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《科学》（20260827出版）一周论文导读。编译未玖

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Tunnel field-effect transistors exhibiting performance beyond the Boltzmann thermionic limit

超越玻尔兹曼热离子极限的隧穿场效应晶体管

▲ 作者：ZEHAN WU, KE YANG, WANQING MENG, WEIZHEN WANG, YIFEI ZHAO, FUMEI YANG, ET AL.

▲ 链接：

<https://www.science.org/doi/10.1126/science.adx6059>

▲ 摘要：

国际器件与系统路线图（IRDS）已将隧穿场效应晶体管（TFET）确定为最有前景的下一代逻辑器件，其可实现驱动电压和功耗的可持续微缩。然而，获得理想的亚玻尔兹曼极限导通电流（称之为 I_{60} ，即当TFET的亚阈值摆幅达到60 mV/dec时的电流水平）和电流开关比一直颇具挑战。

研究组报道了一种基于铋/硒化铟（Bi/InSe）异质结构的TFET，其 I_{60} 高达约 $10 \mu A/\mu m$ ，电流开关比大于 10^7 。研究组将这类颇具潜力的TFET归因于精确的材料设计、真空下制备的清洁界面，以及基于亚阈值摆幅物理学的能带工程。

该研究结果表明，这一高性能基本构建单元可满足下一代集成电路的IRDS要求。

▲ Abstract：

The International Roadmap for Devices and Systems (IRDS) has identified the tunnel field-effect transistor (TFET) as the most promising next-generation logic device that enables sustainable downscaling in driving voltage and power consumption. Demonstrating an acceptable sub – Boltzmann-limit ON current (namely I_{60} , the current level when a TFET switches to a subthreshold swing level of 60 millivolts per decade) and current-switching ratio has presented a formidable challenge. We report a TFET based on a bismuth/indium selenide (Bi/InSe) heterostructure that exhibits an I_{60} of up to ~ 10 microamperes per micrometer and a current-switching ratio of $>10^7$. We attribute such promising TFETs to precise material design, clean interfaces fabricated under vacuum, and band engineering based on subthreshold swing physics. Our results demonstrate a high-performance basic building block that meets the IRDS requirements for next-generation integrated circuits.

材料科学Materials Science

Direct evaporation of single-crystal metal contacts for 2D semiconductors

二维半导体上单晶金属接触的直接蒸发生长

▲ 作者：YING ZHANG, CHANG LIU, HUITING WANG, GUICHEN TENG, YILU QIN, WENCHENG NIU, ET AL.

▲ 链接：

<https://www.science.org/doi/10.1126/science.aee3132>

▲ 摘要：

金属接触仍是二维（2D）半导体电子学中的关键瓶颈之一。

研究组开发了一种原子尺度的逐级蒸发方法，可在具有清洁界面的单层半导体上直接生长单晶金属。该方法获得了一个独特的生长动力学窗口，可抑制二次成核并促进横向聚结，从而实现了多种金属（包括铋、银、铟、金和钯）在二硫化钼（MoS₂）和二硒化钨（WSe₂）上的范德华外延生长。

所得单晶金属支持超薄导电通道，具有空间均匀的功函数，并表现出更优的热稳定性。作为接触电极，其展现出极低的费米能级钉扎效应，接近肖特基-莫特极限。

采用铋和钯接触时，单层MoS₂和WSe₂晶体管分别实现了36和145 $\Omega \cdot \mu\text{m}$ 的超低n型和p型接触电阻，且两类器件的短沟道电流均超过1.1 mA/ μm 。

▲ Abstract：

Metal contacts remain one of the key bottlenecks in two-dimensional (2D) semiconductor electronics. We developed an atomic-scale step-by-step evaporation method to directly grow single-crystal metals on monolayer semiconductors with clean interfaces. This method accesses a distinct growth-kinetic window that suppresses secondary nucleation and promotes lateral coalescence, enabling van der Waals epitaxy of diverse metals—including bismuth, silver, indium, gold, and palladium—on molybdenum disulfide (MoS₂) and tungsten diselenide (WSe₂). The single-crystal metals support ultrathin conduction, provide spatially uniform work functions, and exhibit improved thermal robustness. As contacts, they show minimal Fermi-level pinning, approaching the Schottky – Mott limit. With bismuth and palladium contacts, monolayer MoS₂ and WSe₂ transistors achieved ultralow n- and p-type contact resistances of 36 and 145 ohm-micrometers, respectively, and short-channel currents both above 1.1 milliamperes per micrometer.

High-efficiency, long-lived lead-free perovskite light-emitting diodes

高效长寿命无铅钙钛矿发光二极管

▲ 作者：WENHAO BAI, TONGTONG XUAN, GUANHUA REN, KUNJIE SONG, HUILI LI, CHENGKAI HU, ET AL.

▲ 链接：

<https://www.science.org/doi/10.1126/science.aeg8955>

▲ 摘要：

卤化锡钙钛矿发光二极管（PeLEDs）凭借其溶液加工性和低毒性展现出应用前景，但低效率和差稳定性制约了其实际应用。

研究组发现，CsSnI₃的电致发光失效主要由过量空穴注入所引发的电化学Sn²⁺氧化以及向Cs₂SnI₆的不可逆相变所驱动。通过采用甲脒掺杂与三苯基氧化膦改性相结合的双面优化策略，以稳定钙钛矿晶格、抑制非辐射复合并平衡载流子传输，研究组制备出了高效近红外PeLEDs。

这些无铅器件在963nm处实现了21.2%的峰值外量子效率，最大辐射率高达195.8 W sr⁻¹ m⁻²。值得注意的是，在7.1 W sr⁻¹ m⁻²的初始辐射率下，器件工作半衰期达到920.5小时，这为高性能无铅PeLEDs提供了可行路径。

▲ Abstract :

Tin halide perovskite light-emitting diodes (PeLEDs) offer promise due to their solution processability and low toxicity, yet low efficiency and poor stability hinder practical use. We found that electroluminescence failure in CsSnI₃ is primarily driven by excessive hole injection – triggered electrochemical Sn²⁺ oxidation and an irreversible phase transition to Cs₂SnI₆. Through a dual-side optimization strategy combining formamidine doping with triphenylphosphine oxide modification to stabilize the perovskite lattice, suppress nonradiative recombination, and balance carrier transport, we demonstrate highly efficient near-infrared PeLEDs. These lead-free devices achieve a peak external quantum efficiency of 21.2% at 963 nanometers and a maximum radiance of 195.8 watts per steradian per square meter (W sr⁻¹ m⁻²). Notably, the operating half-lifetime reaches 920.5 hours at 7.1 W sr⁻¹ m⁻², providing pathways for high-performance lead-free PeLEDs.

计算科学Computational Science

Hypervision: An on-chip hyperspectral microsystem for online video-rate computational imaging

片上高光谱微系统Hypervision实现在线视频级计算成像

▲ 作者：： LIHENG BIAN, QINGHAO MENG, LIANJIE LI, ZHEN WANG, YIBO FENG , XUAN PENG, ET AL.

▲ 链接：

<https://www.science.org/doi/10.1126/science.aef8268>

▲ 摘要：

在这项工作中，研究组攻克了高光谱成像长期面临的大规模计算难题，即重构和处理大规模空间-光谱数据立方体所需的海量运算。

具体而言，研究组设计了一款以神经处理单元（NPU）实现的硬件加速器，其16位整数（INT16）运算能力可达每秒9.3万亿次操作，同时为轻量化重构网络提出了一种拓扑感知的结构化修剪策略。

通过与自研的HyperspecI传感器集成，研究组构建了一套完全独立运行的可见-近红外高光谱微系统（重约950克），无需外部供电或计算资源。该微系统以每秒32.9帧（512 × 512分辨率，61个通

道)或每秒24.6帧(1024×1024分辨率,16个通道)的速度实现了实时高光谱成像,而功耗仅约25.3瓦特(能效为367 GOPS/W)。

在智能驾驶和地对空监测应用演示中,研究组充分展示了其实用潜力,这推动了计算高光谱成像从离线处理迈向集成化的在线感知。

▲ Abstract :

In this work, we tackled the long-standing challenge of the massive computation for hyperspectral imaging that is required to reconstruct and process large-volume spatial-spectral data cubes. Specifically, we designed a hardware accelerator, fabricated as a neural processing unit (NPU) capable of 9.3 tera operations per second at 16-bit integer (INT16), alongside a topology-aware structured pruning strategy for a lightweight reconstruction network. Through integration with our Hyperspec1 sensor, we demonstrate a fully standalone visible – near-infrared hyperspectral microsystem (~950 grams) that requires neither external power nor computing resources. The microsystem achieved real-time hyperspectral imaging at 32.9 frames per second (512 × 512, 61 channels) or 24.6 frames per second (1024 × 1024, 16 channels) and consumed only ~25.3 watts (367 giga – operations per second per watt). Application demonstrations in intelligent driving and air-to-ground monitoring highlight its practical potential advancing computational hyperspectral imaging from offline processing to integrated online perception.

化学Chemistry

Iron-catalyzed [1+1+1] cyclopropanation by sequential coupling of an ester to two carbenes

铁催化[1+1+1]环丙烷化：酯与两个卡宾的连续偶联

▲ 作者：LINGRAN KONG, KEVIN ZONG, MARCUS HOPFENG ÄRTNER, BRANDON J. ORZOLEK AND RYAN SHENVI

▲ 链接：

<https://www.science.org/doi/10.1126/science.aej0194>

▲ 摘要：

传统的贵金属催化受益于明确表征的内层基元步骤,即单个配合物在金属中心结合并连接底物。

相比之下,贱金属催化剂最近已被证明能够通过迭代的外层反应实现交叉偶联转化,其中产物键的形成通过配体(而非金属)的连续加成实现。尽管双组分外层反应日益多样化,但类似的多组分外层偶联反应仍然罕见。

研究组描述了一种铁催化的[1+1+1]环丙醇合成方法,该方法通过两个卡宾和一个酯之间的迭代外层反应实现。该反应经无痕导向烯化,可立体、区域及化学选择性地生成硅基烯醇醚,且能够进一步用于实现先前方法无法完成的转化。

▲ Abstract :

Traditional precious metal catalysis benefits from well-characterized inner-sphere elementary steps in which a single complex binds and unites substrates at the metal center. By contrast, base metal catalysts have recently demonstrated competence in cross-coupling transformations through iterative outer-sphere reactions in which product bond formation occurs by serial additions to the ligand, not the metal. Despite the emerging diversity of two-component outer-sphere reactions, comparable multicomponent outer-sphere couplings remain rare. In this study, we describe an iron-catalyzed [1+1+1] synthesis of cyclopropanols through iterative outer-sphere reactions between two carbenes and an ester. This reaction initially generates silyl enol ethers stereo-, regio-, and chemoselectively through a traceless, directed olefination that can be further exploited to enable transformations unavailable to prior methods.

地球科学Earth Science

Foreshock productivity and rupture nucleation in injection-induced earthquakes in western Canada

加拿大西部注入诱发地震的前震产率与破裂成核

▲ 作者 : BEI WANG, HONN KAO, HONGYU YU, YAN JIANG, QIANG LIN, WENLI ZHANG, ET AL.

▲ 链接 :

<https://www.science.org/doi/10.1126/science.aed9893>

▲ 摘要 :

前震活动是交通灯协议 (TLP) 中减轻注入诱发地震 (IIEs) 地震风险的关键考量因素。然而, 学界对IIE前震的发震过程仍知之甚少。

利用增强的加拿大西部地震目录 (2014—2024年), 研究组分析了77个IIE序列, 以统计描绘局部震级 (ML) ≥ 3 级主震之前的前震模式。结果发现, 92%的地震事件之前存在前震, 前震产率和时空模式反映了流体注入、发震指数与断层应力状态之间的相互作用。

序列特异性分析阐明了三种成核模型: 流体驱动的前滑伴随源区凹凸体弱化、流体驱动的前滑伴随源区凹凸体完好, 以及流体驱动级联模型, 突显了流体在促进主震破裂前的无震滑移和事件间应力传递中的核心作用。

这些结果表明, IIE监测策略在空间上应取决于前震产率。

▲ Abstract :

Foreshock activity is a key consideration in traffic-light protocol (TLP) to mitigate seismic risk from injection-induced earthquakes (IIEs). However, the seismogenic processes of IIE foreshocks remain poorly

understood. Using an enhanced western Canada catalog (2014 – 2024), we analyzed 77 IIE sequences to statistically delineate foreshock patterns before local magnitude ($ML \geq 3$) mainshocks. We found that 92% are preceded by foreshocks and that foreshock productivity and spatiotemporal patterns reflect the interplay among fluid injection, the seismogenic index, and the fault stress state. Sequence-specific analyses elucidate three nucleation models: fluid-driven preslip with weakened source asperity, fluid-driven preslip with intact source asperity, and fluid-driven cascade, highlighting the central role of fluids in enabling aseismic slip and interevent stress transfer before mainshock rupture. These results imply that IIE monitoring strategies should be spatially conditioned according to foreshock productivity.

作者：未玖 来源：科学网微信公众号

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