A ferroelectric fin diode for robust non-volatile memory

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Keywords: ferroelctrics, in-memory computing, nonvolatile memory

Among today’s nonvolatile memories, ferroelectric-based capacitors, tunnel junctions and field-effect transistors (FET) are already industrially integrated and/or intensively investigated to improve their performances. Concurrently, because of the tremendous development of artificial intelligence and big-data issues, there is an urgent need to realize high-density crossbar arrays, a prerequisite for the future of memories and emerging computing algorithms. Here, a two-terminal ferroelectric fin diode (FFD) in which a ferroelectric capacitor and a fin-like semiconductor channel are combined to share both top and bottom electrodes is designed. Such a device not only shows both digital and analog memory functionalities but is also robust and universal as it works using two very different ferroelectric materials. When compared to all current nonvolatile memories, it cumulatively demonstrates an endurance up to 1010 cycles, an ON/OFF ratio of ~10^2, a feature size of 30 nm, an operating energy of ~20 fJ and an operation speed of 100 ns. Beyond these superior performances, the simple two-terminal structure and their self-rectifying ratio of ~ 10^4 permit to consider them as new electronic building blocks for designing passive crossbar arrays which are crucial for the future in-memory computing.

Reference:

Guangdi Fen#, Qiuxiang Zhu#, Xuefeng Liu, Luqiu Chen, Xiaoming Zhao, Jianquan Liu, Shaobing Xiong, Kexiang Shan, Zhenzhong Yang, Qinye Bao, Fangyu Yue, Hui Peng, Rong Huang, Xiaodong Tang, Jie Jiang, Wei Tang, Xiaojun Guo, Jianlu Wang, Anquan Jiang, Brahim Dkhil, **Bobo Tian***, Junhao Chu and Chungang Duan. A ferroelectric fin diode for robust non-volatile memory, **Nature Communications**, 15, 513 (2024).

A flexible wearable cross shaped transducer array for blood pressure estimation

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Keywords: 1–3 piezoelectric composite flexible cross-shaped array ultrasound noninvasive

Continuous blood pressure testing is an important method of assessing the body's cardiovascular health and blood circulation in everyday life. A normal blood pressure range is also essential for human health. Existing common blood pressure measurement solutions are not suitable for wearable long-term daily blood pressure monitoring purposes due to the large size of the devices and the fact that the measurement process can cause some discomfort to the human body making them impossible. In this study, a simple multilayer flexible piezoelectric composite ultrasound transducer array is proposed, which can be co-conformable with the skin, and the ultrasound device is capable of continuously tracking the changes in the arterial vessel wall over a long period of time for long-term non-invasive measurement of blood pressure. In the overall array, a single transducer oscillator element is designed and prepared from a 1-3 piezoelectric material with a high electromechanical coupling coefficient composite of PZT-5H and epoxy resin (EPOXY) with a copper-PI stretchable electrode. And the designed two-dimensional array transducer is different from other matrix arrays in that the Mills cross-cross structure can significantly increase the size of the transmitted sound pressure in the centre, and the transducer array as a whole can be delayed and focused towards the centre by less serpentine alignment design. The average frequency and -6 dB main flap width of the flexible piezoelectric array are 5 MHz and 0.3 mm, respectively, which determine the lateral resolution of the transducer array, as

analysed by simulation with field II software.

A solar-blind photodetector based on the metal-doped Ga2O3 films

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Keywords: Ga2O3, RF-sputtering, metal-doping, solar-blind

This research proposes a solar-blind photodetector based on the gallium oxide (Ga_2O_3) films via slight nickel (Ni) doping. The Ni-doped Ga_2O_3 films are deposited using radio-frequency (RF) magnetron sputtering at different argon/oxygen flow ratio as well as a particularly low power density range. The *in situ* optical emission spectroscopy as a crucial evidence is used to investigate the influence of the plasma radicals. Meanwhile, the proposed conductive mechanism can be mainly owing to the variation of the Ni^{3+} ratio and non-lattice oxygen ratio. Finally, a high performance photodetector at an optimized growth condition of the Ni-doped Ga_2O_3 films is explored. The low dark current, high on/off ratio, and short rise/decay time are also measured. This development provides a significant benchmark for undergoing extensive research or large-area industrialization.

Achieving low subthreshold swing of thin film transistors by adoption of high-k HfO2 dielectric annealed at different atmospheres

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Keywords: hafnium oxide; oxide semiconductor; thin film transistor (TFT); high power impulse magnetron sputtering; post-annealing

In this work, high permittivity (high-*k*) hafnium oxide (HfO_2) was adopted as gate dielectric layer of oxide thin film transistors (TFTs), The HfO_2 dielectric layer was deposited by high-power impulse magnetron sputtering (HiPIMS) followed by post-annealing treatment at different atmospheres to improve dielectric properties. The effects of atmospheres during post-annealing treatment on the dielectric properties and TFT performance were investigated. The dielectric properties of HfO_2 film were improved after annealed at 400 ^{o}C in different atmospheres. The HfO_2 film exhibited a *k* value of 25.7, which should be attributed to the high density of 10.2 g/cm^3 after annealed at 400 ^{o}C in nitrogen (N_2, 90%)-hydrogen (H_2, 5%) forming gas. Oxide TFTs with the HfO_2 dielectric layer annealed in forming gas exhibited the lowest subthreshold swing (*SS*) of 65.4 mV/decade. The low *SS* value is of importance for lowering the operation voltage of the TFTs.

Advancements in Micro-nano Fabrication for Thin-Film Lithium Niobate Nanodevices in Integrated Photonics

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Keywords: Plasma Etching, Thin film lithium niobate; Integrated photonics; Nanofabrication

Thin film lithium niobate (LiNbO3) on insulator (LNOI) has emerged as a promising material platform for integrated photonics devices due to its exceptional optical and electro-optical properties, for instance, wide transparent window, high refractive index, substantial electro-optical coefficient, broad intrinsic bandwidth, and minimal optical loss. Despite its potential, challenges persist in the nanofabrication of LNOI, particularly in achieving precise etching control, such as achieving higher etching rates, creating smooth sidewalls, and realizing steep sidewall angles. This report provides an overview of the fabrication techniques for high-quality single crystal thin film LNOI wafers, notably employing crystal ion slicing. Additionally, it reviews various advanced nanofabrication techniques tailored for high-quality LNOI photonic devices, emphasizing methods to enhance etching rates, achieve smooth sidewalls, and create steep sidewall angles. Techniques such as focused-ion-beam (FIB) etching, Ar ion beam etching (IBE), high-density plasma dry etching using inductively coupled plasma (ICP) and reactive ion etching (RIE), as well as hybrid ICP-RIE plasma dry etching, are discussed. Finally, the potential applications of LNOI integrated photonics in large-scale ultra-low-loss photonic circuits are highlighted, along with the associated challenges and opportunities for future research and development.

All-day uninterrupted thermoelectric generator by simultaneous harvesting of solar heating and radiative cooling

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Symposium: 11. Thin Film Devices (TFD)
Keywords: Temperature difference;Ultra-broadband solar absorber;Electrical power generation;

Passive power generation has recently stimulated interest in thermoelectric generators (TEGs) using the radiative cooling mechanism. However, the limited and unstable temperature difference across the TEGs significantly degrades the output performance. In this study, an ultra-broadband solar absorber with a planar film structure is introduced as the hot side of the TEG to increase the temperature difference by utilizing solar heating. This device not only enhances the generation of electrical power but also realizes all-day uninterrupted electrical output due to the stable temperature difference between the cold and hot sides of the TEG. Outdoor experiments show the self-powered TEG obtains maximum temperature differences of 12.67 °C, 1.06 °C, and 5.08 °C during sunny daytime, clear nighttime, and cloudy daytime, respectively, and generates output voltages of 166.2 mV, 14.7 mV, and 95 mV, respectively. Simultaneously, the corresponding output powers of 879.25 mW/m ^{2} , 3.85 mW/m ^{2} , and 287.27 mW/m ^{2} are produced, achieving 24-hour uninterrupted passive power generation. These findings propose a novel strategy to combine solar heating and outer space cooling by a selective absorber/emitter to generate all-day continuous electricity for unsupervised small devices.

An Innovative Self-Cleaning Nanoparticle Hybrid Coating for Highly Efficient, Sustainable All-Day Passive Radiative Cooling

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Symposium: 11. Thin Film Devices (TFD)
Keywords: Daytime radiative cooling; High humidity; Self-cleaning; Superhydrophobic coating

Radiative cooling, a method that offers cooling without the need for energy consumption, presents an environmentally friendly solution. Despite significant advancements, many radiative cooling materials are hindered by their high cost and vulnerability to outdoor pollutants. This is particularly problematic in humid environments, where nighttime dew can accumulate on cooling surfaces, reducing their effectiveness. To address these challenges, we have developed a novel radiative cooling structure composed of three distinct layers: a top layer of superhydrophobic SiO2 nanospheres, a middle layer made of polyvinyl fluoride (PVF), and a metallic silver (Ag) bottom layer. The SiO2 nanosphere layer fulfills a dual function: it scatters light efficiently, achieving an ultrahigh solar reflectivity of 94.2%, and its nanoscale textured surface with low surface energy promotes self-cleaning, achieving a maximum surface contact angle of 154°. Additionally, infrared phonon-polaritonic resonances, such as the Si-O-Si bond in SiO2 and the -C-F group in PVF, ensure a high average thermal emissivity (>90%) within the atmospheric transparency window (8–13 μm). Conducted outdoor experiments in the hot and humid conditions of Xiamen, China, our cooling structure demonstrated impressive results. Under direct sunlight, it achieved a significant sub-ambient cooling effect, lowering surface temperatures by approximately 3.3°C and ambient space temperatures by around 2.4°C. Further, experiments with a tilted radiator surface during humid nights revealed enhanced cooling performance. Importantly, the coating's superhydrophobic and self-cleaning characteristics effectively mitigate issues related to outdoor pollution and surface wetting. This makes it an exceptionally promising solution for building cooling applications.

Asymmetric supercapacitor fabrication based on thin film electrodes doped with AgNWs, MoS2, and MXene

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Symposium: 11. Thin Film Devices (TFD)
Keywords: AgNWs, Asymmetric supercapacitors, MXene, MoS2, Ti3C2Tx

Today, supercapacitors and batteries are the trend in electrochemical energy storage devices. However, their low energy density and uncertain power density limit their applications. Asymmetric supercapacitors are attracting attention because of their ability to increase the operating potential window and the advantage of higher energy density. In the positive electrode, $MoS_2/Ti_3C_2T_x$ composite material is synthesized in this study. By combining the framework structure of $Ti_3C_2T_x$ and MoS_2 with high specific capacitance, excellent multiplicity performance, and excellent electrochemical stability, the two materials achieve the effect of supporting each other and avoiding the agglomeration, which not only increases the stability of the electrode, but also strengthens the ability of charge transfer. At the negative end, a self-synthesized AgNWs@MoS_2 core-shell structured composite material was used to improve the electrical conductivity of MoS_2 with silver nanowires, and the silver nanowires were used as a framework for the growth of MoS_2 to enhance its electrochemical stability, interfacial storage, and transport capability. Finally, the electrodes were fabricated by ultrasonic spraying and assembled into AC-$MoS_2/Ti_3C_2T_x$//AC-AgNWs@MoS_2 asymmetric supercapacitors and tested in two and three electrode setups. Experimental results show that compared with the AC//AC electrode, the specific capacitance value of the AC-$MoS_2/Ti_3C_2T_x$//AC-AgNW@MoS_2 electrode increased from 278.7 to 414.5 F/g, and the R_{ct} also decreased from 17.7 Ω to 6.7 Ω. Therefore, $MoS_2/Ti_3C_2T_x$ as well as AgNW@MoS_2 can be regarded as promising asymmetric supercapacitor electrode materials.

Biomimetic Microstructures for Radiation Colling

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Symposium: 11. Thin Film Devices (TFD)
Keywords: Radiation Colling; Radiation Colling

Buildings thermal management consumes 51% of the world’s energy use. Optimization of the energy use can be potentially achieved *via* daylight harvesting and radiative cooling approaches, yet their simultaneous utilization under static conditions is challenging due to opposite operation principles. Here, an in-situ switchable photoselective polymer (PSP) material was prepared by sequential electrospinning of light-reflecting and light-absorbing layers made of contrasting polymer nanofibers. As-prepared PSP material exhibited high solar light reflectance of 97.7% and high broadband emissivity of 94.9% resulting in radiative cooling power 111.1 $W \cdot m^{-2}$. Such “cooling” state of the PSP film can be easily switched to a “heating” one *via* impregnation of the index matching liquid that suppresses scattering at the film-air interface and reduces solar band reflectivity of the film. Thanks to the highly porous structure of the designed PSP film, its switching takes less than 5 min and allows to achieve an integrated solar absorbance of ~95.6% resulting in the estimated heating power of 781.6 $W \cdot m^{-2}$. Performed numerical calculations further supported high potential of the developed PSP film for thermal management of the buildings located at high latitudes with the energy savings up to 89.74 GJ m^{-2} y^{-1} and reduced CO_2 emissions down to 21.69 t.

CeOx Thin Films as Transparent Nanomaterials for Efficient Gas Sensing

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Keywords: cerium oxide, electron beam evaporation, gas-sensor, nanocrystalline thin film, response at low temperature, transparent oxide sensor

In this study the sensor properties of transparent CeOx thin film nanostructures fabricated through electron beam evaporation (EBE) have been described. An additional Pd film was also as-deposited as a top catalyst layer (using EBE technique). Analysis via GIXRD revealed that the prepared films were nanocrystalline, consisting of CeO_2 crystallites with an average size of approx. 7 nm. The transparency of the CeOx film was around 80% in the visible (VIS) range. However, the addition of a Pd-layer (<10 nm thick) led to a decrease in transparency to around 60%.

The primary focus of prepared transparent CeOx thin-film structures lies in their gas-sensing capabilities, particularly in resistance changes. Remarkably, these sensors exhibited high and rapid responses, even at room temperature. Exceptional sensitivity, with a sensor response (SR) reaching approximately 5x10^3, was achieved for 25 ppm of H_2 at 200°C. Even at a mere 35°C, the resistance change remained significant, reaching a level of 30% (SR = 1.3). These findings underscore the immense potential of CeOx thin-film nanomaterials, which, owing to their high transparency and responsiveness at near-room temperatures, can be deployed in transparent sensor configurations with low energy consumption.

Furthermore, a comprehensive characterization of the manufactured CeOx-based thin-film nanostructures has been conduct. This involved optical characterization based on transmission and reflection measurements, surface analysis via AFM and cross-sectional examination using SEM/EDS, employing Xe-PFIB preparation. Additionally, thorough investigations using photoelectron spectroscopy were carried out to study changes in the oxidation state of cerium under various gas atmospheres. These studies aimed to elucidate the operational mechanism of the sensor and identify the factors influencing its sensor response.

Characteristic of Amorphous Oxide-Based Thin Film Transistors Using Metal Capping Layer

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Keywords: TFT / PLD / Sputtering / Deposition

The number of pixels in displays is continuously increasing for high-quality next generation displays. In particular, an increase in TFT mobility is required. In these respects, oxide semiconductors are reliable as high-mobility TFT materials for next-generation displays. In-Zn series oxide semiconductors have higher mobility due to the large bandgap energy compared to amorphous silicon semiconductors. In addition, oxide semiconductors have the advantages of low-temperature process and being easy to expand into large area.

In this study, we have proposed a capping layer using Al(aluminum) to improve electrical characteristics and stability. IZTO(In-Zn-Sn-O) using PLD (Pulsed Laser Deposition) process was deposited to improve the quality of the thin film. And we compared the mobility of two types TFTs fabricated by PLD and sputtering and analyzed the electrical properties of a reference TFTs without a capping layer.

The reference TFT was measured in mobility of 10.6 $cm^2/v{\cdot}s$, a Vth(threshold voltage) of 5.7 v, an on/off ratio of $2x10^7$, and a S.S(subthreshold swing) of 0.66 decade/v. The low mobility of the reference TFTs was increased through the Al capping layer. The improvement in electrical properties was attributed to the high oxidation capability of Al_2O_3, which leads to increased oxygen vacancies and elevated carrier concentration in the channel layer. The hysteresis curves also were measured to evaluate the reliability of the Al capping TFTs. These results indicated that the ΔVth (threshold voltage shift) tend to decrease as the thickness of the Al capping layer increases. This experiment confirmed that incorporating an Al capping layer enhances TFTs overall electrical performance and reliability.

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Circularly polarized light from organic hybrid nanostructures

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Symposium: 11. Thin Film Devices (TFD)
Keywords: Perovskite; microwires; photodetector

Chiral materials and their mirror images, known as enantiomers or enantiomorphs, exhibit intriguing physical properties such as circular dichroism, circularly polarized luminescence, nonlinear optics effects due to their non-centrosymmetric structures. Halide perovskites have been demonstrated as a promising class of optoelectronic materials with unique optoelectronic properties, including flexible crystal structures, long charge carrier diffusion lengths, high dielectric constants, highly tunable bandgaps, high optical absorption coefficients, and strong spin-orbit coupling, making them suitable for various applications such as light-emitting diodes (LEDs), photonics, photodetectors, and solar cells.

In our works, the chirality can be transferred from chiral organic ligands to halide perovskites, resulting in chiral perovskites that combine the advantages of chiral materials and halide perovskites, providing an ideal platform for designing the next generation of optoelectronic and spintronic devices. The chiral structures of lead iodide perovskite film with NEA+ as cation were fabricated by one-step solution process. The obtained film thickness can be tuned from 280 nm to 220 nm. Therefore, successfully introducing chirality into perovskites to enable potential applications in circularly polarized light photodetectors, memory devices, and spin transistors remains a challenging research topic.

Deposition mechanism of the Eu-doped NiO thin film prepared by RF-sputtering at different oxygen partial pressure

by Ruo-Yan Huang | Yu-Quan Zhu | Wei-Jia Wang | Jyn Liu | Li-Feng Lin | Yan Wang | Xian-Lin Wu | Yujie Mei | Yao-Tian Wang | Jia-Hao Yan | Shui-Yang Lien | Chien-Jung Huang | Zong-Liang Tseng | Pao-Hsun Huang | School of Ocean Information Engineering, Jimei University | School of Ocean Information Engineering, Jimei University | School of Ocean Information Engineering, Jimei University | School of Ocean Information Engineering, Jimei University | School of Ocean Information Engineering, Jimei University | School of Ocean Information Engineering, Jimei University | School of Ocean Information Engineering, Jimei University | School of Ocean Information Engineering, Jimei University | Xiamen Key Laboratory of Development and Application for Advanced Semiconductor Coating Technology; The School of Opto-electronic and Communication Engineering, Xiamen University of Technology | Xiamen Key Laboratory of Development and Application for Advanced Semiconductor Coating Technology; The School of Opto-electronic and Communication Engineering, Xiamen University of Technology | Xiamen Key Laboratory of Development and Application for Advanced Semiconductor Coating Technology; The School of Opto-electronic and Communication Engineering, Xiamen University of Technology, China; Department of Biomedical Engineering, Da-Yeh University, Taiwan | Department of Applied Physics, National University of Kaohsiung, Kaohsiung 81148, Taiwan | Organic Electronics Research Center, Ming Chi University of Technology, New Taipei City 24301, Taiwan | School of Ocean Information Engineering, Jimei University

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Keywords: Eu-doping, NiO, RF-sputtering, oxygen partial pressure

This research proposes a deposition mechanism for the Eu-doped NiO thin film prepared by radio-frequency (RF) magnetron-sputtering. The influences of different oxygen partial pressures on films are analyzed. The experimental results show that at different oxygen partial pressures, the variation in adsorption and desorption on the surface can be mainly induced by the plasma radicals of ionized argon and oxygen. The crystalline structure, growth of the Eu, O, and Ni atoms is controlled at proper oxygen partial pressures to obtain the optical optimization of transmittance and reflectance. The carrier concentration and mobility as well as the electrical properties, are usefully estimated by hall-effects measurement. Furthermore, the RF magnetron-sputtering Eu-doped NiO films at different oxygen partial pressures reveal the huge reference condition for optoelectronic devices.

Design of F-P cavity multilayer planar films based on Bragg grating structure

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Symposium: 11. Thin Film Devices (TFD)
Keywords: F-P cavity; multilayer planar films; Bragg mirror structure; infrared wavelength band

In this paper, we propose a method for exciting multiple infrared reflection peaks through the utilization of a multilayer planar membrane design. This design consists of four sets of planar membranes, employing silicon and silicon dioxide as the principal combining units, with a thicker layer of silicon positioned in the middle. By drawing inspiration from the Bragg mirror structure design, we analyze the reflection characteristics of the combined F-P cavity and distributed Bragg mirror structure using the transmission matrix method (TMM) and finite element algorithm. This structure allows us to obtain a series of narrower reflection peaks.

Furthermore, we investigate the impact of various factors, such as the number of groups, interlayer materials, and the presence or absence of metals, on the reflectance spectra of the multilayer structure. This comprehensive analysis provides valuable insights for the fabrication of optimized multilayer structures.

Notably, our design differs significantly from current multilayer planar membrane structures, which often focus on achieving near-perfect absorption in the visible to near-infrared range or require electrochemical methods to create porous material structures. Instead, our approach enables narrow-band filtering across the near-infrared to mid-infrared wavelength bands. Moreover, by substituting the interlayer material, this filtering capability can be leveraged for refractive-index sensing applications.

Overall, multilayer planar films, as optical devices with excellent performance and flexible design characteristics, have vast potential in areas such as fiber optic communications and lasers. Our research not only contributes to the expansion of optical system functionality but also facilitates performance optimization, thus providing crucial technical support for the advancement of optical technologies.

Designing Two-Dimensional Laser Frequency Doubling Materials from Traditional Crystals

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Symposium: 11. Thin Film Devices (TFD)
Keywords: computational simulation, laser frequency doubling, nonlinear optics, optical quantum devices, two-dimensional material

The requirements of novel laser devices call for novel nonlinear optical(NLO) materials, especially laser frequency doubling(LFD) materials. However, traditional three-dimensional(3D) bulk crystals can hardly be further improved due to the conflicts among the requirements of bonding structure. Specifically, scientists lack prominent LFD materials in (deep)ultra-violet(UV) region for common laser sources, general optical quantum devices and cutting-edge photonic chips.

Our work concentrates on designing two-dimensional(2D) materials with atomical thickness from the corresponding 3D crystals, especially the crystals which are popular NLO materials. The basic idea is that the 2D derivatives generally have two to three magnitudes larger LFD coefficients and wider transparent regions than the 3D crystals, and inherit the merits like phase match behavior, physical and chemical stability, and acceptable preparation cost. Though some 2D materials have lower laser-induced damage threshold(LIDT), they can still work on quantum devices due to very low pump laser intensity.

The simulation uses the QUANTUM ESPRESSO and YAMBO package to realize time-dependent(TD) Green Function and Bethe-Salpeter Equation(GW-BSE) methods. So the calculation results include many-body effect and exciton effect, which are critical to 2D materials' optical properties.

Specifically, we have calculated two models: periodically poled monolayer lithium niobate(PP-ML-LN) from periodically poled lithium niobate(PPLN), and atomically thick barium borate(AT-BBO) from alpha- and beta-BBO crystal.

3D PPLN is a ferroelectric material for frequency conversion in optical quantum devices. We do computational exfoliation in xy plane to get PP-ML-LN. PP-ML-LN has the flexible domain modulation ability and works well on several NLO processes.

Beta-BBO is a commercial NLO crystal, and alpha-BBO is a commercial birefringent crystal.

AT-BBO keeps the planar triangular borate anion of alpha- and beta-BBO, so AT-BBO inherits the large NLO coefficients and wide optical transparent region. This makes AT-BBO a promising NLO material working in deep UV and for multi-photon generators.

Development of gallium-oxide-based non-enzymatic glucose sensing materials for biomedical detection applications

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Keywords: extended-gate field-effect transistors, gallium oxide, glucose sensing, hydrothermal synthesis, pH sensing

This comprehensive study delves into the multifunctional applications of gallium oxide (Ga2O3) nanorods, specifically focusing on pH sensing, real-time living cell viability monitoring, and dual-functional pH-glucose sensing. Ga2O3 nanorods, grown on ITO/glass substrates via chemical bath deposition and hydrothermal synthesis, underwent thorough characterization using various techniques. The resulting nanorods displayed crystalline orientations and excellent crystal quality. For pH sensing, Ga2O3/ITO extended-gate field-effect transistors (EGFETs) exhibited high sensitivity, excellent linearity, and long-term stability. Real-time cell viability sensing using Ga2O3/ITO/glass EGFETs, based on cellular metabolism, demonstrated superior hydrogen ion sensing sensitivity and stability compared to other configurations. The study also explored the synthesis of Ga2O3 nanorods through hydrothermal methods, showcasing their dual functionality for pH and glucose sensing. The hydrothermal-synthesized Ga2O3 nanorods demonstrated superior linearity and sensitivity for pH sensing and maintained a concentration-dependent relationship for glucose detection. Stability and biocompatibility tests further confirmed their consistent performance. In summary, Ga2O3 nanorods, whether synthesized through chemical bath deposition or hydrothermal methods, exhibit promising characteristics for pH sensing, glucose detection, and real-time living cell viability studies. The extensive analysis of their crystalline structure, sensitivity, and stability positions Ga2O3 nanorods as versatile materials for various sensing applications, showcasing their potential impact in both biomedical and environmental monitoring domains.

Effect of Ar/O2 plasma parameters on plasma-enhanced atomic layer annealing of dielectric thin films

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Keywords: Capacitor, High-k thin film, PEALD

Miniaturization is essential in order to integrate a large amount of capacitors in one package. Due to miniaturization, the thickness of the dielectric film becomes thinner, resulting in leakage current. It is replaced with a high dielectric constant material and the thickness is increased to prevent leakage current. High dielectric constant materials can have high leakage current due to their low energy gap. Additionally, leakage current may occur due to voids and particles within the thin film. Additional processes at high temperatures are necessary to reduce voids and crystallize. Atomic layer deposition is used to deposit high-quality thin films without voids and particles. Atomic layer annealing is performed using additional source plasma conditions (power, pressure). Atomic layer annealing uses ion energy in plasma to collide with a thin film. By raising the surface temperature layer-by-layer, the thin film adatom is displaced, causing crystallization and filling the voids to deposit a high-quality thin film.

In this study, atomic layer annealing was performed every cycle as an additional step after oxidation in one chamber. By varying the gas partial pressure in the plasma used for atomic layer annealing, differences in physical and chemical effects on atomic layer annealing were confirmed. We attempted to control crystallinity by confirming the optimal partial pressure, controlling ion energy by adjusting the intensity of the plasma, and controlling the plasma ion density by changing the process pressure. The chemical composition confirmed that voids and particles were reduced due to adatom displacement of the thin film. Atomic layer annealing was applied to the dielectric film to crystallize it, reducing equivalent oxide thickness by 33% from 1.25 nm to 0.84 nm, and leakage current density was confirmed to decrease within 1 x 10^{-1} A/cm^2.

Effect of Low Temperature Ozone Annealing on Thin Film Transistors with Gradient Active Layer

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Keywords: IGZO, Thin film transistor (TFT), low temperature, ozone annealing

Amorphous IGZO thin film transistors (TFTs) with gradient channel was fabricated by high power impulse magnetron sputtering. Ozone annealing treatment at different temperatures was carried out the improve the TFT performance. A subthreshold swing as low as 147 mV/decade was achieved after annealed at 75–100 ℃. The TFT performance stability under positive and negative bias stress were also improved. These results suggested that the deep-level trap state density in the channel and at the channel/insulator interface was reduced after annealing. X-ray photoelectron spectra revealed that the oxygen vacancy defects in the channel was reduced. Annealing at higher temperature led to the deterioration of the carrier mobility, possibly due to scattering center originated from the excess oxygen in the channel and channel/insulator interface. The results suggested that ozone annealing is more suitable for low temperature annealing.

Effect of TiN buffer layer on the performance of Ga2O3-based solar-blind UV photodetectors

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Symposium: 11. Thin Film Devices (TFD)
Keywords: Ga2O3, UV detectors, buffer layer

Gallium oxide (Ga_2O_3), as an ultra-wide bandgap semiconductor (4.2-5.3eV), has attracted extensive attention in recent years and is regarded as a promising material for solar-blind ultraviolet detectors. As we all know, Ga_2O_3 contains five phases- α, β, γ, δ and ε, and the property of monoclinic β-Ga_2O_3 is the most stable among them. The other metastable phases will transform to β-Ga_2O_3 under certain conditions such as high temperature. Si is a promising substrate to grow Ga_2O_3 film, being beneficial for the integration of Ga_2O_3-based device with other devices. However, an amorphous nano-silica layer is often formed on the surface of silicon, resulting in the growth of β-Ga_2O_3 with (100) preferred orientation. The preferred orientation of (100) will cause a large lattice mismatch (46.7 %) in the Ga_2O_3 film, which will reduces the carrier mobility. Therefore, the addition of a buffer layer at the interface between the Si substrate and Ga_2O_3 reduces the lattice mismatch and also reduces the mutual diffusion between Si and Ga in β-Ga_2O_3/Si heterostructure films.

Titanium nitride (TiN), as a structurally stable ceramic compound, has a low lattice mismatch with Si and β- Ga_2O_3, and is very suitable as a buffer layer for the preparation of high quality Ga_2O_3 film. In this work, TiN buffer layers were prepared on Si substrates by radio frequency (RF) magnetron sputtering method. Then, Ga_2O_3 films were also further deposited on TiN buffer layer by RF magnetron sputtering method. The effect of TiN buffer layer on the properties of Ga_2O_3 films was investigated. Ga_2O_3 film solar-blind UV detectors were also fabricated. The effect of TiN buffer layer on the performance of Ga_2O_3 UV detectors was studied in detail.

Electrical and optical properties of (Ti1-x,Ybx)N thin films prepared by pulsed laser deposition

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Symposium: 11. Thin Film Devices (TFD)
Keywords: Kubelka-Munk Function, Optical Band Gap, Pulsed Laser Deposition, Single Phase Thin Films, Titanium Nitride

Titanium nitride (TiN) is broadly known for its wide range of advantageous properties, including high hardness, wear resistance, low resistivity, high transmission in the visible range, and high reflectance in the infrared region. It is used as protective and decorative coatings, optical filters, and thin film resistors.

In this work, single phase homogenous TiN films are deposited with addition of Yb as ternary element by pulsed laser deposition (PLD) as $(Ti_{1-x},Yb_x)N$ thin film. It is prepared on Si substrates under ultrahigh vacuum condition ($<1x10^{-6}$ Pa) and substrate temperature (T_{Sub}) was kept at 673 K. The characterization was carried out using X-ray diffraction (XRD), Rutherford backscattering spectrometry (RBS) and nanoindenter in the previous study. It is revealed from phase identification and composition analysis carried out by XRD and RBS, the thin films displayed single phase B1 structure with homogenous ratio between metal and non-metal. Mechanical properties shown that addition of Yb increased the hardness to 29.0 GPa with 7.4% at x=0.15.

In the present study, the electrical resistivity decreased to 0.74 μΩ□m at x=0.08 and increased to 4.28 μΩ□m at x=0.5 at room temperature. It is observed that the thin films have a metal-like behavior becoming to semiconductor behavior as Yb content increasing. Optical properties measured by UV-Vis spectrometry shows that high reflectance over pure TiN in infrared region at x<0.15 and gradually decreasing. The optical band gap values were calculated by utilizing Kubelka-Munk function and Tauc plot shows decrease pattern from 2.55 eV to 1.37 eV with increasing Yb content. Meanwhile, L*a*b* method shows that the color emits by the thin films also matched the color to naked eye's view. This study showed $(Ti_{1-x},Yb_x)N$ thin films with enhanced optical and electrical properties and high hardness can be used as potential applications in solar energy harvesting and conductive ceramic material.

Epitaxial Growth for Large-Area GaN Films on 2D MoS2 by PA-MBE

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Keywords: GaN; 2D-MoS2; molecular beam epitaxy; pre-nitridation

Gallium nitride (GaN) thin films were grown in a heteroepitaxial structure through plasma-assisted molecular beam epitaxy (PA-MBE) on two-dimensional (2D) MoS_2 layer, prepared by chemical vapor deposition (CVD). Various growth duration, pre-nitridation treatment and substrate temperatures were set as parameters during the GaN epitaxial growth. Utilizing advanced characterization techniques, including *in-situ* monitoring of reflection high energy electron diffraction (RHEED), and *ex-situ* of field emission scanning electron microscopy (FE-SEM), atomic force microscopy (AFM), X-ray photoelectron spectroscopy (XPS), Raman spectroscopy, photoluminescence spectroscopy (PL), and high-resolution X-ray diffraction (HRXRD), systematically examines the morphological structure, optical properties, and crystal quality of GaN thin films. The results reveal the influence of pre-nitridation temperature on maintaining the MoS_2 structure and enhancing optical properties in GaN films with duration epitaxial time, leading to development of surface morphology and crystal structure. The elevation of the nitridation temperature bring out to the degradation of 2D MoS_2 layer, while longer growth durations at low pre-nitridation temperatures promote to surface stability and improve the structure quality of GaN films. This research offers valuable insights into optimizing growth conditions for large-area GaN thin films on 2D MoS_2, demonstrating potential advancements for semiconductor applications.

Fabrication of Giant Magnetoresistance Effect Devices Using multilayer NiFe Thin Films

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Keywords: AMR effect, Giant magnetoresistance effect, Laser Trimming, photolithograph and magnetron sputtering

This study focuses on the fabrication of a [$Fe_{80}Ni_{20}$/SiO_2]n multilayer giant magnetoresistance (GMR) effect device based on the anisotropic magnetoresistance (AMR) effect of $Fe_{80}Ni_{20}$ thin films. Using photolithography, bonding machines, and magnetron sputtering systems, the GMR device was created before the preparation of 50 nm $Fe_{80}Ni_{20}$ and 3 nm SiO_2 thin films onto the SiO_2 substrate, which is alternately photolithographed and magnetron-sputtered as a magnetic resistance and protective layers, respectively. Meanwhile, a 3 nm Ta buffer layer sputtered was as an interlayer between the magnetic resistance and protective layers to improve adhesion among the structures. The electrode material of 300 nm Al metal and Ta were sputtered onto the surface and then followed by laser trimming to connect each $Fe_{80}Ni_{20}$ magnetic resistance layer. Finally, the linear range of the sensor is within ±10 Oe, with a sensitivity of 0.44 mV/V/Oe within this range, a nonlinearity error of 3.29 %FS, which decreases as the measurement range narrows. Additionally, the sensor has a hysteresis error of 3.92% and a repeatability error of 2.15%. The temperature coefficient of resistance was measured to be 0.24 %/°C, and the temperature coefficient of sensitivity was -0.33 %/°C.

Ferroelectric Resistance Switching in Epitaxial BiFeO3/ La0.7Sr0.3MnO3 Heterostructures

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Keywords: resistance switching; interface; ferroelectric polarization; Schottky barrier

The nonvolatile resistive switching (RS) behavior has attracted significant attention due to their high speed, low power dissipation and their potential applications in next-generation, ultra-high-density resistance switching random-access memories of simple devices. Ferroelectric thin films are emerging as alternatives to RS layers to develop high-performance memory devices. With emerging manipulation methods, various interpretations have been proposed to understand the ferroelectric resistance switching behavior, whereas a clear understanding of the switching mechanisms in ferroelectric memristors is still in face of challenge. In this work, we successfully prepared an epitaxial BFO/LSMO heterostructure as the RS layer, and extensively investigate the RS behavior by measuring the temperature-dependent current–voltage properties and calculating the conduction barriers. Stable bipolar resistive switching characteristics regulated by ferroelectric polarization reversal was observed in the Au/BFO/LSMO heterostructures. The conduction mechanism was revealed to follow the Schottky emission model, and the Schottky barriers in high resistance and low resistance states were estimated based on temperature-dependent current–voltage curves. Further, the observed memristive behavior was interpreted via the modulation effect on the depletion region width and the Schottky barrier height caused by ferroelectric polarization reversal, combining with the oxygen vacancies migration near the BFO/LSMO interface. A model of ferroelectric polarization reversal modulation combining the migratory effect of the oxygen vacancies near the BFO/LSMO interface has been proposed to interpret the RS mechanism.

First-principle investigation and solar-blind UV photoelectric detection performance of high-quality Mg-doped β-Ga2O3 thin films

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Keywords: β-Ga_2O_3 thin film; First-principle calculation; Mg doping; Solar-blind UV detector

In this work, we first adopted first-principles calculations to investigate the effect of Mg doping concentration on various aspects of the β-Ga_2O_3 system, including crystal structure, band structure, density of states, and dielectric functions. The results reveal that Mg doping introduces new energy levels, achieving a spin polarization rate of 100%, with Mg atoms preferentially substituting octahedral positions of Ga atoms. As the doping concentration increases, the unit cell volume expands from 213.92 $Å^3$ to 218.86 $Å^3$, the bandgap increases from 4.98eV to 5.16eV, and the absorption edge blueshifts.

Based on the calculations, Mg-doped β-Ga_2O_3 thin films with different Mg concentrations were successfully prepared on (001) c-plane sapphire substrate using radio frequency magnetron sputtering. The results show that the bandgap variation and the absorption edge shift agree well with the calculation results. With increasing Mg doping concentration, the solar-blind UV detection performance of Mg-doped films initially increases and then decreases, reaching the optimal performance at Mg doping concentration of 0.34%. Under a 15V bias, exposed to UV light at 254 nm (2μW/cm^2), the films exhibit a high photocurrent-to-dark current ratio of 1.25 × 10^4, short response times of 0.03/1.29 s (rise time) and 0.01/0.19 s (fall time), with the responsivity, detection rate, and external quantum efficiency of 0.937 mA/W, 1.76 × 10^{12} Jones, and 4.58%, respectively. Additionally, a simple Mg-doped β-Ga_2O_3 MSM-type detector is successfully fabricated using a three-stage amplification circuit, demonstrating nearly linear current response to the light power density (R^2=0.995). This work paves way to the potential applications of Mg-doped β-Ga_2O_3 thin films in UV light detection.

Flexible memristors using multilayer molybdenum disulfide

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Symposium: 11. Thin Film Devices (TFD)
Keywords: 2D Materials, Flexible electronics, RRAM

Resistive random-access memory (RRAM) devices using 2D materials are promising for advancing flexible integrated electronics. This study employs a water-assisted polydimethylsiloxane (PDMS) technique to transfer thermal-decomposed multilayer molybdenum disulfide (TD MoS_2) from sapphire wafers to flexible substrates. This method effectively mitigates the impact of organic solvents (acetone/alcohol) on substrate surface roughness during transfer. The fabricated flexible, nonvolatile memory, utilizing TD MoS_2 with Au electrodes, shows reliable resistive switching, long retention, and low operation bias. Notably, performance remains unaffected even after extensive bending tests, with no significant degradation observed across various curvature radii and up to 10^3 bending cycles. This underscores the potential of flexible RRAM devices as pivotal components in future wearable electronic integration.

High performance flexible self-powered Ga2O3 UV solar-blind photodetectors with asymmetric electrodes

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Symposium: 11. Thin Film Devices (TFD)
Keywords: Gallium oxide, UV detector, magnetron sputtering

Solar-blind UV detectors have attracted increasing attention in many application fields, such as military, communications, healthcare and semiconductor manufacturing due to their excellent properties including high sensitivity and high signal-to-noise. Gallium oxide (Ga_2O_3) is a promising material for the preparation of solar-blind UV detectors due to its advantages such as wide bandgap, higher breakdown electric field and excellent thermal stability. However, with the continuous growth of demand for flexible electronic devices, the development of gallium oxide-based UV detectors on flexible substrates has emerged as a new research focus. In addition, compared with vertical structure devices such as p-n junctions, heterojunctions and Schottky junctions, metal-semiconductor-metal (MSM) type photodetectors based on Schottky junctions with asymmetric electrode structure have the advantages of simple fabrication process, low cost and high carrier collection efficiency, which is conducive to large-scale production.

In this work, a-Ga_2O_3 thin films were grown on flexible PEI substrates by using RF magnetron sputtering. MSM-type self-powered Ga_2O_3 UV solar-blind photodetectors were prepared by adjusting the asymmetric electrode size (Au/Ti/Ga_2O_3/Ti/Au) and the asymmetric electrode material (Au/Ti/Ga_2O_3/ZnGaO (GZO) and Au/Ti/ Ga_2O_3/Au). The devices show high performance for UV detection and good mechanical flexibility while reducing power consumption, and is expected to be applied to flexible wearable devices.

Highly-Performance Gas Sensor Based on PANI/MWCNTs/Pd Ternary Hybrid for Trace-Level Ammonia Detection at Room Temperature

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Symposium: 11. Thin Film Devices (TFD)
Keywords: ppb-level; NH3 sensor; PANI/MWCNTs/Pd ternary nanohybrid; room temperature

The development of flexible ammonia（NH_3） sensors with excellent performance remains of great significance in the field of environmental and human health detection. Herein, polyaniline/multi-walled carbon nanotubes /Pd (PANI/MWCNTs/Pd) ternary nanohybrid was successfully deposited on PET substrate by in-situ polymerization combined with electrostatic self-assembly. By doping and modifying MWCNTs and Pd nanoparticles, the flexible sensor exhibits excellent sensitivity (12.6 / 100ppm) and satisfactory response/recovery time (57s / 442s). The sensitivity of PANI/MWCNTs/ Pd-based sensor is 5.5 times and 2.8 times higher than that of pure PANI-based sensor and PANI/MWCNTs-based sensor, and the detection limit reaches 100 ppb. This is mainly due to the presence of π-π conjugated structures between the ternary composites and the enhancement of the Schottky barrier, which is confirmed by the results of electrochemical tests on charge carriers (including Nyquist plots, cyclic voltammogram Mott-Schottky test). In addition, due to the stability provided by the cross-linking of MWCNTs and PANI, the sensitivity decreases by no more than 15% under repeated bending (100 times /30°). It is worth noting that the baseline drift of the sensor at high humidity is also acceptable. In combination with density functional theory (DFT) and in situ FTIR, the sensitivity mechanism of the hybrid was studied in detail. Therefore, the PANI/MCNTs/Pd ternary hybrid is a strong candidate for ammonia detection material.

Linear study of magnetic sensing for MTJ devices based on CoFeB/MgO/CoFeB magnetic films with large aspect ratio

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Keywords: Magnetic material, magnetic tunnel junction, sensors;

Since the discovery of the tunneling magnetoresistance (TMR) effect in magnetic tunnel junctions(MTJs), magnetic field sensors based on MTJ have gained much attention in the last decades due to their high sensitivity, low cost, and small size. And this kind of sensor has a wide range of applications such as the automotive industry, and consumer electronics. With its high sensitivity and detection accuracy, it has the potential to detect weak biomagnetic fields, which can also be used for biosensing applications. In this paper, a series of film stacks with CoFeB/MgO/CoFeB magnetic tunnel junction film as the core structure was deposited on thermally oxidized silicon wafers by magnetron sputtering. The film stacks were fabricated into magnetic devices--MTJ by photolithography and etching, with the size of the MTJ in the range of 10 to 60 μm^2. Then the MTJs were annealed at a high-temperature magnetic field in a high vacuum to induce crystallization of the magnetic films as well as to define the magnetic direction. The R-H cures were measured by applying an external magnetic field, and a TMR ratio of around 200% was achieved. The study revealed that different sizes of MTJs show different magnetic field variations and the MTJs exhibit high linearity and a sensitivity of 1.19%/Oe under the external varying magnetic field. The research is valuable for linearized sensing of MTJs and for high-sensitivity magnetic field sensing applications.

Optimization of the gasochromic response to hydrogen of WO3 thin films deposited by PVD technique with possible application in optical gas sensors

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Keywords: WO3, gasochromic properties, hydrogen sensing, optical properties, structural properties, thin film

Tungsten trioxide (WO_3) is of great interest due to its electrochromic, photochromic and gasochromic properties and at the same time it is an abundant, non-toxic and inexpensive material. This work presents the gasochromic properties of WO_3 thin films deposited by PVD technique. Deposited WO_3 thin films were subjected to post-process annealing. A wide range of studies carried out for the as-deposited and annealed thin films showed a significant influence on the microstructure as it changed from amorphous to the nanocrystalline monoclinic WO_3. Furthermore, the surface and cross-section morphology changed significantly from fibrous to the coarse-grain agglomerates. For the measurements of gasochromic properties, the platinum and palladium adlayer catalyst was deposited on the surface of WO_3 thin films with the use of electron beam evaporation. The influence of the type and thickness of the catalyst on the gasochromic properties was examined and it was found that the highest responses were obtained for Pd with a thickness of 1.5 nm. The gasochromic properties were measured by means of transmission spectra change upon the presence of diluted hydrogen (concentrations from 25 ppm to 1000 ppm) in a cryostat chamber, while the recovery of the thin films to their initial state was ensured with a synthetic air. Additionally, in-situ XPS studies were performed for thin films before and after exposure to hydrogen, showing meaningful changes in the tungsten oxidation state. Results of this work showed that it is possible to obtain a significant gasochromic effect for WO_3 thin films using proper post-process annealing and selection of the catalyst adlayer. It was shown that gasochromic effect occurred already for very low hydrogen concentration of 25 ppm, which had not been previously presented in the literature.

Plasticity of TiO2/MgO based Resistive switching film for neuromorphic device

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Keywords: Long-term depression (LTD), Long-term potentiation(LTP), Plasticity, Resistance random access memory (RRAM)

A TiO_2/MgO composite film was prepared using ALD, demonstrating superior resistance switching performance, including a higher resistance ration of R_{off}/R_{on} and better retention comparing with the MgO film. Furthermore, gradual resistive switching characteristics were observed, making it suitable for neuromorphic device. And a constructed Ag/TiO_2/MgO/ITO device exhibits excellent multilevel resistive switching properties which is corresponding to the process neuro-plasticity. When a series of positive (or negative) scanning voltage with progressively increasing amplitude were applied to the device, the current though the device gradually increases (or decreases), mimicking synaptic enhancement (or suppression) in artificial synapses. Moreover, long-term potentiation (LTP) and long-term depression (LTD) properties were revealed through resistance switching dependance on the time. Furthermore, the number of pulses required for SET decreases with the increase of pulse voltage amplitude. This phenomenon reflects the synaptic weight, that is, at lower voltage, more pulses required by Ag ions to migrate to form conductive filaments, taking a longer time. This aligns well with the fact that pulse with bigger voltage amplitude stimulates the presynaptic membrane to increase the synaptic weight, consequently the stronger the signal achieved by the synapse. Additionally, when a single pulse voltage with varying amplitude was applied to the device, the voltage with larger amplitude excited the larger current, further validating the synapse’s response characteristic. Thus, threshold of pulse amplitude and time in resistance switching achieved by the prepared TiO_2/MgO composite film well verified the human brain's memory of learning and forgetting.

Polarity-differentiated and charge-regulated graphene field-effect transistors for bio-medical applications

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Symposium: 11. Thin Film Devices (TFD)
Keywords: AlxOy, GdxOy, Graphene, P(VDF-TrFE), charge-regulated field-effect-transistor, nervous system

The central nervous system is primarily composed of the brain and spinal cord. Recent advances in artificial neural networks have focused on implementing brain functions. The spinal cord with the autonomic nervous system is responsible for unconscious behaviors such as heartbeat, breathing, metabolism, reflex, and pain regulation, which have rarely been investigated. Among them, the reflex can avoid further injury, while pain has an important role in determining the degree of damage. In this study, charge-regulated field-effect transistors (CRFETs) with monolayer graphene as a channel material were proposed to realize the functions of the reflex arc and descending pain modulation system (PMS) in the spinal cord. By adopting Gd_xO_y and Al_xO_y as the dielectric layers of CRFETs, the opposite polarities of the oxide charges within the dielectric layers could induce a voltage shift of the Dirac point (ΔV_{Dirac}) in different directions under the same input signals. Thus, Gd_xO_y- and Al_xO_y-based CRFETs were adopted as artificial inhibitory and excitatory synapses, respectively. In this manner, the functions of artificial reflex arc (ARA) were performed completely via the connection of CRFETs with poly(vinylidene fluoride-co-trifluoroethylene) (P(VDF-TrFE))-based actuators to demonstrate the operation of antagonist and agonist muscles in an reflex arc. Additionally, a CRFET was integrated with a memristor at the drain terminal to realize the functions of descending PMS. To operate as an artificial pain modulation system (APMS), the ΔV_{Dirac} of CRFETs induced by afferent noxious signals from the gate terminal was considered as a pain sensation, which could be further regulated through the application of pulse signals to the memristor, functioning as an interneuron. The implementation of the ARA and APMS using Gd_xO_y- and Al_xO_y-based CRFETs has made significant progress in mimicking the nervous systems in the spinal cord for further application in bio-medicine.

Room-Temperature Operated NOx Gas Sensor of n-ZnO/p-Ag2O nanostructure with Photonic Energy

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Keywords: Gas Sensor / Nanorods / Photonic Energy

Extensive research has been conducted to rapidly detect nitrogen dioxide (NO_2) gas, which is known to have adverse effects on human health and the environment. Gas detection methods, classified based on operational principles such as catalytic combustion, thermal conductivity, and metal oxide semiconductor approaches, have been explored. Among these methods, metal oxide semiconductor-based gas sensors have gained attention for their relatively low production costs and high detection performance.

However, these sensors typically operate at temperatures exceeding 150°C for gas detection, leading to challenges such as reduced component lifespan and compromised detection stability. Consequently, recent research has consistently explored gas detection methods at room temperature. A recent approach for room-temperature gas detection involves the application of UV activation. Typically, when light with a wavelength shorter than the material's band gap is applied, generating electron-hole pairs that aid in gas detection. Nevertheless, UV activation methods are limited by the rapid recombination of carriers generated by the light, restricting their effectiveness. This study has overcome the limitation by employing a p-n heterojunction structure to inhibit the recombination of carriers generated by light activation, thereby aiming to achieve high detection performance at room temperature.

n-type ZnO was synthesized in nanorods using a hydrothermal synthesis method. A 5nm layer of *p*-type Silver Oxide (Ag_2O) was applied to the synthesized nanorods using an e-beam evaporator to further enhance the sensor's performance. To prepare the sensing material, the nanorods have done heat treatment from 400 to 800°C in a rapid thermal annealing (RTA) chamber with oxygen gas (O_2). The properties of the ZnO/Ag_2O gas sensor were measured in NO_2 gas concentration (10, 25, 50 ppm) at room temperature.

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Self-powered p-Si/n-ZnGaO heterojunction ultraviolet photodetector with high on/off ratio and responsivity

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Keywords: p-Si/n-ZnGaO heterojunction; plasma enhanced atomic layer deposition; self-powered; ultraviolet photodetector

High-performance self-powered p-Si/n-ZnGaO heterojunction ultraviolet photodetectors has been realized based on ZnGaO thin films with different ZnO cycle ratios deposited on p-type silicon substrates by plasma enhanced atomic layer deposition. Compared to the film with 50% ZnO cycle ratio, the film with 40% ZnO cycle ratio exhibits fewer oxygen vacancies and zinc interstitial, which is beneficial for the carriers transport. The device exhibited excellent self-powered characteristics under 254 nm UV light and 0 V bias with a high photo-to-dark current ratio of 1.5×10^4, an satisfactory responsivity of 78.1 mA/W and a rapid decay response time of 0.38 s. In addition, the carrier transport mechanism of the heterojunction before and after UV irradiation has been demonstrated. This technology provides a low-power and high-performance solution for the design of self-powered UV PDs.

Simulation of the Performance of CdZnTe Crystals and Their Detectors under H-ion Irradiation

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Keywords: CdZnTe, detector, finite element analysis, irradiation damage

Cadmium zinc telluride (CZT) crystal is a kind of ternary compound semiconductor room temperature nuclear radiation detector material with excellent performance, which has been widely used in the fields of radioactive pollution monitoring and nuclear physics experiments. However, it will be seriously damaged by irradiation in space, which can easily lead to device failure. In this paper, the effects of hydrogen ion irradiation damage on the defect distribution and electrical properties of CZT crystal / detector were studied by simulation. The electron stopping power and nuclear stopping power of different charged ions on CZT crystal were analyzed and compared by Monte Carlo program, and the distribution of ionization damage and displacement damage caused by charged ions was analyzed. The irradiation damage of materials caused by ions with different incident energy and incident angle was compared, and the causes were analyzed. Finally, the changes of potential, weight potential and charge collection efficiency of CZT flat panel detector before and after hydrogen particle irradiation were simulated by finite element method. The charge collection efficiency of the detector decreases after irradiation.

Study on the Properties of Gallium Oxide grown on SiC Substrate and Applied to Schottky Barrier Diodes

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Keywords: MOCVD, drift layer, oxygen annealing, □-Ga2O3

This study successfully utilized metal organic chemical vapor deposition (MOCVD) to grow □-Ga_2O_3 epitaxial films on silicon carbide (SiC) substrates, and fabricated vertical Schottky diodes by lithography, dry etching, electron beam evaporation, and furnace annealing at high temperature with oxygen. The high surface roughness and oxygen vacancies of the unannealed device caused large leakage current. To repair the surface oxygen vacancies, three different annealing times were used under O_2:N_2=1:4 gas environment. The results showed that the 5-minute thermal annealing process is the most effective for repairing the surface oxygen vacancies, and by XPS oxygen elemental analysis, the percentage of oxygen vacancies decreases from 56.56 % to 49.71 %, the leakage current density decreases from 10^{-3} to 10^{-5} A/cm^2, and the surface roughness decreases to 32.6 nm due to the stress release. We design the devices with different shapes and sizes, and the $R_{on,sp}$ decreases as the size decreases. As we design different shapes and sizes, the $R_{on,sp}$ decreases with size down to 6.05 Ω×cm^2 the breakdown voltage is less related to the electrode shape but increases with size down to -132 V.

Switching Mechanism and Reliability of γ-ray Irradiated Al: HfOx-based Memristor Devices

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Keywords: Radiation hardened memory, memristor, resistive switching, space electronics

Memristor is an emerging two-terminal metal/insulator/metal memory technology with a vast potential for high-density data storage applications. The working mechanism of a memristor is based on the redox process in the cell that creates a conduction path for electrons to flow from cathode to anode; this path can be a form of oxygen vacancy defects (conducting filament), metallic ions (conducting bridge), or combination of both. Memristor is an intrinsically rad-hard element that could be used for long-term space missions. Owing to the memristor’s thin insulator thickness, the amount of deposited high-energy radiation into the device can be limited, consequently limiting the generation of defects and the possibility of phase transformation in chalcogenide and oxide materials that could degrade the device's performance. Radiation-induced defects or phase transformation can cause issues such as increased leakage current, reduced switching stability and memory window, and altered memristor switching characteristics.

In this work, we report that radiation can positively affect the resistive switching characteristics of the memristor. The electrical behavior and the mechanism behind this phenomenon are discussed. Our study delves into the dependability of cross-point memristor devices crafted with Al: HfOx when subjected to intense ^{60}Co γ-ray radiation. Our findings reveal that the affected device necessitates a more incredible forming voltage and exhibits an elevated HRS, along with more fluctuations than its initial state. This occurrence is attributed to radiation rupturing Hf-O bonds in the insulator layer. Nonetheless, the device demonstrates a remarkable resistance to radiation exposure of up to 5 Mrad while maintaining its exceptional stability and endurance performance.

The effects of different ozone annealing temperatures at ultrafast time on the nickel-doped Ga2O3 films

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Keywords: Ga2O3, RF magnetron sputtering, annealing, nickel-doped

The nickel-doped Ga_2O_3 (Ni-doped Ga_2O_3) films prepared by radio-frequency (RF) magnetron-sputtering on sapphire substrates were annealed in an ozone atmosphere with an ultrafast processing time. The effects of different annealing temperatures in the range of 600-900°C are analyzed. The experimental results showed variations in the structural, optical, and electrical properties of the annealed Ni-doped Ga_2O_3 films. Also, the *in situ* optical emission spectroscopy is used as crucia evidence to investigate the influence of the plasma radicals. The structural lattice change contributes to the change in transmittance and reflectance as well as the bonding of Ni-O and Ga-O. As a result, these RF magnetron-sputtering Ni-doped Ga_2O_3 films with annealing engineering not only provide a new reference condition but are also suitable for optoelectronic devices.

The effects of temperatures on the tungsten-doped titanium oxide coatings in photocatalytic technology

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Keywords: doping, photocatalytic, titanium oxide, tungsten

In this study, the tungsten-doped titanium oxide (W-TiO_2) was prepared by the spin-coating method after the solution preparation of titanium oxide (TiO_2) and tungsten oxide (WO_3) nanoparticles. The dynamic and steady spin coatings were adapted. The effects of hot-plate temperatures on the W-TiO_2 thin films are analyzed to research their optical, structural, chemical, and electrical properties. The hot plate temperature is varied from 100 to 700 °C. The experimental results demonstrate that the W addition increases the forming temperature of film and also decreases its transmittance. The W atom may be a substitution site for the Ti atom during the deposition. Finally, the deposition mechanism is proposed to describe, at different temperatures, the contribution of the migratory module of the W, Ti, and O atoms.

The influence structural design to the electronic properties of Frisch-grid CZT detector by finite element method

by Meng Cao | Weifan He | Zhiheng Jiang | Zexin Wang | Zhenzhao Zhang | Qingzhi Hu | Zhen Xu | Jian Huang | Linjun Wang | Shanghai University | Shanghai University | Shanghai University | Shanghai University | Shanghai University | Shanghai University | Shanghai University | Shanghai University | Shanghai University

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Symposium: 11. Thin Film Devices (TFD)
Keywords: CZT;Frisch-grid;finite element method;simulation

Cadmium zinc telluride (CZT) detectors have the advantages of high detection efficiency and good energy resolution, which are widely used in the fields of X-ray detection, environmental monitoring and nuclear radiation detection. The Frisch-grid structure is used more often in the preparation of detectors because of its good unipolarity and simple structure. In this paper, the effects of changing the gate position, width and relative dielectric constant on the electrical properties of Frisch-grid CZT detectors, such as potential, weight potential, electric field distribution and charge collection efficiency, are simulated in detail by the finite element method. We found that the changes of all these conditions produce significant changes in the electrical performance of the detector. And based on the simulation results, the structure of the Frisch-grid CZT detector is optimized to find the structure combination that can improve the performance of the detector. The results can guide the design and optimization of the structure of CZT detectors.

The investigation of metal nanoparticle-doped TiO2 coatings on flexible substrates

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Keywords: TiO2, doping, flexible substrate, metal nanoparticle

In this study, the solution preparation of TiO_2 with the metal nanoparticle and its growth of thin film via the spin-coating method on different flexible substrates are proposed. In solution processing, chlorobenzene (C_6H_5Cl) as a polar additive is used as an optimized experimental parameter to enhance the film-forming property. Before solution coating, the surface energy of different flexible substrates, including PET, PEN, and PI materials, was improved by oxygen plasma treatment. The experimental results illustrate that the optical transmittance and reflectance, as well as the electrical properties, are a function of the variation of the film thickness of metal nanoparticle-doped TiO_2, where the film thickness is varied from 100-500 nm. The calculation of the curvature radius and its bending testing windows are demonstrated. Finally, the temperature resistance via hot plate or thermal annealing is also illustrated to compare with conventional glass and silicon substrates.

The new in-memory sensing and computing device

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Keywords: in-memory sensing and computing transisitor

Rapid developments in the Internet of Things and Artificial Intelligence trigger higher requirements for image perception and learning of external environments through visual systems. However, limited by von Neumann's bottleneck, the physical separation of sense, memory, and processing units in a conventional personal computer-based vision system tend to consume a significant amount of energy, time latency, and additional hardware costs. By integrating computational tasks of multiple functionalities into the sensors themselves, the emerging bio-inspired neuromorphic visual systems provide an opportunity to overcome these limitations. With high speed, ultralow power and strong adaptability, it is highly desirable to develop a neuromorphic vision system that is based on highly precise in-sensor computing devices, namely retinomorphic devices. Although dedicated electronic hardware has inspired the development of in-memory computing and in-sensor computing, folding the entire signal chain into one device remains challenging. The new in-memory sensing and computing architecture has been widely concerned by people. Image recognition can be performed without any external memory and computing units. The three-in-one paradigm, integrating high-level computing, weight memorization and high-performance sensing, paves the way for a computing architecture with low energy consumption, low latency and reduced hardware overhead.

The photoelectric devices from perovskite 1D microwire to 2D nanostructure

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Keywords: Perovskite; microwires; photodetector

Organic halide perovskite material, $CH_3NH_3PbI_3$, with advantages of long carrier diffusion length, low cost, and simple process, and now is widely applied in several fields of photonic devices. In this work, we prepared the perovskite microwires (MWs) and the films with the solution processes. Then, by integrating them with electrodes, perovskite photodetector can be fabricated. Here, we found that MWs in the performance of light sensing is relatively excellent, and MWs also have the advantage of being able to make small area components, unlike the film devices to rotate the coating of the whole surface substrate. The perovskite thin film photoconductor was assembled, and the channel aspect ratio is 0.8 mm length x 0.3 mm wide. The green laser of different intensity is irradiated and its response rate is found. In our report, we designed lateral-structured photodetectors based on the perovskite MWs witch wire diameter is tuned from 30 to 300 μm. We also showed the electrooptic response and detectivity of the perovskite microwires MWs and the films when they are exposed to red (650 nm), green (532 nm), blue (450 nm) lasers. Compared with the perovskite films, the perovskite MWs showed better photo response. The spectral photo responses had been investigated when their wire diameters were tuned. High extinction ratio for blue- and red-light illumination was found when the 30-μm perovskite MWs was used. The dynamic range is 42 dB, and the linearity is 0.99.

Titanium-doped hafnium oxide thin film with high dielectric constant deposited by PEALD and its application in thin film transistors

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Keywords: Plasma enhanced atomic layer deposition, Thin film transistors, Titanium-doped hafnium oxide

The relentless scaling down of semiconductor devices has necessitated the development of high-k materials to replace conventional SiO_2 gate oxides. In this study, titanium-doped hafnium oxide (HTO) thin films were prepared by plasma-enhanced atomic layer deposition (PEALD) which enables precise control over film composition and thickness. The effects of varying the cycle ratio of hafnium oxide (HfO_2) to titanium oxide (TiO_2) on the properties of obtained films were explored. The properties of these HTO films were analyzed through spectroscopic ellipsometry, X-ray diffraction, X-ray photoelectron spectroscopy, X-ray reflectivity, scanning electron microscopy , and ultraviolet-visible spectrophotometry. The experiment results show that the titanium content and optical bandgap of the HTO films were increased with the increase of the titanium oxide cycle ratio. The dielectric constant of the HTO film with 10% TiO_2 circulation ratio reaches ~25.31, and the breakdown electric field is about 5.62 MV/cm. To illustrate the applications of HTO thin film as a gate dielectric in thin film transistors (TFTs), indium-gallium-zinc oxide (IGZO) was used as channel layer. The optimized IGZO/HTO TFT devices resulted in enhanced electrical performance, including high on/off current ratio of 3.62×10^7, a saturation mobility of 5.56 cm^2/Vs, a subthreshold swing of 0.13 V/decade and a low threshold voltage of -0.1V. This work indicates that HTO films deposited by PEALD could be a promising candidate for high-k dielectric layers in various semiconductor devices, especially in TFTs.

Zinc-doped gallium oxide films with prepared by spatial atomic layer deposition in low temperature and applications in UV photodetectors

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Keywords: Atomic layer deposition, doping, gallium oxide, photodetector

Gallium oxide (Ga_2O_3) with its wide bandgap of ~5 eV has emerged as a promising semiconductor platform for power electronics and deep ultraviolet optoelectronics. However, the preparation of p-type Ga_2O_3 remains a challenge, and zinc has been widely considered as a potential dopant candidate. In this study, zinc-doped gallium oxide ($Zn:Ga_2O_3$) thin films are prepared using high-speed spatial atomic layer deposition (sALD) at a temperature of 150 ºC. The deposition process involves co-injecting trimethylgallium and diethylzinc (DEZ) as the gallium and zinc precursors, respectively, into the deposition zone, while ozone is used as the oxygen source. The effects of the DEZ flow rate ranging from 0 to 100 sccm on doping level and optoelectronic properties of the $Zn:Ga_2O_3$ films are systematically investigated. The experimental results show that the deposition rate of the films has a linear relationship with the zinc flow rate. X-ray diffraction analysis reveals that the $Zn:Ga_2O_3$ films were amorphous due to the low deposition temperatures. The optical properties of the films demonstrates a tunability from 5.26 to 4.98 eV in the optical bandgap with increasing DEZ flow rate. Finally, an ultraviolet photodetector is fabricated using a $Zn:Ga_2O_3$ layer prepared at DEZ flow rate of 0~75 sccm. The photodetector exhibits remarkable performance such as a low dark current of 5.05 pA, a high photo-to-dark current ratio of ~6.83×10^5, and short rise/fall times of 0.03/0.19 ms. This study is helpful for the preparation of sALD $Zn:Ga_2O_3$ films and their applications in Ga_2O_3-based optoelectronic devices.

Zn Ohmic Contact on P-type β-Ga2O3 with High Hall Hole Concentration

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Keywords: electrical behavior, gallium oxide, nitrogen-doped, ohmic metal contract, p-type conductivity, thermal oxidation

The development of P-type β-Ga_2O_3 with good conductivity is the key to realizing its devices and applications. The formation of good metal metal-ohmic contacts is another key issue in the fabrication of high-power electronic devices using β-Ga_2O_3 films. In this paper, high-quality P-type β-Ga_2O_3 thin films are firstly prepared by using the method of thermal oxidation of GaN, and then metal zinc is utilized, and comparative analysis is used to seek a suitable rapid thermal annealing temperature to form a good ohmic contact between zinc and P-type β-Ga_2O_3. we used Photoluminescence (PL), X-ray diffraction (XRD), secondary ion mass spectrometry (SIMS), and transmission electron microscopy (TEM) to characterize the β-Ga2O3 films. Then, zinc was sputtered onto the P-type β-Ga_2O_3 film by magnetron sputtering technique to form a metal electrode. The electrodes were then further tuned and optimized by rapid thermal annealing at different temperatures. Then, using Hall measurements, the overall electrical properties of the film and electrode were comparatively analyzed at different RTA temperatures. Finally, it is concluded that It is finally concluded that the optimum RTA temperature for the formation of a good ohmic contact of metallic zinc on P-type β-Ga_2O_3 films is 350 °C.

ZnO:(B, Ga)/Au Electrodes for Improved Ohmic Contacts on Ultrawide-Bandgap Ga2O3 Films

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Keywords: , Contact characteristics, Gallium oxide, Ohmic Contacts, Ultra-wide bandgap

Gallium oxide (Ga_2O_3) is an ultrawide-bandgap semiconductor material with a bandgap width of approximately 4.9 eV, a high breakdown field strength of around 8 MV/cm, large Baliga's figure of merit, good thermal stability, and chemical stability. These outstanding properties position Ga_2O_3 as a promising candidate for diverse applications, including deep ultraviolet photodetectors, high-power electronic devices, and field-effect transistors. In the realm of semiconductor device applications, the quality of contacts between the semiconductor and electrodes is a pivotal factor directly influencing device performance and reliability. For high-resistivity and ultrawide-bandgap Ga_2O_3 materials, establishing high-quality Ohmic contacts has emerged as a significant challenge and research focus in device applications.

In this work, various composite electrodes, including Au, Ti/Au, Al/Au, and B and Ga co-doped ZnO (BGZO)/Au with semiconductor intermediate layers, were fabricated on Ga_2O_3 films. The specific contact resistance between these electrodes and the thin films was quantitatively measured using the d-CTLM method, shedding light on the impact of electrode types, structures, and annealing treatment on the contact characteristics.