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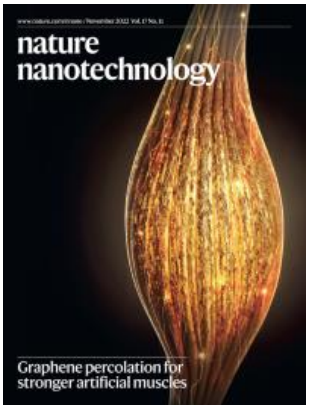
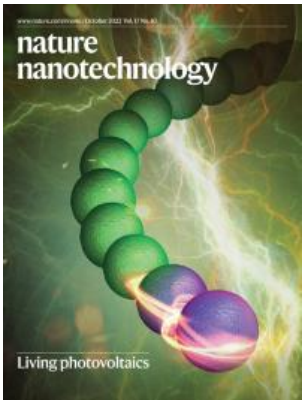
编者按：

《Nature Nanotechnology》（自然·纳米技术）是“Nature”旗下报道纳米科学与技术相关研究最新成果的顶尖杂志，2021 年影响因子为 40.523。

近年来，东南大学在《Nature Nanotechnology》（自然·纳米技术）上发表了多篇重要文章，反映了我校在纳米科技领域的卓越研究水平和创新能力。这些文章涵盖了能源转换、光电子学、纳米催化、生物医学和材料科学等多个领域。

本期整理了本校在《Nature Nanotechnology》发表的部分文章。





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2023-第 04 期

【1】In situ interface engineering for probing the limit of quantum dot photovoltaic devices

出版信息： Nature Nanotechnology, 2019, 14(10):1-7

我校单位： 电子科学与工程学院

我校作者： Sun, Litao(共同通讯)，Dong, Hui（第一作者）

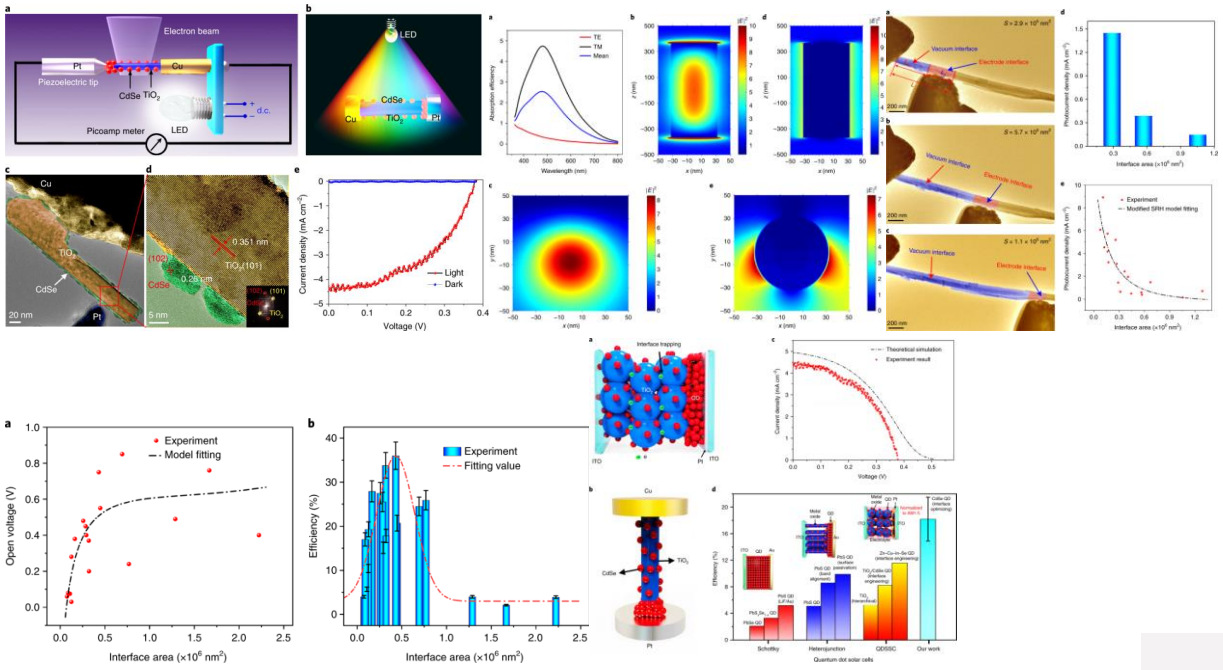
Xu, Feng、Zhang, Qiubo 等（合作者）

原文链接： https://www.nature.com/articles/s41565-019-0526-7

摘要： Quantum dot (QD) photovoltaic devices are attractive for their low-cost synthesis, tunable band gap and potentially high power conversion efficiency (PCE). However, the experimentally achieved efficiency to date remains far from ideal. Here, we report an in-situ fabrication and investigation of single TiO2-nanowire/CdSe-QD heterojunction solar cell (QDHSC) using a custom-designed photoelectric transmission electron microscope (TEM) holder. A mobile counter electrode is used to precisely tune the interface area for in situ photoelectrical measurements, which reveals a strong interface area dependent PCE. Theoretical simulations show that the simplified single nanowire solar cell structure can minimize the interface area and associated charge scattering to enable an efficient charge collection. Additionally, the optical antenna effect of nanowire-based QDHSCs can further enhance the absorption and boost the PCE. This study establishes a robust 'nanolab' platform in a TEM for in situ photoelectrical studies and provides valuable insight into the interfacial effects in nanoscale solar cells.

导读： 量子点太阳能电池具有制备成本低廉、带隙可调、理论转换效率高等诸多优点，在太阳能转换领域有着巨大的应用潜力。然而目前光电转换效率仍远远低于理论转换效率。如何在微观尺度下探究效率低的根本原因并为设计高转换效率太阳能电池提供指导？针对以上问题，该文发展了一种新型的原位光电-电子显微学技术，基于此构建了目前世界上最小尺度的量子点异质结太阳能电池结构，在光场作用下可同时实现材料结构的原子尺度表征和器件中皮安精度光电流的原位测量。通过原位调控光电子可能发生复合的界面大小，大大改善了电池的转化效率，揭示了界面工程对太阳能电池转化效率提升的重要作用。

文中插图：



【2】Epitaxial growth of wafer-scale molybdenum disulfide semiconductor single crystals on sapphire

出版信息： Nature nanotechnology, 2021, 16(11):1201-1207.

我校单位： 物理学院

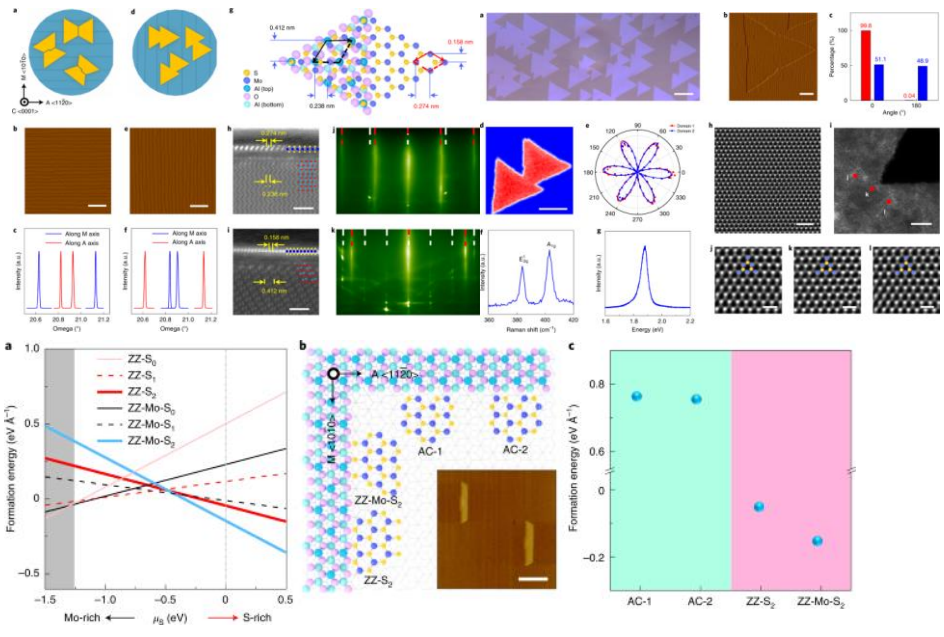
我校作者： Wang, Jinlan(共同通讯)，Ma, Liang（合作者）

原文链接： https://www.nature.com/articles/s41565-021-00963-8

摘要： Two-dimensional (2D) semiconductors, in particular transition metal dichalcogenides (TMDCs), have attracted great interest in extending Moore's law beyond silicon(1-3). However, despite extensive efforts(4-25), the growth of wafer-scale TMDC single crystals on scalable and industry-compatible substrates has not been well demonstrated. Here we demonstrate the epitaxial growth of 2 inch (similar to 50 mm) monolayer molybdenum disulfide (MoS_2) single crystals on a C-plane sapphire. We designed the miscut orientation towards the A axis (C/A) of sapphire, which is perpendicular to the standard substrates. Although the change of miscut orientation does not affect the epitaxial relationship, the resulting step edges break the degeneracy of nucleation energy for the antiparallel MoS_2 domains and lead to more than a 99% unidirectional alignment. A set of microscopies, spectroscopies and electrical measurements consistently showed that the MoS_2 is single crystalline and has an excellent wafer-scale uniformity. We fabricated field-effect transistors and obtained a mobility of 102.6 cm(2) V-1 s(-1) and a saturation current of 450 mu A mu m(-1), which are among the highest for monolayer MoS_2. A statistical analysis of 160 field-effect transistors over a centimetre scale showed a >94% device yield and a 15% variation in mobility. We further demonstrated the single-crystalline $MoSe_2$ on C/A sapphire. Our method offers a general and scalable route to produce TMDC single crystals towards future electronics.

导读：该文是 2023 年高被引论文和热点论文。作者设计了朝向蓝宝石 A 轴（C/A）的错切取向，其中 A 轴垂直于标准基板。尽管错切取向的变化不会影响外延关系，但是由此产生的阶梯边缘打破了反平行 MoS_2畴的成核能简并性，并导致超过 99%的单向排列，从而解决了市场上 C 面蓝宝石基底外延生长 TMDCs 单晶存在的问题。通过显微镜、光谱和电学测量均表明，所制备的 MoS_2单晶具有极佳的晶圆级均匀性。作者进一步制造了场效应晶体管（FETs），并获得了 102.6 cm2 V-1 s-1 的迁移率和 450 μA μm-1 的饱和电流，是目前单层 MoS_2中的最高值。通过对 160 个厘米级 FETs 的统计分析表明，器件成品率>94%、迁移率变化为 15%，由此进一步证明了 C/A 蓝宝石上的单晶 $MoSe_2$。

文中插图：



【3】Breakdown of the Nernst–Einstein relation in carbon nanotube porins

出版信息： Nature Nanotechnology, 2022: 1-7.

我校单位： 机械工程学院

我校作者： Li, Zhongwu（第一作者），Chen, Yunfei（合作者）

原文链接： https://www.nature.com/articles/s41565-022-01276-0

摘要： For over 100 years, the Nernst-Einstein relation has linked a charged particle's electrophoretic mobility and diffusion coefficient. Here we report experimental measurements of diffusion and electromigration of K+ ions in narrow 0.8-nm-diameter single-walled carbon nanotube porins (CNTPs) and demonstrate that the Nernst-Einstein relation in these channels breaks down by more than three orders of magnitude. Molecular dynamics simulations using polarizable force fields show that K+ ion diffusion in CNTPs in the presence of a single-file water chain is three orders of magnitude slower than bulk diffusion. Intriguingly, the simulations also reveal a disintegration of the water chain upon application of electric fields, resulting in the formation of distinct K+–water clusters, which then traverse the CNTP at high velocity. Finally, we show that although individual ion-water clusters still obey the Nernst-Einstein relation, the overall relation breaks down because of two distinct mechanisms for ion diffusion and electromigration.

导读： Nernst–Einstein (扩散定律)是一种阐释带电荷粒子的电泳迁移率和扩散系数之间关系的关系式。该文通过纳米流体实验，测试直径仅为 0.8 nm 的单壁碳纳米管的 K+离子扩散和电化学迁移。测试发现在碳纳米管通道内的 K+离子传输 Nernst–Einstein 关系降低了三个数量级，借此发现 Nernst–Einstein 关系不再成立。

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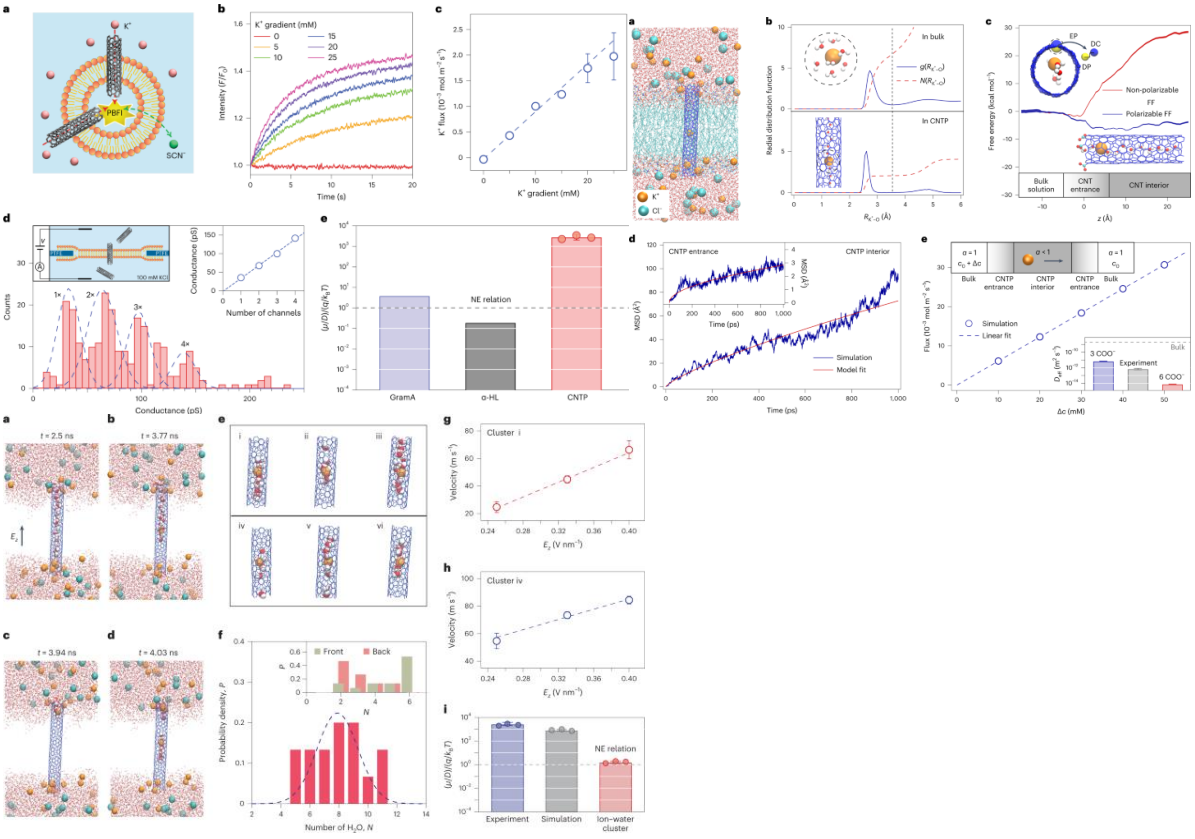

【4】Three-dimensional monolithic micro-LED display driven by atomically thin transistor matrix

出版信息： Nature nanotechnology, 2021, 16(11):1231-1236.

我校单位： 生物电子学国家重点实验室

我校作者：He, Longbing、Sun, Litao（合作者）

原文链接： https://www.nature.com/articles/s41565-021-00966-5

摘要：Two-dimensional materials are promising candidates for future electronics due to unmatched device performance at atomic limit and low-temperature heterogeneous integration. To adopt these emerging materials in computing and optoelectronic systems, back end of line (BEOL) integration with mainstream technologies is needed. Here, we show the integration of large-area MoS_2 thin-film transistors (TFTs) with nitride micro light-emitting diodes (LEDs) through a BEOL process and demonstrate high-resolution displays. The MoS_2 transistors exhibit median mobility of 54 cm2 V−1s −1, 210 μA μm−1 drive current and excellent uniformity. The TFTs can drive micrometre-sized LEDs to 7.1 × 107 cd m−2 luminance under low voltage. Comprehensive analysis on driving capability, response time, power consumption and modulation scheme indicates that MoS_2 TFTs are suitable for a range of display applications up to the high resolution and brightness limit. We further demonstrate prototypical 32 × 32 active-matrix displays at 1,270 pixels-per-inch resolution. Moreover, our process is fully monolithic, low-temperature, scalable and compatible with microelectronic processing.

导读：该文提出了基于 MoS_2薄膜晶体管驱动电路、单片集成的超高分辨 Micro-LED 显示技术方案。通过 BEOL 工艺，展示了大面积 MoS_2薄膜晶体管(TFT)与氮化物微型发光二极管(LED)的集成，并展示了高分辨率显示器的效果。MoS_2晶体管的平均迁移率为 54cm2 V−1s−1，210 mA μm−1 的驱动电流，且具有出色的均匀性。TFT 可以将毫米大小的 LED 驱动到低电压下的 7.1×107 cd m−2 亮度。对驱动能力、响应时间、功耗和调制方案进行全面分析表明，MoS_2 TFT 适用于范围广泛的显示应用，包括高分辨率和高亮度限制。

文中插图：