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Meeting Abstracts

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Nanoapproach to Cancer Based on APA Microarrays Leading Genes and a Combination of Mass Spectrometry and Nanoconductimetry

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Abstract

Nanoproteomics and Nanogenomics in nanoarrrays advance the molecular biology, systems biology and nanobiotechnologies for humans, leading to a new industrialized label free nanoapproach to cancer. According to the last available report in the literature, there were 14.9 million incident cancer cases, 8.2 million deaths, and 196.3 million disability-adjusted life years (DALYs) in 2013. Moreover, the "one-size-fits-all" axiom, which is to say the mantra for which a single medical diagnostic/therapeutic procedure would fit in all instances, has proven ineffective in properly handling and managing human disorders. For example, while one patient may not respond to a certain drug, another patient might benefit from the same treatment. The discovery of biomarkers and molecular signatures originating from nanoproteomics and nanogenomics contribute to fill this gap, leading to new, individualized avenues. The oncologist Leroy Hood has coined the expression of "P4 medicine", where the four P's stand for personalized, predictive, preventive, and participatory. This indicated a new approach to medicine, in discontinuity with the classical, conventional approach whereby diseases were diagnosed on the basis of symptoms and cured reactively, not proactively prevented, and through which drugs were administered mostly "ex adiuvantibus" and without rationale. This traditional approach resulted in failure despite enormous investment of resources. Prevention represents the core of this novel paradigm. For example, "personalized vaccinology" is emerging as a crucial component of the new framework of personalized medicine due to pathogen and host variability and the high degree of tumor heterogeneity that hinder the effectiveness of "universal" vaccines. Understanding molecular interactions, as captured by omics-based high-throughput devices and a unique combination of nanobioinformatics and label-free APA microarrays based on nanotechnologies such as mass spectrometry and nanoconductimetry that enable researchers to overcome the issues of fluoresce-based and other tagged/labeled tools, may lead to new targets and drugs, drawing the diagnosis and imaging, the therapeutics and drug delivery, and the prognosis very close. This is the concept of "nanotheranostics" (a port-manteau of diagnostics and therapeutics) focused on brain tumor.

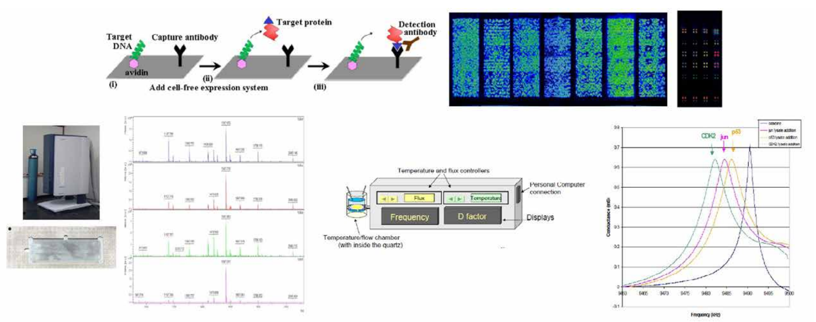

Figure 1: The shown mass spectrometry and QCM_D nanoconductimetry of NAPPA and SNAP APA (Anodic Porous Allumina) micrarrays lead to an effective nano approach to cancer when combined to innovative software for leader genes identification and for SPADS characterization of dominant protein-protein interactions.

Time Resolved Structure Determination of Biomolecules with X-ray Free Electron Lasers

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Abstract

The study of the dynamics biomolecules is one of the grand challenges of in the discovery of the building blocks of life as most structures determined so far only provide a static picture of the molecule. Serial Femtosecond Crystallography (SFX) provides a novel concept for structure determination, where X-ray diffraction "snapshots" are collected from a fully hydrated stream of nanocrystals, using femtosecond pulses from high energy X-ray free-electron lasers (XFELs) [1-4]. The XFEL pulses are so strong that they destroy any solid material, but a femtosecond is so short (1 fs = 10^{-15} s) that X-ray damage is diminished and diffraction from the crystals is observed before destruction takes effect [3]. It opens new avenues to determine molecular movies of Photosynthesis "in action" [6-10]. In this talk we will present results from recent experiments to study the dynamic processes in Photosystem II by light-induced time-resolved femtosecond crystallography conducted at LCLS, the X-ray Free Electron Laser in Stanford and also report preliminary results from the first time resolved studies on Photosystem I from the European XFEL in Hamburg, Germany.

The talk will close with a progress report on the development of compact femto and attosecond X-ray Sources at ASU (CXLS and CXFEL) and DESY (AXSIS) [11], which will provide unique new opportunities to study the ultrafast dynamics of reactions of biomolecules with a combination of X-ray diffraction, X-ray spectroscopy and ultrafast optical spectroscopy.

Acknowledgment

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Nanotechnology Enables Hot Gold Nanorods to Kill Cancer Cells and to Stop Alive Cells from Migrating and Killing More Sick People

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Abstract

Cancer kills many people after several years of suffering and after using a great deal of different unsuccessful treatments,

like surgery, chemical and/or radiation treatments. The field of nanotechnology showed us how different materials acquire so many different properties when their size is reduced to the nanometer scale. Gold nanoparticles having rod shape of nanometer size and a length:width ratio of 3:1 can absorb near infrared light (to which our body is transparent) and convert it into heat. If solution containing gold nanorods is injected into a cancer lump and exposed to near infrared light the hot solution (resulting from the gold nanorods upon absorbing the near infra-red light) melts the cancer cells leading to their death. This was demonstrated by our group in the photo-thermal destruction and destroying cancer cells in solution, in cancer lumps in small and in large animals [1-4].

Normally, some of the cancer cells that do not die are able to migrate to other parts of the body away from the location of their initial formation spot until they are located in a sensitive part of the body that leads to the cancer patient death. Thus, most of the cancer patients die from cancer after the cancer cells migrate by a process called metastasis to more a very sensitive part of the body.

Very recently, however, we discovered [5] that in our photo-thermal treatment, while treating cancer cells in the first cancer location with hot gold nano-rods, the cancer cell legs and arms and the motion proteins are photo-thermally destroyed. This makes it difficult for the cancer cells to migrate to new more important functional locations in the body. This treatment is thus effective in stopping cancer cell migration through the patient body and increases the success rate of the patient recovery.

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Nanomaterials for High Energy Conversion Efficiency

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Abstract

Materials in nano scale have better properties than their bulk. In this talk, I will discuss our studies on the high performance of nanostructured thermeoelctric materials, enhanced oil recovery by a novel amphiphilic nanofluid, and efficient water splitting to produce hydrogen by electrolysis using outstanding nano catalysts.

Novel Two-dimensional Materials

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Abstract

The talk will describe a series of novel two-dimensional (2D) materials that have recently been fabricated and imaged by collaborators and whose properties were examined by both experimental probes and density-functional-theory calculations. Imaging was done by either scanning transmission electron microscopy (STEM) or scanning tunneling microscopy (STM). Whereas most 2D materials have a hexagonal structure, we show experimental and theoretical results on monolayers of copper oxide that has a square lattice. Whereas in virtually all cases a monolayer exfoliated from a layered bulk material retains the intrinsic structure of a single bulk layer, we show experimental and theoretical results on Pd_2Se_3 monolayers that fuse together from two layers of bulk $PdSe_2$ by the emission of Se atoms. We also discuss novel 2D lateral heterostructures between monolayer Pd_2Se_3 and bilayer $PdSe_2$. We show that the growth of Si monolayers on Ru(0001) leads to several distinct 2D structures, leading up to silicene. Finally, we unveil a unique new family of "intrinsically patterned 2D materials" that allow selective or dual functionalization.

Primary collaborators: Wu Zhou, Matthew F. Chisholm, Junhao Lin, Kazu Suenaga (STEM), Yeliang Wang, Xiao Lin, Hong-Jun Gao (STM), Yu-Yang Zhang, Sebastian Zuluaga, Shixuan Du

Nanoparticles and Biomembranes

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Abstract

The endocytosis of nanoparticles by biomembranes is essential for many processes such as biomedical imaging, drug delivery, nanotoxicity, and viral infection. In all cases, the cellular uptake of the nanoparticles starts with the adhesion of the nanoparticles to the membranes, followed by the complete engulfment of these particles. The key parameters for these endocytic processes are particle size and adhesive strength of the particle-membrane interactions as well as bending rigidity and spontaneous (or preferred) curvature of the membranes [1, 2]. Under certain conditions, the nanoparticles may assemble into membrane nanotubes [3]. Complete engulfment of the nanoparticles generates an effective constriction force [4]. A sufficiently large force leads to membrane fission and particle uptake. The dependence of uptake on particle size is often nonmonotonic as observed for clathrin-dependent endocytosis of gold nanoparticles.

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DOS Engineering for New Nano-materials

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Abstract

The property of element is correlated directly with its electron configuration. In a solid, the density of states (DOS) at the Fermi level affects the physical and chemical properties. The method of alloying elements has been used to improve the properties of materials for many years. In particular, the solid-solution-type alloy is advantageous because tuning the compositions and/or combinations of the constituent elements can continuously control the properties. However, the majority of bulk alloys are of the phase-separated type under ambient conditions, where constituent elements are immiscible with each other. To overcome the challenge of the bulk-phase metallurgical aspects, we have focused on the nanosize effect and developed methods involving “non-equilibrium synthesis” or “a process of hydrogen absorption/desorption”. We propose a new concept of “density-of-states engineering” for the design of materials having the most desirable and suitable properties by means of “inter-element fusion”. Novel solid-solution alloys of Pd-Pt, Ag-Rh, and Pd-Ru systems in which the constituent elements are immiscible in the bulk state are presented and discussed [1]. Our present work provides a guiding principle for the design of a suitable DOS shape according to the intended physical and/or chemical properties and a method for the development of novel solid-solution alloys [2, 3].

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What Can We Learn from the High-Resolution Structure of the Heliobacterial Photosystem and Photosystem I of Cyanobacteria in Respect of Evolution of Photosynthesis and Nanotechnology?

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Abstract

The origin of photosynthesis is related to the first reaction centers which could convert the energy of sun light. As much our knowledge about photosystems and reaction centers has increased with structures of these membrane proteins since the mid-1980s, the trajectory of this important part of evolution is by far not understood.

With an estimated age of 4.6 billion years the planet earth had life with primitive organisms at least since 3.7 billion years ago. In these early times the earth atmosphere was strict anaerobic or oxygen free. Photosynthesis evolved from procyanobacteria which had an early branching to heliobacteria these gram-positive bacteria firmicutes are still to be found in volcanic muddy waters or even in rice paddies. The structure of the photosystem from Heliobacterium modesticaldum at 2.2 Å resolution gives the first insight how an ancestral photosystem has been organized.

Since around 3.5 billion years oxygen was produced which was enriched at 2.3 billion years ago to an oxygenic atmosphere. Cyanobacteria are still a major source of oxygen production on earth. The trimeric form of the cyanobacterial photosystem I has be now solved in our lab to 2.3 Å resolution which allows a direct comparison of structures and predictions about evolutionary developments. With the new structural knowledge obtained we try to translate this information to nanotechnology devices.

LB Protein Nanotechnology for Synchrotron Radiation and XFEL

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Abstract

Langmuir-Blodgett (LB) protein nanofilm technology is a novel approach for direct "on chip" protein molecules organization into the 3D ordered diffracting arrays. The specific properties of LB protein thin films (long range order, thermal stability, ability to trigger protein crystallization in those not crystallizable by classical methods) can be exploited by the new procedures for fixed target Serial Femtosecond Crystallography (SFX). This includes diffraction data collection from nanocrystals grown by LB nanotemplate and from multilayered LB films, deposited onto ad hoc designed chips with membrane windows of submicron thickness. The novel idea for this method for X-ray free electron laser (XFEL) is supported by previous extensive research and encouraging results obtained on LB nanofilms and nanocrystals properties by highly focused Synchrotron Radiation. SFX at XFELs has created many new opportunities for protein crystallography, including radiation damage mitigation and the study of dynamics at room temperature. This field is rapidly evolving, requiring new methods of macromolecule organization into diffracting arrays, since current methods of sample delivery are often the bottleneck which limits productivity. Indeed, the production of the protein crystals as well as their quality still remains the major problem for SFX. The combination of advanced LB nanotechnology with the XFEL has the potential to become an important tool for the structure determination of proteins that are difficult to crystallize, such as membrane proteins of life science interest and pharmaceutical industry impact.

Emerging Interconnect Technologies for Nanoelectronics

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Abstract

Modern electronics has advanced at a tremendous pace over the course of the last half century primarily due to enhanced performance of MOS transistors due to dimension scaling, introduction of new materials and novel device structures. However, while this has enhanced the transistor performance, the opposite is true for the copper interconnects that link these transistors. Looking into the future the relentless scaling paradigm is threatened by the limits of copper/low-k interconnects, including excessive power dissipation, insufficient communication bandwidth, and signal latency for both off-chip and on- chip applications. Many of these obstacles stem from the physical limitations of copper/low-k electrical wires, namely the increase in copper resistivity, as wire dimensions and grain size become comparable to the bulk mean free path of electrons in copper and the dielectric capacitance. Thus, it is imperative to examine alternate interconnect schemes and explore possible advantages of novel potential candidates. This talk will address effects of scaling on the performance of Cu/low-k interconnects, alternate

interconnect schemes: carbon nanotubes (CNT), graphene, optical interconnect, three-dimensional (3-D) integration and heterogeneous integration of these technologies on the silicon platform. Performance comparison of these technologies with Cu/low-k interconnects will be discussed.

ZnO Micro/Nanostructures Based Ultraviolet Photodetectors

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Abstract

Benefitting from the continuous innovations in semiconductor materials and device fabricating techniques, ultraviolet (UV) photodetectors have been successfully used in advanced communications, flame detection, air purification, ozone sensing and leak detection in the past few decades.

ZnO micro/nanostructures has been paid significant attentions in ultraviolet photodetectors due to their wide bandgap (about 3.37 eV at room temperature), abundant morphologies and ease preparation methods. Typically, post prepared ZnO micro/nanostructures show intrinsic n-type property and p-type ZnO is rather difficult to be realized. In this talk, we present various researches of composite structural ultraviolet photodetectors based on composite heterostructures between ZnO and different p-/n- type materials (such as SnO_2@ZnO core-shell, ZnO@Ga_2O_3 core-shell, ZnO/BiOCl heterostructures et al.). The two different semiconductors were artfully chosen to meet the requirement of forming type-II heterojunction (i.e., staggered gap). Therefore, in all of these devices, self-powered characteristic was shown because of the photogenerated electron-hole pairs can be collected by the built-in electric filed. Our device design method would provide a new approach to realize the high performance energy saving photodetectors.

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