Fall Meeting Hudson Mohawk Chapter of the AVS Sept. 28, 2015

Union College
807 Union Street
Schenectady, NY 12308
Wold Center Atrium & Olin Center Center (Rm 106)

AGENDA

4:00 PM	Reception and Refreshments **(Wold Center Atrium)**
4:30 PM	Welcome, Kim Michelle Lewis, Rensselaer Polytechnic Institute National AVS Update, Vincent Smentkowski, GE **(Olin Center 106)**
4:40 PM	Oral Presentations **(Olin Center 106)**
6:30 PM	Poster Presentations and Dinner **(Wold Center Atrium)**
8:00 PM	Best Poster and Oral Presentation Awards **(Wold Center Atrium)**
8:05 PM	Adjourn (Brief meeting of Chapter Board Members) **(Wold Center Atrium)**

ORAL PRESENTATIONS

AN STM INVESTIGATION OF THE REACTION OF HYDROGEN WITH CHEMISORBED OXYGEN ON Cu(110)

Qianqian Liu and Guangwen Zhou
Department of Mechanical Engineering & Multidisciplinary Program in Materials Science and Engineering, State University of New York, Binghamton, NY 13902

EFFECTS OF POST-DEPOSITION HYBRID ANNEAL ON THE OPTICAL, PHOTOLUMINESCENCE, AND STRUCTURAL PROPERTIES OF SiC_xO_y MATERIALS

Brian Ford, Natasha Tabassum, Mounika Kotha, Lukas Kiehl, Maik Katko, Vasileios Nikas, Alain E. Kaloyeros and Spyros Gallis
Colleges of Nanoscale Sciences and Engineering, State University of New York Polytechnic Institute, Albany, New York 12203

METROLOGY FOR ATOMIC LAYER DEPOSITED HIGHER-K METAL OXIDE SEMICONDUCTOR BASED DEVICES

Sonal Dey and Alain Diebold
Colleges of Nanoscale Science & Engineering, SUNY Polytechnic Institute, 257 Fuller Rd., Albany, NY 12203

WILL ZINC OXIDE SERVE AS AN ELECTRONIC MATERIAL FOR FUTURE HIGH-POWER AND HIGH-FREQUENCY ELECTRON DEVICE APPLICATIONS?

Poppy Siddiqua[1], Walid A. Hadi[1], Stephen K. O'Leary[1], and Michael S. Shur[2]
[1]*School of Engineering, The University of British Columbia, Kelowna, British Columbia V1V 1V7*
[2]*Department of Electrical, Computer, and Systems Engineering, Rensselaer Polytechnic Institute, Troy, New York 12180*

STRONG METAL SUPPORT INTERACTION OF Pt ON TiO_2 GROWN BY ATOMIC LAYER DEPOSITION FOR FUEL CELL APPLICATIONS

R. Paul Hansen, Richard Phillips, Eric Eisenbraun, and Carl Ventrice, Jr.
Colleges of Nanoscale Science and Engineering, SUNY Polytechnic Institute, Albany, NY

ORAL PRESENTATION ABSTRACTS

AN STM INVESTIGATION OF THE REACTION OF HYDROGEN WITH CHEMISORBED OXYGEN ON Cu(110)

Qianqian Liu, Guangwen Zhou

Department of Mechanical Engineering & Multidisciplinary Program in Materials Science and
Engineering, State University of New York, Binghamton, NY 13902

Email: qliu16@binghamton.edu

The interaction of hydrogen with oxygen adsorbed on metal surface is widely studied because of its relevance to a wide range of technological processes such as heterogeneous catalysis, but the atomic processes leading to the transition of different oxygen chemisorbed phases are still poorly understood. In our work, Scanning Tunneling Microscopy (STM) is employed to study the evolution of oxygen chemisorption induced surface reconstruction of Cu(110) during the reaction of chemisorbed oxygen and hydrogen . The reduction is performed at 150 °C with hydrogen pressure varying from 1×10^{-8} Torr to 5×10^{-5} Torr on the chemisorbed-oxygen covered Cu(110) surface. Cu(110)-c(6×2) phase transits to the (2×1) phase along the step edges and then the (2×1) phase grows larger and finally covers the entire surface with higher hydrogen exposure. We show that the (6×2) → (2×1) transition occurs via the H_2 induced loss of chemisorbed oxygen in the (6x2) phase, resulting on releases extra Cu atoms diffusing to the step edges and terraces. The STM observation of the atomic processes of the H_2-induced (6×2) → (2×1) transition will be described in detail.

EFFECTS OF POST-DEPOSITION HYBRID ANNEAL ON THE OPTICAL, PHOTOLUMINESCENCE, AND STRUCTURAL PROPERTIES OF SiC_xO_y MATERIALS

Brian Ford, Natasha Tabassum, Mounika Kotha, Lukas Kiehl, Maik Katko, Vasileios Nikas, Alain E. Kaloyeros and Spyros Gallis

Colleges of Nanoscale Sciences and Engineering, State University of New York Polytechnic Institute,
Albany, New York 12203, USA

Email: brford@sunypoly.edu

Silicon-oxycarbide (SiC_xO_y) materials have been the focus of studies due to their potential use in a plethora of technological applications such as white light emitting materials,[1,2] hydrogen storage materials,[3] gas sensors,[4] and even in biomedical devices.[5] Prior work by the investigators has been dedicated to the development of a thermal CVD strategy for the growth of SiC_xO_y thin films for light emission applications. It is demonstrated that the as-deposited SiC_xO_y thin films follow closely the pure silicon-oxycarbide stoichiometry [$SiC_xO_{2(1-x)}$, ($0<x<1$)] and exhibit strong white light emission, originating from the recombination of photo-generated carriers between the energy bands and at their tail states, associated with the Si-O-C/Si-C bonding configuration.[1,6] Herein we present results from a systematic study of the effects of single- and multi-step (hybrid) post-deposition passivation treatments on the structural, optical, and photoluminescence (PL) characteristics of two sets of SiC_xO_y films, namely carbon-rich ($SiC_{0.5}O_{1.3}$) and oxygen-rich ($SiC_{0.3}O_{1.6}$). The effects of different ramifications of oxygen and forming gas (FG) (H_2 5 at.%, N_2 95 at.%) thermal passivation treatments on the structural and optical properties of the resulting samples were investigated using Fourier transform infrared spectroscopy (FTIR), spectroscopic ultraviolet-visible ellipsometry (UV-VIS-SE), and x-ray photoelectron spectroscopy (XPS) measurements. A two-step hybrid passivation process, comprising of an oxygen (500°C) then a forming gas (700°C) treatment, resulted in an approximately seven-fold enhancement of the white luminescence in the visible/ultraviolet range (1.5 - 4.0 eV). Time resolved PL and FTIR analysis showed that the luminescence enhancement is related to the decrease of the non-radiative recombination paths through carbonyl sites. To that end, an inverse correlation between the carbonyl groups and the PL intensity is reported. In addition to the PL enhancement due to the engineering of the quenching centers in SiC_xO_y, a complementary PL three-fold enhancement by sub-100nm thermal CVD-grown SiC_xO_y nanowire (NW) arrays fabricated by e-beam lithography and reactive-ion-etching will also be reported.

[1] S. Gallis, V. Nikas, H. Suhag, M. Huang, and A.E. Kaloyeros, Appl. Phys. Lett. **97**, 081905 (2010).
[2] A. V Vasin, *Functional Nanomaterials and Devices for Electronics, Sensors and Energy Harvesting* (Springer International Publishing, Cham, 2014).
[3] Q.D. Nghiem, S.J. Cho, and D.-P. Kim, J. Mater. Chem. **16**, 558 (2006).
[4] A. Karakuscu, A. Ponzoni, P.R. Aravind, G. Sberveglieri, and G.D. Soraru, J. Am. Ceram. Soc. **96**, 2366 (2013).
[5] R. Zhuo, P. Colombo, C. Pantano, and E. a. Vogler, Acta Biomater. **1**, 583 (2005).
[6] V. Nikas, S. Gallis, M. Huang, A.E. Kaloyeros, A.P.D. Nguyen, A. Stesmans, and V. V. Afanas'ev, Appl. Phys. Lett. **104**, 061906 (2014).

METROLOGY FOR ATOMIC LAYER DEPOSITED HIGHER-K METAL OXIDE SEMICONDUCTOR BASED DEVICES

Sonal Dey and Alain Diebold

Colleges of Nanoscale Science & Engineering, SUNY Polytechnic Institute
257 Fuller Rd., Albany, NY 12203

Email: sdey@sunypoly.com

The down-scaling of metal oxide semiconductor field effect transistor (MOSFET) based devices necessitates research and development efforts for increasing the dielectric constant (K) of the gate dielectric, control of short-channel effects, and gate leakage current minimization. Research is currently underway for developing still higher-k gate dielectric materials[1] by lattice engineering (e.g., monoclinic to tetragonal and/or cubic phase for HfO_2, ZrO_2) and effective incorporation of high mobility channel materials (e.g., Ge, III-V) under the purview of the existing 300 mm Si VLSI technology. Engineering the structure of higher-k thin films, stabilizing the higher-k phases by using a variety of atomic layer deposition (ALD) processes and compositional alloying schemes are some of the key challenges being addressed in this work.[2-4] We will illustrate multiple aspects of synchrotron based x-ray metrology efforts, namely, grazing incident x-ray diffraction (GI-XRD) and pole figure analysis, for identifying and comparing the phases and fiber texture developed in these films (≤ 100 ALD cycles) deposited on Si substrates. Findings from x-ray photoelectron spectroscopy (XPS) and x-ray absorption spectroscopy (XAS) will also be discussed for complete characterization of these technologically relevant higher-k thin films.[5,6]

References:

1. X. Zhao, D. Vanderbilt, *Phys. Rev. B*. **65**, 233106 (2002).
2. S. Consiglio *et al.*, *J. Electrochem. Soc.* **159**, G80–G88 (2012).
3. K. Tapily *et al.*, *ECS Trans.* **45**, 411–420 (2012).
4. A. C. Diebold, *J. Vac. Sci. Technol. A*. **31**, 050804 (2013).
5. E. Bersch *et al.*, *J. Appl. Phys.* **107**, 043702 (2010).
6. R. Vasic *et al.*, J. Appl. Phys. **113**, 234101 (2013).

Acknowledgements:

S.D. thanks the TEL Technology Center, America, LLC for funding support. Dr. Steven Consiglio, Dr. Kanda Tapily, Dr. Robert Clark and Dr. Gert Leusink of TEL Technology Center, America, LLC, previous postdocs Dr. Eric Bersch and Dr. Relja Vasic and students Dr. Ming Di, Mr. Josh LaRose and Dr. Manasa Medikonda are gratefully acknowledged for their contribution to this work. Use of the National Synchrotron Light Source (NSLS), Brookhaven National Laboratory was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under contract No. DE-AC02-98CH10886. Use of the Advanced Photon Source (APS) was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357. The authors also acknowledge the contribution of Dr. Jean L. Jordan-Sweet and Dr. Christian Lavoie at IBM T.J. Watson Research Center for parts of this research made at the NSLS.

WILL ZINC OXIDE SERVE AS AN ELECTRONIC MATERIAL FOR FUTURE HIGH-POWER AND HIGH-FREQUENCY ELECTRON DEVICE APPLICATIONS?

Poppy Siddiqua[1], Walid A. Hadi[1], Stephen K. O'Leary[1], and Michael S. Shur[2]

[1]School of Engineering, The University of British Columbia, Kelowna, British Columbia V1V 1V7
[2]Department of Electrical, Computer, and Systems Engineering, Rensselaer Polytechnic Institute, Troy, New York 12180

Presenter's Email: stephen.oleary@ubc.ca

At the present moment, zinc oxide is primarily being used as an electronic material for low-field thin-film transistor and transparent conducting oxide device applications. In this paper, we present some recent results on the steady-state electron transport within zinc oxide suggesting that this material may also be considered as an alternative material to gallium nitride for high-power and high-frequency electron device applications. The expected device performance of zinc oxide-based devices is then projected and contrasted with that expected from gallium nitride-based devices. It is shown that zinc oxide-based devices have a slight advantage when compared with the case of gallium nitride.

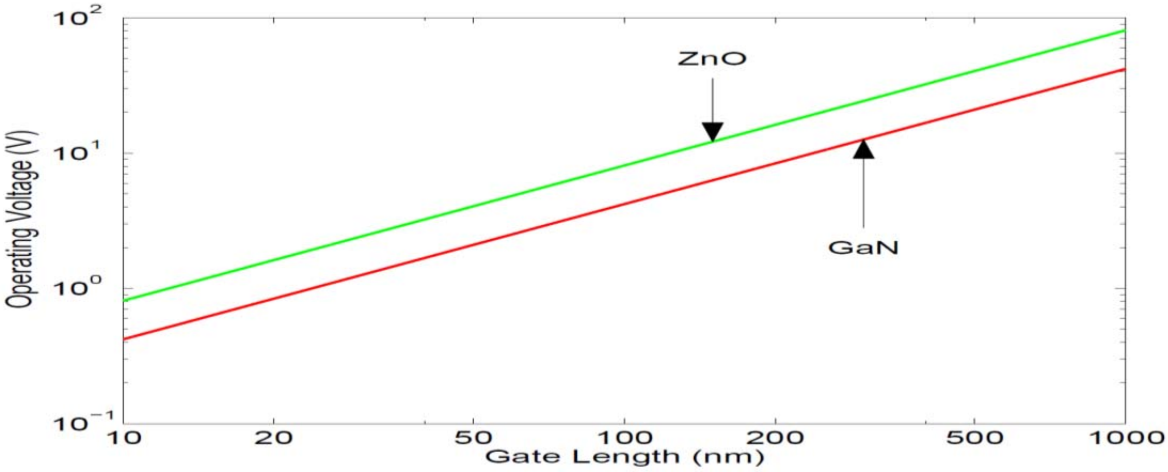

Figure 1. The expected operating voltage plotted as a function of the gate length for the case of zinc oxide (ZnO) and gallium nitride (GaN) based devices.

STRONG METAL SUPPORT INTERACTION OF Pt ON TiO_2 GROWN BY ATOMIC LAYER DEPOSITION FOR FUEL CELL APPLICATIONS

R. Paul Hansen, Richard Phillips, Eric Eisenbraun, and Carl Ventrice, Jr.

Colleges of Nanoscale Science and Engineering, SUNY Polytechnic Institute, Albany, NY

Email: phansen@albany.edu

A central barrier to the commercialization of fuel cell technologies has been the high cost of the platinum catalyst used in the fuel cell and its durability. Recently, several groups have used atomic layer deposition to reduce the amount of Pt used in fuel cells. Atomic layer deposition is a method used to create uniform and conformal layers of one material on another. Atomic layer deposition has also been used to grow TiO_2 substrates for the support of the catalyst. In this research project, the deposition of Pt on TiO_2 by atomic layer deposition onto TiO_2 substrates is examined to determine the affect of the growth conditions and growth morphology of the Pt on the catalytic dissociation of oxygen and hydrogen. The substrates used for this study are grown by atomic layer deposition on SiO_2/Si wafers. The Pt was grown at either 380 °C or 225 °C. Well dispersed Pt nanoparticles were achieved at both temperatures, as seen in Figure 1. However, for samples grown at 380 °C, the catalytic activity of the sample was completely suppressed. This has been attributed to the strong metal-support interaction. Angle-resolved photoelectron spectroscopy measurements of sample grown at this temperature indicate that the surface is terminated with a thin TiO2 layer.

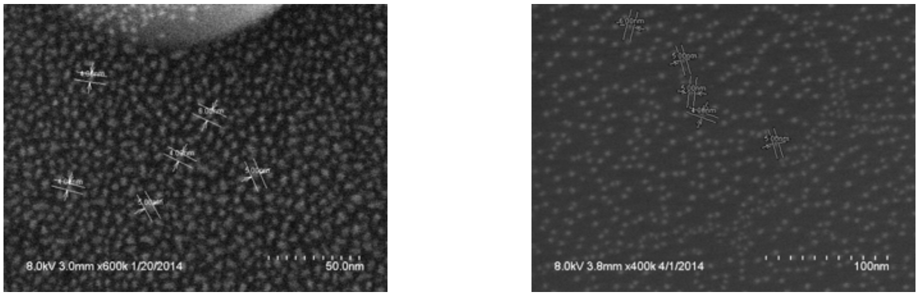

Figure 1: SEM images of Pt particles grown on a $TiO_2/SiO_2/Si$ at a) 380 °C and b) 225 °C.

POSTER PRESENTATIONS

RESISTIVITY OF ULTRATHIN EPITAXIAL COPPER FILMS

Michael Giordano, Andrew Horning, Yukta Timalsina, Kim M. Lewis
Center for Materials, Devices & Integrated Systems, and Department of Physics, Applied Physics and Astronomy, Rensselaer Polytechnic Institute, Troy, NY 12180

THE BENEFITS OF USING ALL OF THE MEASURED MASS CHANNELS DURING MVSA OF TOF-SIMS DATA SETS

Vincent Smentkowski, Mike R. Keenan[2], Henrik Arlinghaus[3]
General Electric Global Research Center, Independent Scientist[2]*, ION-TOF GmbH*[3]

NANOSTRUCTURED CATALYST OF POLYMER ELECTROLYTE FUEL CELL

Breena M. Sperry, J. Nicholas Alexander, Dr. Harry Efstathiadis
E2TAC, Department of Physics, University at Albany
College of Nanoscale Science of Engineering, Polytechnic Institute of Technology, Albany NY, 12222

ONE STEP GROWTH METHOD FOR ULTRATHIN SINGLE CRYSTAL SnS_2 FLAKES AND THEIR PHYSICAL PROPERTIES

Yun-Bo Yang, J. K. Dash, A. Littlejohn, Y. Xiang, T.-M. Lu, Y. Wang[+], J. Shi[+], L.H. Zhang[++], and K. Kisslinger[++], and G.-C. Wang
Department of Physics, Applied Physics and Astronomy, Rensselaer Polytechnic Institute
[+]*Department of Materials Science and Engineering, Rensselaer Polytechnic Institute*
[++]*Center for Functional Nanomaterials, Brookhaven National Lab*

BIAXIALLY ORIENTED CdTe FILMS ON GLASS SUBSTRATE THROUGH NANOSTRUCTURED Ge/CaF_2 BUFFERED LAYERS

P.-Y. Su*, R.J. Lord, I. Bhat*, S.B. Zhang, T.-M. Lu, and G.-C. Wang
*Department of Physics, Applied Physics, and Astronomy, *Department of Electrical, Computer, and Systems Engineering, Rensselaer Polytechnic Institute, 110, 8th Street, Troy, NY 12180*

EXPERIMENTAL STUDY OF SPATIAL CONFINEMENT EFFECT ON ACOUSTIC PHONON TRANSPORT IN SIO_2 NANORODS USING ULTRAFAST PUMP-PROBE SPECTROSCOPY

Xiaohan Shen, Yukta P. Timalsina, Toh-Ming Lu, Masashi Yamaguchi
Department of Physics, Applied Physics, and Astronomy, Rensselaer Polytechnic Institute, Troy NY 12180

CHARACTERIZATION OF $Cu(In, Ga)Se_2$ WITH VARYING Ga RATIOS

Isaiah Mori[A], Jesse Claypoole[A], Bernadette Peace[A], Neville Sun[A], Pradeep Haldar[A], Harry Efstathiadis[A]
[A] *SUNY Colleges of Nanoscale Science and Engineering, 257 Fuller Road, Albany, NY 12203, USA*
[B] *Angstrom Sun Technologies Inc., 31 Nagog Park, Acton, MA 01720, USA*

CREATION OF FRONTWALL CdS/CdTe PHOTOVOLTAICS USING NICKEL SUBSTRATES AS THE BACK CONTACT LAYER

L.J. Seewald, P.-Y. Su*, S.B. Zhang, G.-C. Wang, I. Bhat*, and T.-M. Lu
*Department of Physics, Applied Physics and Astronomy, *Department of Electrical Computer and System Engineering, Rensselaer Polytechnic Institute, 110, 8th Street, Troy, NY 12180, USA*

EFFECT OF SURFACE TERMINATION ON THE GROWTH OF GRAPHENE ON Cu SINGLE CRYSTAL SUBSTRATES

Tyler R. Mowll[1], Eng Wen Ong[1], Parul Tyagi[2], Zachary Robinson[3], Carl A. Ventrice Jr.[4]
[1]*University at Albany-SUNY,* [2]*GLOBALFOUNDRIES,* [3]*College at Brockport-SUNY,* [4]*SUNY Polytechnic Institute*

POSTER PRESENTATION ABSTRACTS

RESISTIVITY OF ULTRATHIN EPITAXIAL COPPER FILMS

Michael Giordano, Andrew Horning, Yukta Timalsina, Kim M. Lewis

Center for Materials, Devices & Integrated Systems, and Department of Physics, Applied Physics and Astronomy, Rensselaer Polytechnic Institute, Troy, NY 12180

Email: giordm3@rpi.edu

The study of electrical properties of nanoscale copper are of great interest as it is a common interconnect material used in electronic devices such as integrated electronics. In-depth understanding of substantial increase in resistivity observed in ultrathin copper films is required to control resistivity and to maximize the performance of microchips as the dimensions of the interconnect continue to scale down. At the nanoscale, the dominant contributor to the resistivity of copper film arises from surface scattering of electrons[1]. A study has been performed to measure the resistivity of films ranging in thickness between 10 and 100 nm over temperatures ranging from 5-300 K (Fig 1.). We use classical, quasi-classical and quantum models to predict experimentally measured resistivity[2]. We show that the quasi-classical model which uses no fitting parameters can better describe the resistivity due to surface scattering than other models.

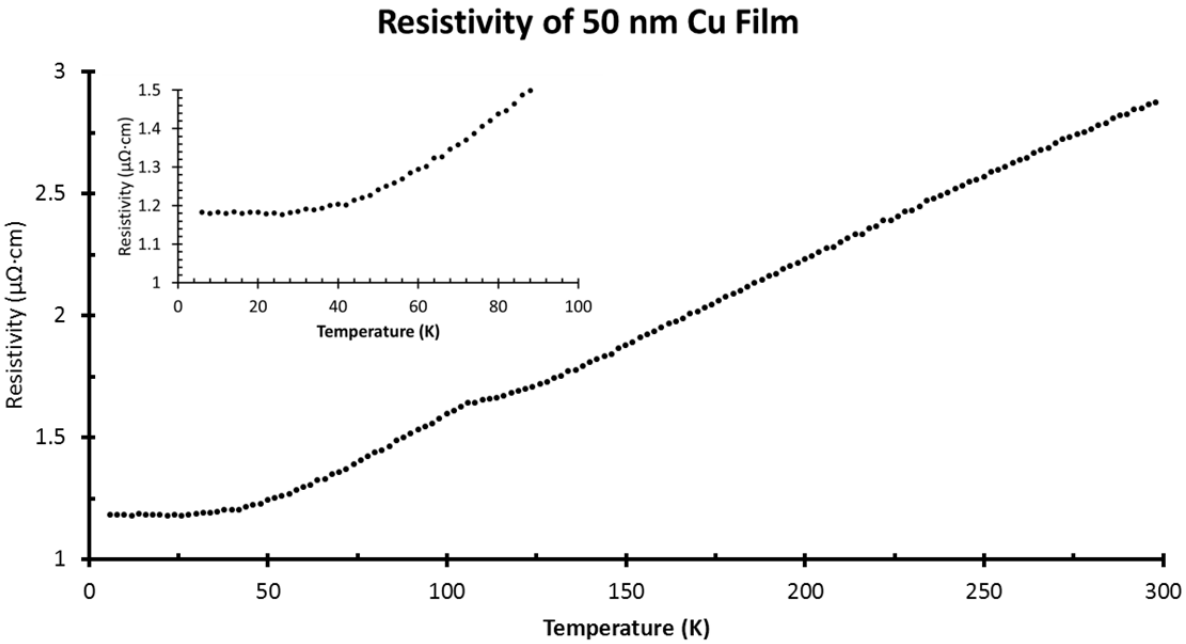

Fig 1. Temperature dependent resistivity data for a single film.
Inset: Resistivity approaches the residual resistivity at low T of 1.183 μΩ·cm.

[1] Y.P. Timalsina, A. Horning, R.F. Spivey, K.M. Lewis, T.-S. Kuan, G.-C. Wang, and T.-M. Lu, Nanotechnology 26, 075704 (2015).

[2] S.Chatterjee and A.E. Meyerovich, Phys. Rev. B 81, 245409 (2010).

THE BENEFITS OF USING ALL OF THE MEASURED MASS CHANNELS DURING MVSA OF TOF-SIMS DATA SETS

Vincent Smentkowski, Mike R. Keenan[2], Henrik Arlinghaus[3]
General Electric Global Research Center, Independent Scientist[2], ION-TOF GmbH[3]

Email: smentkow@ge.com

Time of flight secondary ion mass spectrometry (ToF-SIMS) data sets are very large and contain a wealth of information about the material being analyzed. A typical image data set can be comprised of 256 x 256 pixels with a 0 to 900 amu (or greater) mass spectrum collected at high (M/ΔM ~10,000) mass resolution at every pixel. Data sets are often comprised of >1 x 1015 spectral channels. The challenge for a ToF-SIMS analyst is to scrutinize all of the measured information without bias in order to provide for the most robust understanding of the material being analyzed; this is especially important in an industrial setting where unknown samples are analyzed. Multivariate statistical analysis (MVSA) algorithms have assisted in ToF-SIMS data work up [1,2], however commercially available software is not able to handle data sets this large and the analysts often select mass intervals to utilize and/or degrades the mass resolution prior to MVSA analysis. In this poster, we will report first results obtained using MVSA software that is able to handle massive ToF-SIMS data sets. We demonstrate two important benefits of unbiased analysis of the massive ToF-SIMS data sets: (1) finding unexpected elements in real world samples (this is a reason why the authors never use peak lists for MVSA analysis) and (2) the ability to obtain high mass resolution results from data sets collected at nominal mass resolution (e.g., the beam alignment pulsing mode on ION-TOF instruments). The importance of these two benefits will be highlighted.

References:

[1] Surface and Interface Analysis, Special issue on Multivariate Analysis. Volume 41, issue 2 Feb 2009.
[2] Surface and Interface Analysis, Special issue on Multivariate Analysis II. Volume 41 issue 8, Aug 2009.

NANOSTRUCTURED CATALYST OF POLYMER ELECTROLYTE FUEL CELL

Breena M. Sperry, J. Nicholas Alexander, Dr. Harry Efstathiadis

E2TAC, Department of Physics, University at Albany
College of Nanoscale Science of Engineering, Polytechnic Institute of Technology
Albany NY, 12222

Email: BSperry@sunypoly.edu

The negative effects of fossil fuels on the environment has led to an increasing demand in the innovation and implementation of renewable energies. Among the green alternative energies currently being researched are fuel cells which are renowned for their usage of abundant fuels and clean byproducts. Due their high electrical efficiency and versatility, 88% of all fuel cells currently being produced are Polymer Electrolyte Membrane Fuel Cells (PEMFC)[1]. Despite PEMFC's attraction of potentially being a suitable replacement for fossil fuels, they have yet to reach large scale commercialization. The cost and life cycle of the electrode's catalyst—platinum (Pt)—is primarily at fault. For maximum efficiency, large quantities of Pt are required at the cathode due oxygen's electrochemical potentials, making PEMFC a nonviable long-term investment. In order to reduce the amount of Pt used in the cathode, compounds that have high oxygen reduction reaction (ORR) rates with comparable durability and chemical integrity have been researched[2].

Tantalum oxide (Ta_2O_5) qualifies as a possible replacement catalyst in PEMFC due to its high ORR, stability in fuel cell conditions, lifespan, and cost. Still, due to the insulating properties of Ta_2O_5, it alone does not match or surpass Pt; it must be coated with a conductive material to be active[2]. As a solution, Ta_2O_5 nanoparticles were explored as a core with a conductive Pt monolayer grown on its surface.

Ta_2O_5 nanoparticles were grown onto the catalyst support— carbon nanotubes (CNT)—through plasma physical vapor deposition (PVD) of tantalum (Ta), which oxidized to Ta_2O_5. The Ta_2O_5/CNT surface was then sputtered with Pt, forming a thin coating. Characterization of the materials was done through XPS and x-ray diffraction (XRD). The sample's viability as a catalyst was then tested by measuring the ORR of Pt-Ta_2O_5/CNT through cyclic voltammetry (CV) using a rotating disk electrode (RDE). The authors find that a Ta_2O_5 core coated in Pt has promise as a viable alternative catalyst for PEMFC.

[1] Barbir, Franco. *PEM Fuel Cells: Theory and Practice*. 2nd ed. Waltham: Academic, 2013. Print.

[2] Kim, Jin Yong, Tak-Keun Oh, Yongsoon Shin, Jeff Bonnett, and K. Scott Weil. "A Novel-platinum Group Electrocatalyst for PEM Cell Applications." *International Journal of Hydrogen Energy* 36 (2011): 4557-564. *ScienceDirect*. Web. 15 June 2010.

ONE STEP GROWTH METHOD FOR ULTRATHIN SINGLE CRYSTAL SnS_2 FLAKES AND THEIR PHYSICAL PROPERTIES

Yun-Bo Yang, J. K. Dash, A. Littlejohn, Y. Xiang, T.-M. Lu, Y. Wang[+], J. Shi[+], L.H. Zhang[++], and K. Kisslinger[++], and G.-C. Wang
Department of Physics, Applied Physics and Astronomy, Rensselaer Polytechnic Institute
[+]Department of Materials Science and Engineering, Rensselaer Polytechnic Institute
[++]Center for Functional Nanomaterials, Brookhaven National Lab

Email: yangy20@rpi.edu

Remarkable properties of layered transition metal dichalcogenides and their potential applications in electronics and optoelectronics have raised intense world-wide interest. Reports of SnS_2 have been relatively scarce. We report that tens of microns-sized ultrathin single crystal SnS_2 flakes can be grown on amorphous SiO_2 substrates using a simple and cost-effective one step thermal co-evaporation method (See Fig. 1). The structure, composition, morphology, vibrational modes, and optical bandgap were characterized by multiple techniques. X-ray diffraction shows the flakes have a 2H hexagonal structure. X-ray pole figure analysis reveals a distribution in flake orientations with a majority of flakes oriented with the (0001) plane parallel to the substrate but some flakes with their [0001] direction tilted away from the substrate normal by either ~60° or ~90°. These results show that SnS_2, grown on amorphous substrates, can form layered flakes with preferred fiber texture orientations. The transmission electron microscopy (TEM) and reflection high energy electron diffraction show each ultrathin flake is a single crystal (See Figs. 2(a) and (c)). For few layer thick SnS_2, Moire patterns resulting from relative rotation between SnS_2 layers are observed in high resolution TEM imaging and diffraction (See Figs. 2(b) and (d)). Atomic force microscopy images of islands on a single flake support the existence of step edge barriers in island nucleation and growth. The difference in free energy associated with different step edge terminations determines the shape of the island. The photoluminescence (PL) spectrum supports that these ultrathin flakes possess a bandgap of ~2.25 eV. The time resolved PL shows a carrier lifetime of 3±0.6 ns. These results greatly improve our basic understanding of the texture formation and shape of ultrathin flake of layered metal dichalcogenides materials.

Acknowledgement: The work is supported by the NYSTAR through Focus Center-NY, and Rensselaer. TEM study was carried out in whole at the BNL.

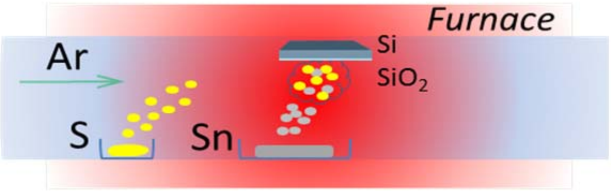

Fig. 1 A schematic (not to scale) of the experimental setup for the synthesis of SnS_2 flakes in a one zone furnace. The SiO_2 on Si(001) substrate is facing down.

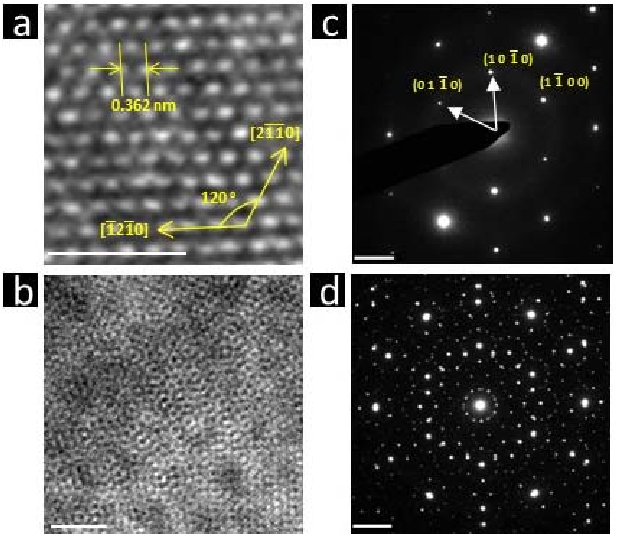

Fig. 2 (a) High resolution TEM image of SnS_2, scale bar 2 nm; (b) Moire fringe of ultrathin SnS_2, scale bar 10 nm; (c) and (d) TEM diffraction patterns from (a) and (b), respectively, scale bar 2 nm^{-1}.

BIAXIALLY ORIENTED CdTe FILMS ON GLASS SUBSTRATE THROUGH NANOSTRUCTURED Ge/CaF_2 BUFFERED LAYERS

P.-Y. Su*, R.J. Lord, I. Bhat*, S.B. Zhang, T.-M. Lu, and G.-C. Wang
Department of Physics, Applied Physics, and Astronomy
*Department of Electrical, Computer, and Systems Engineering
Rensselaer Polytechnic Institute, 110, 8th Street, Troy, NY 12180, USA

Email: sup@rpi.edu

Semiconductor films grown on amorphous surfaces such as glass are normally either amorphous or polycrystalline in nature. Glass has no regular crystalline structure and one cannot induce an "epitaxial" growth of single crystal films on top of it. At best one can grow polycrystalline films with random grain orientations. However, it has been shown recently that with a biaxial buffer layer, it is possible to grow near-single crystal semiconductors on amorphous substrates [1]. We present heteroepitaxial CdTe films grown by metal organic chemical vapor deposition on glass substrates through nanostructured Ge/CaF_2 buffer layers which were biaxially oriented. It allows us to explore the structural properties of multilayer biaxial semiconductor films which possess small angle grain boundaries and to test the principle of a solar cell made of such low-cost, low-growth-temperature semiconductor films. Through the x-ray diffraction and x-ray pole figure analysis, the heteroepitaxial relationships of the mutilayered films are determined as [111] in the out-of-plane direction and $<1\bar{1}0>_{CdTe}//<1\bar{1}0>_{Ge}//<\bar{1}10>_{CaF_2}$ in the in-plane direction. See {111} poles in Figs. (a)-(c). The I-V curves measured from an ITO/CdS/CdTe/Ge/CaF_2/glass solar cell test structure (see Fig. (d)) shows a power conversion efficiency of ~ $\eta = 1.26\%$, illustrating the initial success of such an approach. The observed non-ideal efficiency is believed to be due to a low shunt resistance and high series resistance as well as some residual large-angle grain boundary effects, leaving room for significant further improvement [2].

Acknowledgement: This work is supported by the National Science Foundation DMR-1305293 and NYSTAR through Focus Center-New York. We thank Drs. Weiyu Xie and Rajendra Dahal for discussions.

References: [1] Small angle grain boundary Ge films on biaxial CaF_2/glass substrate, C. Gaire, P.C. Clemmer, H.-F. Li, T.C. Parker, P. Snow, I. Bhat, S. Lee, G.-C. Wang, T.-M. Lu, J. of Cryst. Growth 312, 607-610 (2010); Biaxial CdTe/CaF_2 films growth on amorphous surface, W. Yuan, F. Tang, H.-F. Li, T. Parker, N. LiCausi, T.-M. Lu, I. Bhat I, G.-C. Wang, and S. Lee, *Thin Solid Films* 517, 6623-8 (2009). [2] Biaxially oriented CdTe films on glass substrate through nanostructured Ge/CaF_2 buffer layers, accepted by Materials Express.

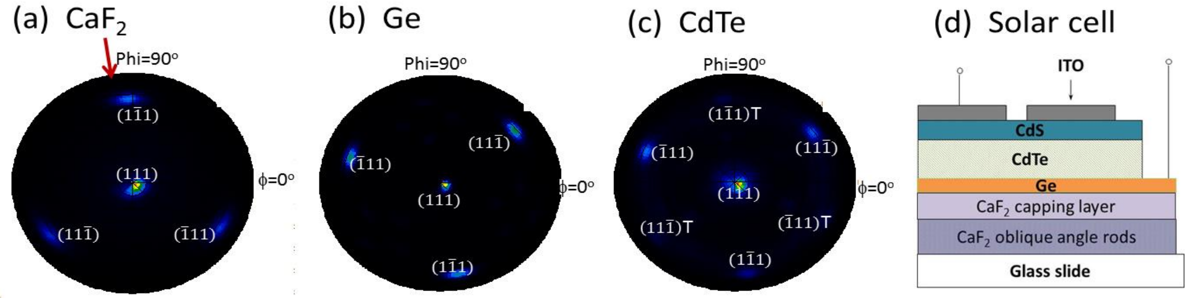

Fig. 1 X-ray {111} pole figures of (a) CaF_2 film, (b) Ge film, (c) CdTe film, and (d) solar cell text structure.

EXPERIMENTAL STUDY OF SPATIAL CONFINEMENT EFFECT ON ACOUSTIC PHONON TRANSPORT IN SiO_2 NANORODS USING ULTRAFAST PUMP-PROBE SPECTROSCOPY

Xiaohan Shen, Yukta P. Timalsina, Toh-Ming Lu, Masashi Yamaguchi

Department of Physics, Applied Physics, and Astronomy
Rensselaer Polytechnic Institute, Troy NY 12180

Email: shenx4@rpi.edu

The thermal management in nanoscale electronic devices is urgently necessary. Theoretical predictions indicate the acoustic transport in nanostructures with dimensions comparable to phonon wavelength behaves fundamentally different compare to bulk materials due to the spatial confinement. Consequently, the thermal transport, which is an ensemble of acoustic transport of phonons with various wavelengths, is affected to some extent due to spatial confinement effect on acoustic phonon transport. We use the continuum model to calculate the acoustic phonon dispersion relation of cylindrical SiO_2 nanorods with various dimensions, and find the phonon (frequency below 100 GHz) group velocity in SiO_2 nanorod with diameter smaller than 200 nm is reduced from the sound speed of bulk SiO_2. Experimental investigation of the spatial confinement effect on the longitudinal acoustic phonon transport in cylindrical SiO_2 nanorods with diameter equals 200 nm is conducted using ultrafast pump-probe spectroscopy. Vertically grown SiO_2 nanorod arrays on a substrate with various array periods are used to investigate the periodicity effect on acoustic phonon transport. The transient reflectivity signals show two types of contributions. First contribution is independent of the array pitch, and the other contribution depends on the pitch. The former contribution is assigned to be the mechanical vibration mode of individual SiO_2 nanorod. For the latter contribution, the period of the oscillation is found to be close to the round trip time of surface acoustic wave propagates between two adjacent nanorods. Considering the optical detection mechanism of acoustic waves propagate on the sample, some coupling between the surface acoustic wave and the longitudinal strain propagates through the nanorod is necessary for the acoustic modes to be detected. We propose a model of the coupling between the surface acoustic wave and longitudinal wave propagates along the nanorods. In addition, a novel technique of narrowband acoustic phonon spectroscopy with center frequency continuously tunable throughout hundreds of GHz regime is developed, which can be applied in the future to investigate the frequency dependent acoustic phonon transport in nanostructures with a high spectral resolution.

CHARACTERIZATION OF Cu(In, Ga)Se_2 WITH VARYING Ga RATIOS

Isaiah Mori[A], Jesse Claypoole[A], Bernadette Peace[A], Neville Sun[A], Pradeep Haldar[A], Harry Efstathiadis[A]

[A] SUNY Colleges of Nanoscale Science and Engineering, 257 Fuller Road, Albany, NY 12203, USA
[B] Angstrom Sun Technologies Inc., 31 Nagog Park, Acton, MA 01720, USA

Email: imori@sunycnse.com

$Cu(In_{1-x},Ga_x)Se_2$ (CIGS) is one of the leading materials in the study of thin film photovoltaics. Key features of CIGS based devices are a tunable bandgap (1.0 – 1.7eV), lower fabrication cost, and a current world efficiency record of 21.7%. These factors have made CIGS solar thin films a promising cost-effective technology. CIGS bulk layers of varying Ga content (described as Ga/(In+Ga) ratios) were deposited onto molybdenum (Mo) coated soda-lime glass substrates. In order to further understand the effect of Ga content on film quality, Ga ratios ranging from 0.29 – 0.414 (as determined by x-ray florescence spectroscopy (XRF)) were used, as the mechanisms responsible for performance limitations with high Ga content CIGS devices are not well understood. Ga grading in the CIGS layer is responsible for creating higher bandgaps toward the front and rear contacts while lowering the bandgap in the middle of the CIGS layer. Additionally, a wider Ga grading dip in the CIGS layers tend to lead to form larger crystal grains in regions of lower Ga/(In+Ga) ratios. Moreover, the surface roughness of the CIGS layers was found to decrease from 51.2nm to 41.0nm with increasing Ga/(In+Ga) ratios. However, the surface roughness also decreases depending on how deep the Ga grading dip occurs in the bulk layer.

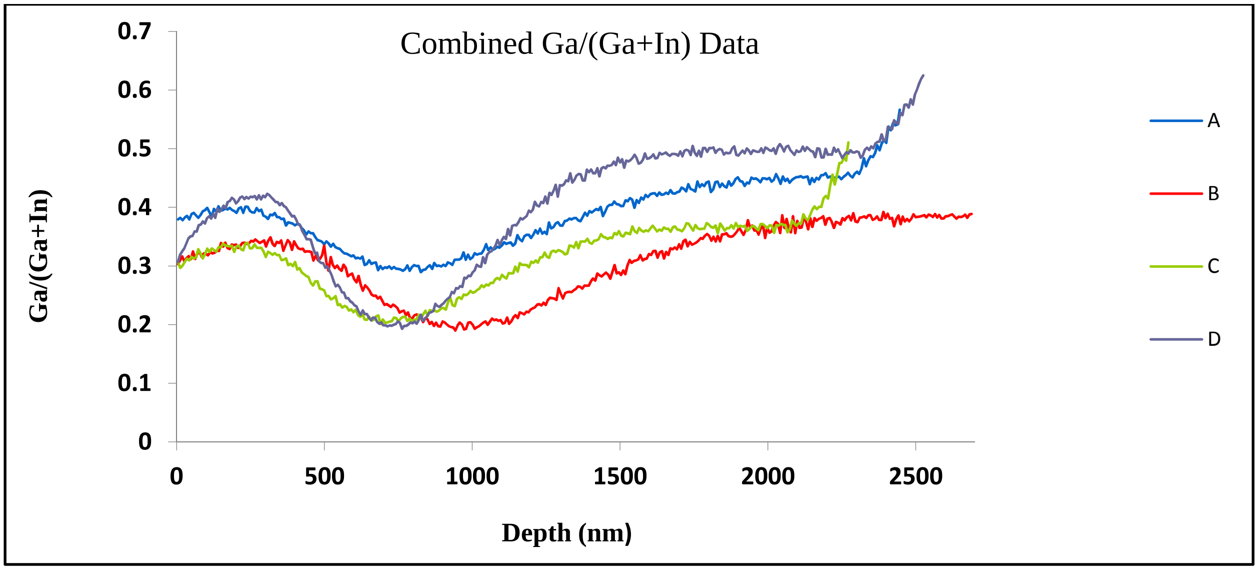

Figure 1. SIMS profile of all four samples, Ga/(In+Ga) ratios are as follow: A (0.29), B (0.321), C (0.353), D (0.414).

CREATION OF FRONTWALL CdS/CdTe PHOTOVOLTAICS USING NICKEL SUBSTRATES AS THE BACK CONTACT LAYER

L.J. Seewald, P.-Y. Su*, S.B. Zhang, G.-C. Wang, I. Bhat*, and T.-M. Lu

Department of Physics, Applied Physics and Astronomy
*Department of Electrical Computer and System Engineering
Rensselaer Polytechnic Institute, 110, 8th Street, Troy, NY 12180, USA

Email: seewal@rpi.edu

Commercially available CdTe photovoltaics traditionally are fabricated using the “backwall” configuration. In the backwall configuration a transparent conducting oxide (TCO) coated piece of glass is used as the substrate for device fabrication. This method of fabrication limits the CdTe film to a polycrystalline texture. We have created CdS/CdTe photovoltaic devices in the “frontwall” method, which allows for different textures of CdTe to be grown depending on the substrate used. For testing purposes, initial experiments have been conducted using polycrystalline nickel substrates. The structure for these devices is ITO/CdS/CdTe:As/ZnTe:As/poly-Ni (Fig. 1). The 50 nm thick ZnTe layer in this structure is heavily As-doped and used as a buffer layer for conduction between the poly-Ni substrate and the 2 μm thick CdTe layer [1]. Both ZnTe and CdTe were grown using metal organic chemical vapor deposition, CdS was grown with thermal evaporation, and the ITO was grown with sputter deposition. A power-conversion efficiency of $\eta = 1.4\%$ has been achieved using this device structure. This efficiency is much lower than commercially available devices, though these devices use a $CdCl_2$ treatment which has not yet been applied to our devices. Our work demonstrates that the fabrication of our “frontwall” device structure is feasible and the substrate can serve as the back side electrode contact. If near single-crystal metal substrates are employed to grow near single-crystal CdTe [2] layer, the structure can lead to possible high efficiency solar cells. **Acknowledgements:** This work is supported by the National Science Foundation DMR-1305293 and NYSTAR through Focus Center-New York.

References: [1] CdTe/ZnTe/GaAs Heterostructures for Single-Crystal CdTe Solar Cells. Peng-Yu Su, Chungho Lee, Gwo-Ching Wang, Toh-Ming Lu, and Ishwara B. Bhat. J. of Electronic Materials 43 (8), 2895-2900 (2014). [2] Epitaxial growth of CdTe thin film on cube-textured Ni by metal-organic chemical vapor deposition. C. Gaire, S. Rao, M. Riley, L. Chen, A. Goyal, S. Lee, I. Bhat, T.-M. Lu, G.-C. Wang. Thin Solid Films 520, 1862–1965 (2012).

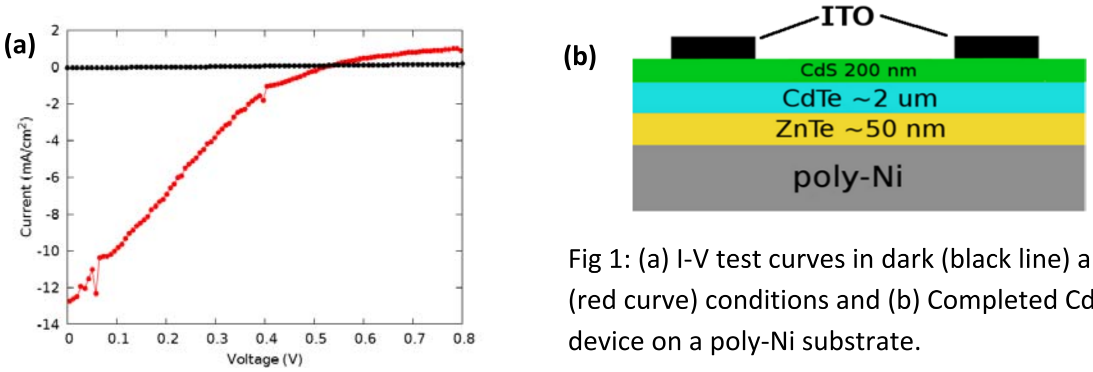

Fig 1: (a) I-V test curves in dark (black line) and bright (red curve) conditions and (b) Completed CdS/CdTe PV device on a poly-Ni substrate.

EFFECT OF SURFACE TERMINATION ON THE GROWTH OF GRAPHENE ON Cu SINGLE CRYSTAL SUBSTRATES

Tyler R. Mowll[1], Eng Wen Ong[1], Parul Tyagi[2], Zachary Robinson[3], Carl A. Ventrice Jr.[4]

[1]University at Albany-SUNY
[2]GLOBALFOUNDRIES
[3]College at Brockport-SUNY
[4]SUNY Polytechnic Institute

Email: tylermowll@gmail.com

The most common technique for synthesizing single-layer graphene films with large lateral dimensions is chemical vapor deposition (CVD) on Cu foil substrates. The primary reasons for choosing Cu substrates are the extremely low solubility of carbon in Cu, which allows a self-limited growth of graphene, and the relatively low cost of the Cu foil substrates. However, the transport properties of the CVD grown graphene films are typically a couple of orders of magnitude lower than for graphene flakes mechanically exfoliated from graphite. One of the reasons for the reduction in transport properties is the presence of crystalline defects in the CVD grown films. These structural defects arise in part from the multidomain structure of the Cu films. In order to achieve a better understanding of the influence of the surface termination of the Cu substrate on the crystallization of graphene during the CVD growth process, a systematic study of graphene growth on Cu(100), Cu(110), and Cu(111) crystals has been performed. The growth process is performed in an ultra-high vacuum (UHV) chamber that has been modified to perform CVD growth at pressures as high as 100 mTorr. The precursor gas used is ethylene. This growth procedure allows for the preparation of the clean surfaces in UHV, growth under typical CVD conditions, and characterization of the surface structure in UHV, without exposing the sample to atmospheric contaminants. Our results indicate that the Cu(111) surface has the lowest catalytic activity of the three surfaces for the decomposition of ethylene. In fact, the decomposition rate is so low that graphene growth is suppressed because of the sublimation of Cu at the elevated temperatures used to grow the graphene. By using an Ar overpressure, it was found that graphene could be grown on that surface. The surface symmetry of the Cu substrate has a strong influence on the rotational alignment of the graphene grains as they nucleate on each surface. For Cu(111), single-domain graphene growth can be achieved for ethylene pressures of 5 mTorr or less. For both Cu(100) and Cu(110), a minimum of two graphene domains is always observed.