UC San Diego –National Sun Yat-sen University

2019 Bilateral Research Symposium

Photonics and Materials Breakout Session I

FRIDAY AFTERNOON, MARCH 8, 2019

HENRY BOOKER'S CONFERENCE SUITE
ROOM 2512, JACOBS HALL

14:00 - 16:00 Photonics and Materials I (co-Chairs: Tsung-Hsien Lin, Paul Yu)

- Dr. Andrew Grieco, ECE Department, UC San Diego
  "Integrated Dispersive Fourier Transform Spectrometer"
- Chao-Kuei Lee, Professor, Department of Photonics, NSYSU
  "Efficient Octave Spanning Supercontinuum Generation from Ta_2O_5-based Nonlinear Waveguide"
- Tina Tse-Nga Ng, Professor, ECE Department, UC San Diego
  "Organic Materials and Devices for Shortwave Infrared Photodetectors"
- Chun-Ta Wang, Professor, Department of Photonics, NSYSU
  "Polarization Grating and its Applications"
- Sheng Xu, Professor, Department of NanoEngineering, UC San Diego
  "Controlled Homo-Epitaxial Growth of Hybrid Halide Perovskites"
- Chih-Yen Chen, Department of Materials and Optoelectronic Science, NSYSU
  "Self-powered GaN-based Nanowire LEDs"
- Dr. Shen Wang, Department of NanoEngineering, UC San Diego
  "Hole Transport Layer Components in Perovskite Solar Cells"
- Shi-Hsin Lin, Professor, Department of Materials and Optoelectronic Science, NSYSU
  "First-principles Calculations of the Hydrogen Evolution Reaction using Earth-abundant Pyrite CoS_2 as Electrodes"

ABSTRACTS

Integrated Dispersive Fourier Transform Spectrometer

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The integration of miniaturized optical spectrometers will have an enormous impact on applications ranging from remote sensing to mobile health technology. Conventionally, the Fourier transform (FT) spectrometer is the most successful design, combining superior throughput, noise tolerance, and absolute accuracy. However, miniaturization of this design to the chip-scale regime is confounded by the presence of strong optical dispersion present in waveguides, and nonlinearity in the material thermo-optic response. We present a theoretical method that accounts for these effects, and experimentally demonstrate a broadband integrated FT spectrometer. The unanticipated virtuous effects of optical dispersion in this class of device are also discussed.

Efficient Octave Spanning Supercontinuum Generation from Ta_2O_5-based Nonlinear Waveguide

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To achieve high bit rate signal processing in the integrated optical system, the ultrafast all-optical-modulator is regarded as the key element in the modern optical communication system. Up to date, number of material systems, such as Si, SiO, SiN and so on, have been chosen for nonlinear optical processing in waveguide photonics fields. However, the physical limitation on application is on the inevitable linear or nonlinear absorption performance. Recently, a low-loss and high-Q Ta_2O_5 based micro-ring resonator is developed and presented. The micro-ring resonator and channel waveguide with core area of the 700 by 400 nm^2 were fabricated on amorphous Ta_2O_5 thin films prepared by reactive sputtering with Q as high as $2x10^5$. Meanwhile, the nonlinear refractive index of Ta_2O_5 waveguide at 1550 nm as high as 4×10^{-14} cm^2/W was also reported. In this work, the progress of nonlinear optical properties of low loss waveguide based on Tantalum Pentoxide (Ta_2O_5) will be introduced. The anomalous dispersion Ta_2O_5 based waveguide was designed and fabricated for super-continuum generation (SCG) due to its nature of two photon absorption free and high optical nonlinearity. The measurements show that SCG ranging from 585 to 1697 nm (at -30 dB) is obtained at a pumping wavelength of 1056 nm and the spectrum broadens at least 1.5 octaves. The pumping power of the aforementioned spanning result is 396 W, much lower than other materials for achieving the same SCG result that had been reported. In addition, the SCG from high order mode waveguide will be discussed as well.

Keywords: Ta_2O_5; Nonlinear waveguide; Super continuum

Organic Materials and Devices for Shortwave Infrared Photodetectors

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The shortwave infrared spectral region (SWIR: 1-3 μm) is particularly powerful for health monitoring and medical diagnostics, because biological tissues show low absorbance and minimal SWIR auto-fluorescence, enabling greater penetration depth and improved resolution in comparison to visible light. However, current SWIR photodetection technologies are largely based on epitaxially grown inorganic semiconductors which are costly because of complex processing. Organic semiconductors offer numerous advantages including large-area and conformal coverage, biocompatibility, and low-cost integration for enabling ubiquitous SWIR optoelectronics. This talk will discuss organic SWIR devices and discuss the main bottlenecks associated with charge recombination and trapping, which are more challenging to address in narrow bandgap photodetectors in comparison to devices employing wider bandgap materials that operate in the visible. The performance of organic SWIR photodetectors is rising with detectivity exceeding 10^{11} Jones, comparable to commercial germanium photodiodes. Several integrated system demonstrations will show the various potential applications of organic SWIR photodiodes including spectroscopic identification and image reconstruction.

Polarization Grating and its Applications

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Polarization gratings (PG) formed by space-variant anisotropic media with a periodic distribution are a special class of diffraction gratings that can deflect or split light. In general, polarization gratings are polarization-dependent devices and exhibit only three diffraction orders, 0th and ±1st order. When operating at half-wavelength condition, the polarization grating can completely diffract the incoming wave into the ±1st orders and convert the incoming wave into two circularly-polarized waves with opposite helicities; therefore, an extremely high diffraction efficiency of the grating can be obtained when the incoming wave is circular polarized light. This makes them promising for use in many applications such as beam switching, steering, and optical coupling.

In this work, we realized a >95% diffraction efficiency polarization grating based on liquid crystals (LCs) with large birefringence. To realize the periodic structure of the polarization grating, the photo-alignment technique and polarization holographic exposure were used to create the periodic alignment of liquid crystal molecules. The fabricated polarization grating exhibits excellent diffraction performance. In addition, we further proposed a bistable electrical switching operation in a liquid crystal polarization grating by combining a π-bistable twisted nematic (π-BTN) cell as a polarization converters.Such a π-BTN cell, based on dual-frequency liquid crystals, has a twist structure, with 0° and 180° twist states. Both states can provide suitable phase retardation to switch the polarization of the laser beam and change the diffraction behavior of the LCPG, and both states are stable and can be reversibly switched to each other by applying a low- or a high-frequency voltage pulse.

Keywords: Polarization grating; Photo-alignment; Bistable operation

Controlled Homo-Epitaxial Growth of Hybrid Halide Perovskites

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Organic–inorganic hybrid perovskites have demonstrated tremendous potential for the next-generation electronic and optoelectronic devices due to their remarkable carrier dynamics. Current studies are focusing on polycrystals, since controlled growth of high quality single crystals is extremely challenging. In this presentation, I will discuss the first chemical epitaxial growth of single crystal hybrid halide perovskites with controlled locations, morphologies, and orientations, using combined strategies of advanced microfabrication, homoepitaxy, and low temperature solution method. The growth is found to follow a layer-by-layer model. A light emitting diode array, with each perovskite crystal as a single pixel, with enhanced quantum efficiencies than its polycrystalline counterparts is demonstrated. This approach opens up broad opportunities for hybrid halide perovskite materials based high performance electronic and optoelectronic devices.

Self-powered GaN-based Nanowire LEDs

Chih-Yen Chen

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Single-crystal n-type GaN nanowires have been grown epitaxially on a Mg-doped p-type GaN substrate. Piezoelectric nano generators based on GaN nanowires are investigated by conductive AFM, and the results showed an output power density of nearly 12.5 mW/m^2. Luminous LED modules based on n-GaN nanowires/p-GaN substrate have been fabricated. CCD images of the luminescent LED and the corresponding electroluminescence spectra are recorded at a forward bias. Moreover, the GaN nanowire LED can be lighted up with the power provided by a ZnO nanowire based nanogenerator, demonstrating a self-powered LED using wurtzite-structured nanomaterials.

Keywords: GaN nanowires; LED; Piezoelectric; Nanogenerator; Self-powered system

Hole Transport Layer Components in Perovskite Solar Cells

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The perovskite solar cell (PSC) is a photovoltaic device. With the tunable bandgap, long carrier diffusion length, and low exciton binding energy of various perovskite materials, power conversion efficiency (PCE) of 23.7% has been achieved. However, low device stability limits its further application and commercialization.One of the major bottlenecks hindering the improvement of device stability is the interaction of components in the hole transport layer: lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) and 4-tert-butylpyridine (tBP). LiTFSI is hygroscopic and accelerates perovskite decomposition. tBP, which evaporates easily, is corrosive to perovskite materials. Previous research has assumed that tBP and LiTFSI have similar working mechanisms in perovskite solar cells as what they performed in solid-state dye-sensitized solar cells (ss-DSSCs). However, due to the different device configurations and functional layers, their roles in PSCs had been changed. In our study, a spectrum-dependent mechanism for the oxidation of hole transport material 2,2′,7,7′-tetrakis(N,N-di-p-methoxyphenylamine)-9,9′-spirobifluorene (Spiro-OMeTAD) with LiTFSI in PSCs was proposed. Regarding tBP, we confirmed its role as a HTL morphology controller in PSCs for the first time. We also observed the formation of tBP-LiTFSI complexes in PSCs. These complexes in PSCs can alleviate the negative effects of tBP and LiTFSI while maintaining their positive effects on perovskite materials. Our understanding of the functions of these hole transport layer components and perovskite on a molecular level paves the way for further improvements to PSCs performance.

First-principles Calculations of the Hydrogen Evolution Reaction using Earth-abundant Pyrite CoS_2 as Electrodes

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In this work, we investigated hydrogen evolution reaction using earth-abundant pyrite CoS_2 as electrodes, with first-principles calculations. Hydrogen has been considered as a strong candidate for clean energy. How to produce hydrogen with lower costs is then the first problem. CoS_2 recently has been adopted as the electrode for hydrogen evolution reaction (HER), and showed good performance. However, the active facets were not fully identified. We therefore calculated the HER performance of various facets to identify all reactive facets. Thus, it is possible to enhance the production with maximizing those effective planes with crystal-growth techniques and nano-structures. Furthermore, we computed the density of states to analyze the mechanism. Applying the mechanism, we investigated new materials possibilities utilizing alloys and doping with other elements to boost the HER efficiency.

Keywords: Hydrogen evolution reaction; Pyrite; First-principles calculation