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Editorial

Special Issue: Advanced Semiconductor Materials and Films: Properties and Applications

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Advanced semiconductor materials and films are building blocks for multifunctional devices and circuits, integrated optoelectronic chips, and high-throughput communications, which have proved basic material platforms for nanoscience and technologies. With unique structural properties and having potential to act as significant optoelectronic and nanophotonic units, advanced semiconductor materials, e.g., quantum dots, one-dimensional (1D) nanostructures, 2D materials, and semiconductor thin films, have been used in a variety of fields. In particular, 1D bandgap modulated structures, heterostructures, and artificial optical systems (fabricated via a chemical vapor deposition (CVD), metal-organic chemical vapor deposition (MOCVD), molecular beam epitaxy (MBE), atomic layer deposition (ALD), solution-based process, and sputtering, etc., may provide new opportunities for wavelength-tunable lasers, photovoltaics, solid-state lighting, spectrometers, and multicolor displays, as well as other highly integrated optoelectronic devices.

Over the past decade, tremendous progress has been made in the development of advanced semiconductor materials. This Special Issue aims to provide a forum for researchers to share current research findings and investigations to promote further research into the highly integrated photonic and optoelectronic performance of advanced multifunctional materials, including experimental and theoretical calculations. Authors are invited to submit original research articles, critical review articles, or short communications focused on, but not limited to, the following topics: the on-structure synthesis of 1D or 2D materials with radially or axially modulated compositions along a single nanostructure; innovative techniques for the realization of bandgap engineering on a single nanowire or 2D materials; recent advances in thin films and optoelectronic applications; the fabrication and physical properties of semiconductor materials; and semiconductor–metal interactions or light–mater interactions, etc.

Most of the traditional semiconductor materials have too large a footprint to be suitable for applications in the miniaturization of on-chip photonic circuits and systems. Thus, a composition tunable within a single nanostructure is urgently needed for low-power consumption, miniaturization, and high-integration devices [1]. Due to versatile physical/chemical properties, semiconductor nanostructures with axial or lateral on-wire bandgap engineering have emerged as building blocks for fundamental nanophotonic and optoelectronic devices [2,3]. Prof. Pan and Prof. Tong reported the created of axial bandgap-graded CdSSe nanowires and ZnCdSSe composition gradient nanowires through a magnetic-pulled CVD method, which were used as solid-state light sources, wavelength tunable lasers, and photodetectors [1]. Prof. Jo and Prof. Picraux reported the creation of composition-graded Si_xGe_{1-x} (x = 0–1) nanowires by means of an in situ catalyst-alloyed CVD approach and a thermal evaporation process [4,5]. Additionally, this magnetic-pulled system was also applied in fabricating 2D composition-graded nanoribbons as well as heterostructure nanoribbons. Prof. Ning reported lateral ZnCdSSe heterostructure nanoribbons, which were used to fabricate monolithic white lasers [6]. Composition-graded CdSSe alloy nanoribbons and CdSSe/CdS heterostructure nanoribbons were reported

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Citation: Shen, X.; Lv, Q.; Guo, P. Special Issue: Advanced Semiconductor Materials and Films: Properties and Applications. *Coatings* **2022**, *12*, 1365. https://doi.org/10.3390/coatings12091365

Received: 14 September 2022
Accepted: 16 September 2022
Published: 19 September 2022

in Prof. Pan's group, which were used to realize nanoscale dual-color and multi-color lasing [7,8]. Besides traditional semiconductor materials, novel perovskite nanomaterials are being developed rapidly in the application of nanophotonic and optoelectronic materials. For example, spatially resolved multi-component $CsPbX_3$ (X = Cl, Br, I) nanowires and $CsPbCl_3$-$CsPbI_3$ axial perovskite heterostructure nanowires were constructed to realize dual-wavelength lasing and asymmetric waveguide [9,10].

In recent years, transition metal dichalcogenides (TMDs), such as WS_2, MoS_2, WSe_2, $MoSe_2$ and van der Waals (vdWs) heterostructures with a nearly perfect crystalline structure and dangling-bond-free surface, have attracted considerable interest, making TMDs materials useful for flexible optoelectronic applications [11]. For example, Prof. Duan reported the synthesis of $WS_{2x}Se_{2-2x}$ alloy nanosheets with composition-tunable electronic properties [12]. A general synthetic strategy for 2D vdWs heterostructure arrays, including VSe_2/WSe_2, VSe_2/MoS_2, $NiTe_2/WSe_2$, $NbTe_2/WSe_2$ etc., was successfully realized in the same group, which acted as high-performance transistors [13]. Moreover, Zhao et al. reported a straightforward approach to realizing high-order SnS_2/WSe_2 vdWs superlattices by rolling up vdWs heterostructures [14]. This strategy can be extended to create diverse 2D/2D vdWs superlattices, more complex 2D/2D/2D vdWs superlattices, and beyond-2D materials.

Although 1D semiconductor nanostructures and 2D materials are of particular interest with respect to their unique low-dimensional footprint and versatile physical properties, several research groups have shown critical insights into disordered nanomaterials for integrated optoelectronic devices and systems. Prof. Joselevich reported a large-scale guided growth of horizontal nanowire arrays on sapphire substrates, including GaN nanowires, CdS nanowalls, $CsPbBr_3$ nanowires and CdSe/CdS nanowire heterostructures, which have devoted significant efforts to the development of high integrated devices and circuits in optoelectronic and nanotechnology [15]. The authors claimed that the guided growth of horizontal nanowires demonstrated in their group could be extended to a large variety of semiconductor materials, which were suitable for a wide range of applications in the future [15,16]. Prof. Li reported the fabrication of a wide variety of InP nanostructures with smooth sidewalls using an inverse metal-assisted chemical etching method without UV irradiation, which may find applications in transistors and optoelectronic devices with better performance and at lower cost than conventional etching methods [17].

In summary, advanced semiconductor materials provide new opportunities for integrated nanophotonics and optoelectronics. The results from recent investigations suggest that low-dimensional semiconductor nanostructures and thin films are excellent candidates for detectors, nanolasers, solid-state light sources, transistors, light emitting diodes, spectrometers, etc. More research efforts will be inspired to address the challenges in the optoelectronics field in the future.

Author Contributions: Conceptualization, X.S. and P.G.; investigation, X.S. and Q.L.; writing—original draft preparation, P.G. and X.S.; writing—review and editing, P.G.; supervision, P.G.; funding acquisition, P.G. All authors have read and agreed to the published version of the manuscript.

Funding: The authors are grateful to the start-up funding from Taiyuan University of Technology and Shanxi Basic Research Program Project (No. 20210302123128) for financial support.

Conflicts of Interest: The authors declare no competing financial interest.

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