synthesized from Electrospun Nanofiber. *J.-Y. Hong*, *M.-H. Lee*, *W.C. Choi*, *C.-Y. Park*, Sungkyunkwan University, Korea

One-dimensional carbide materials can be synthesized using multiwalled carbon nanotubes as templates by reaction with volatile oxide and/or halide species. Nanofibers may also be used as templates to produce carbon nanotubes with catalyst by temperature reactions. Electrospinning has received steadily increasing interest due to its ability to produce nanometer-sized fibers with a high level of reinforcement. Here we introduce carbon nanotubes (CNTs) synthesized using electrospun polyacrylonitrile (PAN) nanofibers. PAN and Fe composites as a catalyst were added to dimethylformamide (DMF) and the solution was stirred magnetically until PAN was fully dissolved. The spinning dope was transferred to a glass pipette mounted vertically in the electrospinning station. A voltage of 20kV was applied to the solution to start the spinning process. And the electrospun fibers were collected in a random mat. The PAN nanofibers were stabilized for 30min at 200°C and carbonized for 1h at 700°C. Then, the nanofibers were further heated to 900°C in acetylene as the carbon source. As the results of Raman spectroscopy and HR-TEM measurements, carbon nanotubes were synthesized, at the same time, it was confirmed that the size of CNTs varies directly as that of the electrospun nanofibers. From

these results, we suggest that the size of CNTs may be controlled by the PAN concentration in the electrospun nanofibers.

NS-ThP6 Field Emission Properties of Noble-Metal Coated Carbon Nanotube-Emitters, S.Y. Lee, D.H. Ryu, J.H. Yang, W.C. Choi, C.-Y. Park, Sungkwan University, South Korea

Because of their unique geometrical structure and high aspect ratio, many researchers have studied the potential applications of carbon nanotubes (CNTs) in field emission display and high current electron source that requires low turn on voltage, high current density and emission stability. To enhance the field emission properties of CNTs, the intertube distance, densities, alignments and work function are very important factors, so which have been extensively studied in recent years.¹⁻⁴ However, as yet, the sensible solution have not been obtained. In this study, we report the field emission properties of CNT-emitters coated with noble metals (Au, Ag, etc.) and their alloy (Ag-Cu). The vertical aligned multi wall CNTs and the sequential noble metal coating are synthesized by DC-plasma chemical vapor deposition in ambient of the mixed gas (C₂H₂ and NH₃) and DC-magnetron sputtering, respectively. The results of the field emission measurements show that the field emission properties of noble metal coated CNTs have remarkably improved in the emission current density and the turn on electric field. We can find one of the reason for the enhancement in the field emission properties from SEM images obtained from the samples before and after noble metal coating. The density of emitter can be controlled by the suitable coating conditions. Also, we can enhanced the contact resistance and the emission stability under coarse condition. We suggest that the enhanced filed emission performance of the noble metal coated CNTs emitters are attributed by the reducing the emitting sites and low work function, and low contact resistance. The details will be introduced.

¹Advanced Materials 14 (20), 1464-1468 (2002)

²Applied Physics Letters 90, 013120 (2007)

³Chemical Physics Letters 434, 92-95 (2007)

⁴Applied Physics Letters 80 (13), 2392 (2002).

NS-ThP7 Synthesis and Control of Carbon Nanotubes using Diffusion Mechanism of Fe Catalyst, W. Song, C. Jeon, Y.S. Shin, W.C. Choi, C.-Y. Park, Sungkyunkwan University, Republic of Korea

Since electrical properties of single-walled carbon nanotubes (SWCNTs) are primarily determined by its diameter and chirality, control of diameter is the crucial issue for application of CNTs-based electronic device. Thus, the preparation of catalyst with small and uniform size is essential factor to grow the SWCNTs with narrow diameter distribution. In this work, we investigate the growth of SWCNTs with narrow diameter distribution using a sandwich-like structures (Al/Fe/Al) deposited on Si substrate by DC magnetron sputter. The Fe catalyst layer is 1nm and the Al top-layer has various thickness from 1 nm to 10 nm. All samples are pre-annealed at 800°C by furnace in Ar ambient. Then, CNTs are grown by thermal chemical vapor deposition with C₂H₂, H₂ at 850°C for 10 min. A sort of CNTs are determined using Raman spectroscopy, and after pre-annealing, the variety of catalyst size with the thickness of top-Al layer is checked by X-ray photoelectron spectroscopy, transmission electron microscopy and magnetic force microscopy. It shows that the density and the kind of CNTs are depend on the thickness of Al top-layer and pre-annealing conditions. From these results, we can consider the following: (1) The catalyst is out-diffused through the Al top-layer by pre-annealing process, and the exposed catalyst size will be controlled by the thickness of Al top-layer and the pre-annealing conditions. Thus, we can be control a sort of CNTs. (2) This technique can be used for the device application that employ SWCNTs.

NS-ThP8 Phosphorylation of Multiwalled Carbon Nanotubes, T.M. Ndzimandze, X.Y. Mbianda, M. Johnson, University of Johannesburg, South Africa

Carbon nanotubes are among the most exciting new materials being investigated and synthesized, owing to their outstanding mechanical, electronic and optical properties.^{1,2} For more than a decade, the translation of these properties into realistic applications has been hindered by solubility and processing difficulties.³ Recently the development of efficient methodologies for covalent chemical modifications has raised hope for the use of these materials in various fields of application such as biosensors, vaccine and drug delivery systems, medical imaging, biomaterials, water purification⁴ etc. As part of an ongoing project on the application of carbon nanotubes, we which to report here the incorporation of phosphorus moieties on the end and side walls of the multiwalled carbon nanotubes obtained through NaClO oxidation followed by condensation reactions with alkyl or aryl chlorophosphates. Characterization of the phosphorylated multiwalled carbon nanotubes has been done by transmission electron microscopy (TEM), scanning electron microscopy (SEM), energy dispersive X-ray (EDX), thermal gravimetric analysis (TGA) and Raman spectroscopy. It is anticipated that these new compounds could provide

interesting biological activity in biological systems, and properties that might allow their incorporation into both organic and inorganic polymer matrices.

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² R. Saito, G. Dresselhaus and M.S. Dresselhaus. Physical properties of carbon nanotubes, Imperial College Press; London, 1998

³ Gabriel G. Sauthier, Fraxedas J, Moreno-Manas M, Martinez M. T, Miravittles and Casabo J. Carbon 44 (2006) 1891-1897.

⁴ Son S. J., Reichel J, He B, Schuchman M and Lee S. B. J. Am. Chem. Soc. 127 (2005) 7316-7317.

NS-ThP9 Ring-shaped Emission Patterns from Carbon Nanotube Films, M. Zumer, V. Nemanic, B. Zajec, "Jozef Stefan" Institute, Slovenia, E. Bryan, R.J. Nemanich, North Carolina State University

Field emission patterns in the shape of perfect rings were observed on the luminescent screen of a specially designed triode cell with parallel electrodes. This cell is designed for investigation of 25.5 mm diameter flat samples. During the routine I-U measurements of broad-area flat cathodes, consisting of silicon or molybdenum substrates coated with carbon nanotubes (CNTs), rings appeared sporadically as relatively stable images among other field emission patterns like lobes and daisies. Their projected size was a few mm and was thus big enough to allow providing the analysis of their details. The origin of the electrons projected onto the screen is presumably a uniformly emitting cap atop of a long single wall CNT. This is consistent with models which predict high enhancement of the electric field and a ring-shaped pattern mainly as a result of imaging on a flat screen. The macroscopic value of the electric field at which rings were recorded was between 0.7 and 2.5 V/μm. The picture brightness analysis allows estimating the current corresponding to a particular ring and its brightness profile. The current of an individual ring was in the order of 2 - 4 μA. An outstanding finding of this study is a much greater angular width of the emitted beam for most of the rings compared to those that had been observed or predicted by reported calculations. The true mechanism that causes the difference between the model and our experiment is probably related to the atomic scale phenomena not included in their calculations.

NS-ThP10 Growth of Conducting Polypyrrole on Nanometer-Scaled Holes Array by Nanosphere Lithography, K.S. Kim, H.K. Moon, B.K. Lee, N.H. Kim, Y.H. Roh, Sungkyunkwan University, Republic of Korea

Conducting polymers are attractive materials that could be used at all levels of microelectronics as alternatives for metal and semiconductors. Particularly, polypyrrole is one of the most promising conducting polymers because of its ease of synthesis, environmental stability and higher sensitivity. Additionally, through combination with nano-fabrication, this conducting polymer will provide a valuable method of large-area, easy fabrication of nanometer-scaled conducting polymer patterns that would be useful in polymer-based electronics. In this work, we have used nanosphere lithography technique using polystyrene beads and oxygen plasma ashing technique. Using nanosphere lithography, oxygen plasma ashing and chemical vapor deposition, we could fabricate the nanometer-scaled holes (< 50 nm) array on the gold coated silicon substrate. The fabricated nanometer-scaled holes are well-ordered and have high density. The polypyrrole was successfully grown on the nanometer-scaled holes by electrochemical polymerization. We confirmed that the polypyrrole was grown toward the vertical direction of the substrate by AFM and SEM. The C-V measuring of obtained polypyrrole arrays was performed. The obtained electrical and geometrical properties of polypyrrole were superior to use electrical sensors. These results will also open the possibilities to fabricate the unique tools for the highly aligned emitters, diode and vertical-type field effect transistors.

NS-ThP11 Creating a Nano-Scale Porous Network of Porphyrin Molecules, C. Urban, M. Trelka, D. Ecija, Universidad Autonoma de Madrid, Spain, P. de Mendoza, Instituto Catalan de Investigaciones Quimicas (ICIQ), Spain, J.M. Gallego, Instituto de Ciencia de Materiales de Madrid (ICMM-CSIC), Spain, R. Otero, Universidad Autonoma de Madrid, Spain, A. Echavarren, ICIQ, Spain, R. Miranda, Universidad Autonoma de Madrid, Spain

Molecular self-assembly is a very promising alternative for designing and fabricating new nano-scale materials in the so-called "bottom-up" approach. In addition, the possibility of creating patterns of molecular networks with predefined, well-controlled geometries that could be used as a sort of nanoporous molecular material is opening new ways to fields as different as catalysis, electronics, or information storage. In particular, porphyrin molecules are of special interest due to the main role they play in a wide variety of biological, and chemical processes, and also photovoltaic devices. In this work we report on the self-assembly of meso-tetrakis (2,4,6-trimethyl) phenyl porphyrin (TMSP) when vapour-deposited in UHV conditions on Cu(100). For low coverages, the porphyrins can be found isolated or forming small clusters on the surface. Intramolecular resolution allows to determine their conformation and orientation, which come dictated by the

substrate, the porphyrin main axis being parallel to the Cu[110] directions. Upon increasing the coverage, the TMsP molecules self-assemble to form a square lattice. Interestingly, our calculation reveal that the intermolecular distance and relative orientation are almost independent of the substrate, indicating that the assembly process comes mainly dictated by the intermolecular forces. An open, nano-porous, square network of TMsP can also be fabricated by depositing the molecules on Cu(100) $c(2 \times 2) / N$. This surface, formed after adsorbing < 0.5 ML of N on Cu(100) and annealing to 600 K, is composed of square N islands, ~ 5 nm wide, separated by thin Cu lines, and has been used as a template to create arrays of metallic nanostructures. When the TMsP molecules are deposited on this surface, they nucleate almost exclusively on the Cu lines, leaving empty the N islands. In this way, by carefully controlling the width of the Cu lines and the molecule coverage, a film with 5 nm wide square pores of variable density that could be use as template for the growth of other nanoparticles can be created.

NS-ThP12 Effective Model for InGaAs/GaAs Quantum Dot with Material Mixing. *I. Filikhin, M.H. Wu, V.M. Suslov, B. Vlahovic*, North Carolina Central University

We model an InGaAs/GaAs quantum dot (QD), including the height dependence of the Ga content of the QD. The effect of material mixing on the electron energy spectra is considered, using the experimentally measured height dependence of the Ga fraction from Ref.¹ Our theoretical model is based on a single sub-band approach with an energy dependent effective electron mass. We apply an approach in which the combined effect of strains, piezoelectricity and interband interactions are simulated by an effective potential². It is shown that these effects may be taken into account in an effective manner using this approach. Based on our model, we perform an analysis of the results obtained by direct treatment of strain effects in Refs.³ ("ab initio" calculations). To prove the adequacy of our model, we compare the results obtained for energy spectra of few electrons tunnelling into InAs/GaAs QDs, with experimental capacitance-gate-voltage data⁴. We find that the effective method is valid for the case of material mixing in the InGaAs/GaAs quantum dot. In the case of a linear height dependence of the Ga fraction, the strength of the effective potential must be chosen to correspond with the averaged value for the Ga distribution function. Effects of the QD cross section and the Ga fraction distribution are studied. We also compare our results with those obtained from pseudopotential calculations⁵.

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NS-ThP13 Guide for Optical Observation of Quantum Confinement or Quantum Size Effects at Room Temperature. *A.C. Diebold*, University at Albany, *J. Price*, SEMATECH

Although quantum confinement effect and quantum size effects are often considered low temperature phenomena, quantum confinement has been observed by ellipsometry at room temperature. This presentation will review examples of the observation of nanoscale effects at both low and room temperature. For example, the shift in the E1 critical point of thin silicon on insulator films has been shown to be due to quantum confinement and to roughly follow a $1/L^2$ trend.¹ XPS has also observed quantum size effects for multi-monolayer Al on Si(111).² Often, effect are seen despite the shift being less than the thermal energy, KT. Despite this, attempts to observe theoretically predicted resonances in the IR region of thin, polycrystalline TiN films failed. Based on this information we will propose some guides for when these effects can be observed at room temperature.

¹ J. Price and A.C. Diebold, J. Vac. Sci. Technol. B24, (2006), pp2156 - 2159.

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NS-ThP14 Observation of Si/Co/Cu/Co Surface and Interface Processes for Nanostructure Formation by Scanning High Electron Energy Diffraction. *H. Shirinzadeh*, Materials and Energy Research Center, Iran

We observe the oxidation process on clean Si surfaces using high-resolution scanning reflection electron diffraction and form nanostructures on them, through focused electron-beam (EB) induced surface reactions. Si thermal oxidation occurs layer by layer, and the interface between the oxide film (< 1.5 nm thickness) and Si substrate becomes atomically abrupt. When the sample is heated to 700-800 °C, resulting in the exposure of a clean Si substrate. The typical width of the clean Si 'open windows' is about 10 nm. Using selective reactions during heating after the deposition of Si and Co

films on the patterned samples, Si and Co nanoislands with 25 nm size are formed on Si surfaces.

Magnetic of surface and ultrathin film.

NS-ThP15 Cerium Oxide Nanoparticles: Distinguishing Influences of Size from Chemical or Environmental Effects. *S.V.N.T. Kuchibhatla, A.S. Karakoti, S. Seal*, University of Central Florida, *M.H. Engelhard, D.R. Baer, S. Thevuthasan*, Pacific Northwest National Laboratory

Quantum confinement is a frequently observed and potentially useful property of nano-sized particles. An increase in band gap with the decrease in particle size is the phenomena of quantum confinement, typically valid when the particle size is approximately the exciton radius. However, because small particles are highly dependent on their surface, sample history and the local environments may also alter their properties and produce effects that may be interpreted as quantum confinement. We show that cerium oxide (Cerium, CeO₂) is impacted by such effects. Nanoceria is a potential material for a spectrum of applications including solid oxide fuel cells, catalysis, oxygen sensors, biomedical use, and chemical mechanical planarization. The major characteristic of ceria crucial for these applications is its oxygen storage capability (OSC). The OSC is rendered to ceria by the ability to effectively switch between the 3+ and 4+ oxidation states based on ambient conditions. In the nanoscale regime, there are a number of reports that analyzed the ceria particles synthesized under different conditions. Many authors have computed the band gap and particle size by comparing the experimental UV Vis absorbance data to the effective mass approximation (EMA) theory. While some of the researchers have hypothesized that counter acting phenomena like dielectric confinement will nullify the confinement effects in ceria, others have strongly supported the quantum confinement effect. We attribute the reason for such a discrepancy in the open literature to the differences in synthesis and characterization environments along with the agglomeration of nanoparticles. We have synthesized ceria nanoparticles in different aqueous media (DI water, poly (ethylene glycol), dextran, and glucose). The optical absorbance spectra were collected as a function of time. A careful analysis of these data has clearly indicated that the ceria nanoparticles change their oxidation state in solution with time and the rate is dependent on environment. This change in chemistry denies the possibility to use the EMA theory for the particle size interpretation from the absorbance data and also raises questions about reported band gap values. Transmission electron microscopy and X-ray photo electron spectroscopy have been used to compliment the results from UV Vis analysis.

NS-ThP16 Nanofabrication of Deep Sub-wavelength Plasmonic Waveguides for Characterization. *M. Lu, L.E. Ocola, S. Gray, G. Wiederrecht*, Argonne National Laboratory

Conceptual plasmonic devices show promising potential in transmitting and processing light at deep sub-wavelength scale.¹ The design and fabrication of a 100-nm-wide hybrid light-bending waveguide structure is discussed. Numerical modelling using finite-difference time-domain (FDTD) algorithm shows the device has an efficient confinement that is capable of transmitting light around 90 degree corners with minimal loss ($< 10\%$). The waveguide core is made by electron beam lithography and reactive ion etching with a bilayer resist. Sharp inner corners, which is important for low loss light bending, are achieved by an effective proximity correction (PEC) during e-beam lithography. The 800-nm-thick metal cladding is then formed by a selective electroplating. The wave guide is designed for near-field scanning optical microscope (NSOM) characterization, by leaving open the top of the waveguide. Achievement of this waveguide will enable submicron optical devices without the need of photonic crystals.

¹T-W. Lee and S. K. Gray, Optics Express, 13, 9652-9659 (2005).

NS-ThP17 Light Emission from STM Tunneling Junction on Ag Films Grown on Si(111) Surface. *J. Woo, H. Shim, G. Lee*, Inha University, South Korea

Detection of lights emitted from the STM tunneling junction has been developed as one of the local spectroscopic method to probe optical properties of surfaces. Recently, we set up the STM with light detection apparatus which uses an optical fiber for collection of the emitted light from the tunneling junction. We obtained STM-induced light emission spectra emitted from Ag surfaces grown in two different forms on a Si(111)-7x7 surface. As characterized by STM images, films with flat terraces are grown on a 7x7 surface of Si(111), while Ag clusters with varying sizes are formed on a H/Si(111)-1x1 surface. The light emission spectra shows peaks at the energy range of 2.3~2.7 eV. The peak positions in the emission spectra remain the same for different tunneling bias voltages, indicating that the emission is induced through inelastic tunneling. The detected light emission is interpreted as due to the decay of a tip-induced plasmon (TIP) which is confined between the tip and the surface. The differences in the peak position and in the energy broadening are attributed to the difference in

roughness and in shape. Comparison of the two surfaces and discussion will be made based on the theory of light emission from TIP.

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