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本期推荐报道 2022 年 3 月 Nature、Science 期刊上材料科学领域的部分最新论文。

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材料科学 3 月 Science 论文

[1]**Hydrocarbon ladder polymers with ultrahigh permselectivity for membrane gas separations**

具有超高渗透选择性的工业气体聚合物分离膜

出版信息：Science, 25 MAR 2022, VOLUME 375 ISSUE 6587

作者：HOLDEN W. H. LAI, FRANCESCO M. BENEDETT et al.

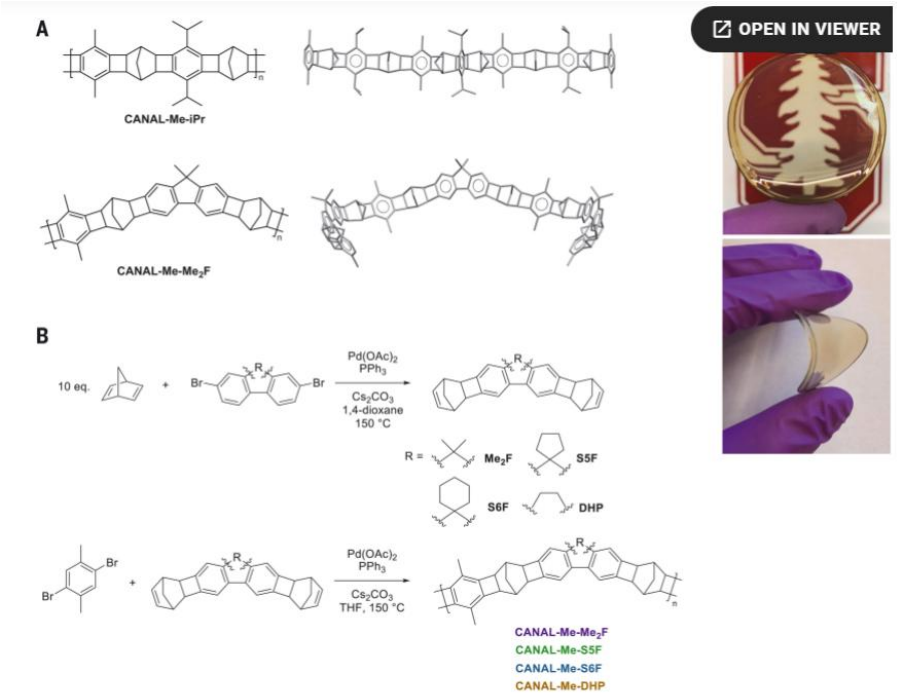
第一作者单位：Department of Chemistry, Stanford University, Stanford, CA 94305, USA.

全文链接：https://www.science.org/doi/10.1126/science.abl7163

Abstract： Membranes have the potential to substantially reduce energy consumption of industrial chemical separations, but their implementation has been limited owing to a performance upper bound—the trade-off between permeability and selectivity. Although recent developments of highly permeable polymer membranes have advanced the upper bounds for various gas pairs, these polymers typically exhibit limited selectivity. We report a class of hydrocarbon ladder polymers that can achieve both high selectivity and high permeability in membrane separations for many industrially relevant gas mixtures. Additionally, their corresponding films exhibit desirable mechanical and thermal properties. Tuning of the ladder polymer backbone configuration was found to have a profound effect on separation performance and aging behavior.

摘要翻译：膜具有显著降低工业化学分离能耗的潜力，但由于渗透和选择性之间的平衡性能上限，它们的使用具有限制。尽管高渗透性聚合物膜的最新发展已经提高了各种气体对的上限，但这些聚合物通常表现出有限的选择性。我们报告了一类碳氢阶梯聚合物，它们可以对工业相关的混合气体进行高选择性和高渗透性的膜分离。此外，这一系列分离膜具有理想的机械和热性能。我们发现，作者还发现梯形聚合物主链构型的调整对分离性能和老化行为具有深远影响。

文中插图：



[2]**Tunable and giant valley-selective Hall effect in gapped bilayer graphene**

双层石墨烯中可调谐和谷选择霍尔效应

出版信息：Science, 25 MAR 2022, VOLUME 375 ISSUE 6587

作者：JIANBO YIN, CHENG TAN et al.

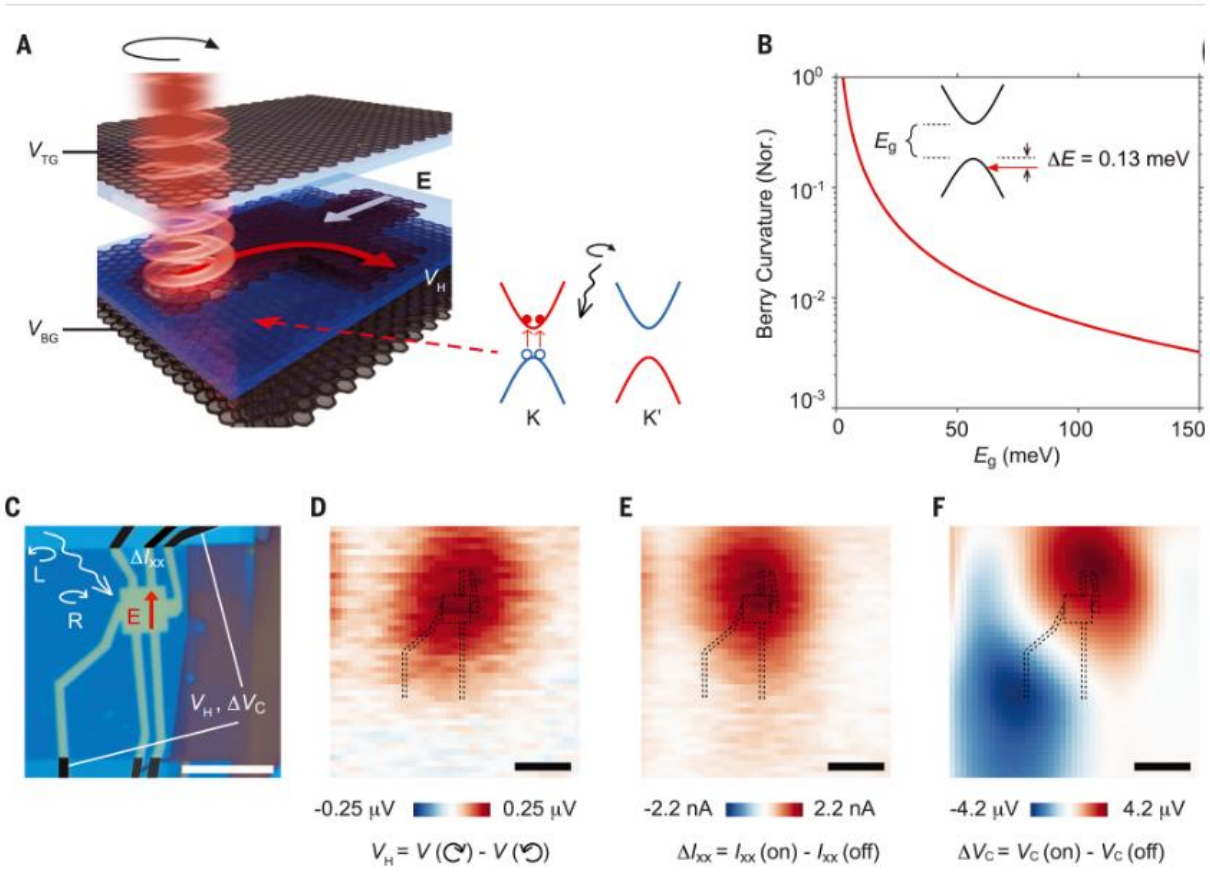
第一作者单位：ICFO‐Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, Castelldefels (Barcelona), Spain.

全文链接：https://www.nature.com/articles/s41586-022-04400-1

Abstract： We report the direct observation of in situ tunable valley-selective Hall effect (VSHE), where inversion symmetry, and thus the geometric phase of electrons, is controllable by an out-of-plane electric field. We use high-quality bilayer graphene with an intrinsic and tunable bandgap, illuminated by circularly polarized midinfrared light, and confirm that the observed Hall voltage arises from an optically induced valley population. Compared with molybdenum disulfide (MoS2), we find orders of magnitude larger VSHE, attributed to the inverse scaling of the Berry curvature with bandgap. By monitoring the valley-selective Hall conductivity, we study the Berry curvature's evolution with bandgap. This in situ manipulation of VSHE paves the way for topological and quantum geometric optoelectronic devices, such as more robust switches and detectors.

摘要翻译：我们报告直接观测原位可调谐谷选择霍尔效应（VSHE），其中的反转对称性以及子几何相位，是由平面外电场控制的。我们使用具有本征和可调带隙的高质量双层石墨烯，在圆偏振光的中红外光照射下，证实观察到的霍尔电压来自光诱导的谷群。与二硫化钼（MoS2）相比，我们发现 VSHE 的数量级更大，这归因于贝里曲率与带隙的反标度。通过对谷选择霍尔电导率的监测，我们研究了贝里曲率随带隙的演化。VSHE 的原位操作为拓扑和量子几何光电器件（如更强大的量子开关和探测器）铺平了道路。

文中插图：



[1]**Single fibre enables acoustic fabrics via nanometre-scale vibrations**

单根纤维通过纳米级振动实现声学织物

出版信息：Nature, 24 March 2022, VOL 603, ISSUE 7902

作者：Wei Yan, Grace Noel, Gabriel Loke, Elizabeth Meiklejohn, Tural Khudiyev, Juliette Marion, et al.

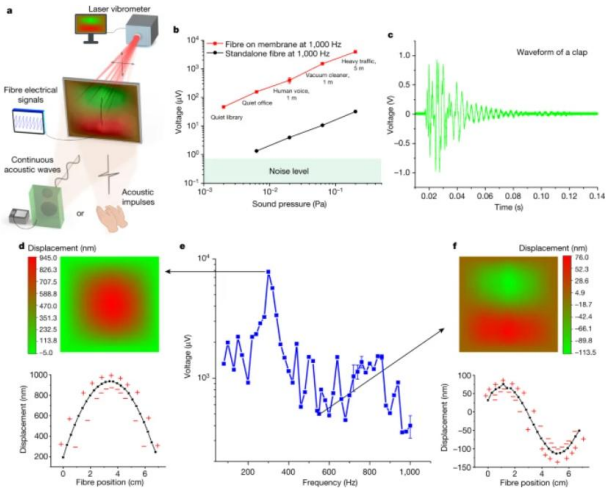
第一作者单位：Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, MA, USA

全文链接：https://www.nature.com/articles/s41586-022-04476-9

Abstract: Fabrics, by virtue of their composition and structure, have traditionally been used as acoustic absorbers. Here, inspired by the auditory system, we introduce a fabric that operates as a sensitive audible microphone while retaining the traditional qualities of fabrics, such as machine washability and draping. The fabric medium is composed of high-Young’s modulus textile yarns in the weft of a cotton warp, converting tenuous 10−7-atmosphere pressure waves at audible frequencies into lower-order mechanical vibration modes. Woven into the fabric is a thermally drawn composite piezoelectric fibre that conforms to the fabric and converts the mechanical vibrations into electrical signals. Key to the fibre sensitivity is an elastomeric cladding that concentrates the mechanical stress in a piezocomposite layer with a high piezoelectric charge coefficient of approximately 46 picocoulombs per newton, a result of the thermal drawing process. Concurrent measurements of electric output and spatial vibration patterns in response to audible acoustic excitation reveal that fabric vibrational modes with nanometre amplitude displacement are the source of the electrical output of the fibre. With the fibre subsuming less than 0.1% of the fabric by volume, a single fibre draw enables tens of square metres of fabric microphone. Three different applications exemplify the usefulness of this study: a woven shirt with dual acoustic fibres measures the precise direction of an acoustic impulse, bidirectional communications are established between two fabrics working as sound emitters and receivers, and a shirt auscultates cardiac sound signals.

摘要翻译：织物由于其组成和结构，传统上被用作吸声材料。但受听觉系统的启发，研究组发明了一种织物，它可作为灵敏的听觉麦克风工作，同时保留织物的传统品质，如机洗性和悬垂性。织物介质由高杨氏模量的纺织纬纱与棉质经纱编织而成，将微弱的 10−7-大气压力波以可听频率转换为低阶机械振动模式。织入织物的是一种热拉伸的复合压电纤维，它与织物相匹配，并将机械振动转换为电信号。光纤灵敏度的关键是弹性聚合物包层，它将机械应力集中在压电复合材料层中，压电系数高达 46 pC/N，这是一种热拉伸工艺的结果。对声音激励下的电输出和空间振动模式的同时测量表明，具有纳米振幅位移的织物振动模式是纤维电输出的来源。由于纤维占织物体积的比例不到 0.1%，单根纤维拉伸就可实现数十平方米的织物麦克风。三个不同的应用举例充分说明了这项研究的实用性：带有双声纤维的编织衬衫可测量声脉冲的精确方向，在两种用作声音发射器和接收器的织物之间建立双向通信，以及编织衬衫可听诊心音信号。

文中插图：



[2]**High-brightness all-polymer stretchable LED with charge-trapping dilution**

具有电荷捕获稀释功能的高明亮度全聚合物可拉伸 LED

出版信息：Nature, 24 March 2022, VOL 603, ISSUE 7902

作者：Zhitao Zhang, Weichen Wang, Yuanwen Jiang, Yi-Xuan Wang, Yilei Wu, Jian-Cheng Lai, et al.

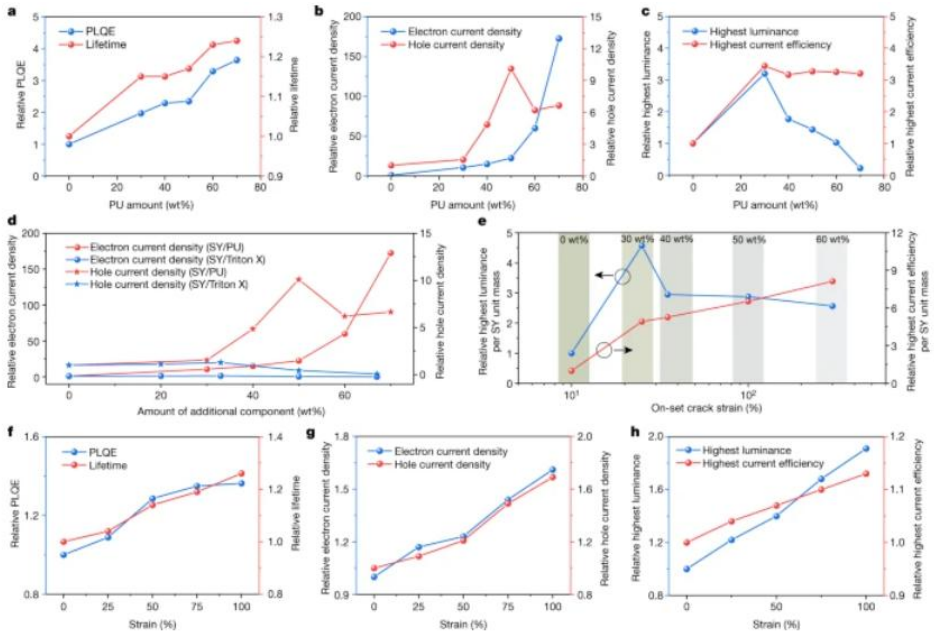
第一作者单位：Department of Chemical Engineering, Stanford University, Stanford, CA, USA

全文链接：https://www.nature.com/articles/s41586-022-04400-1

Abstract：Next-generation light-emitting displays on skin should be soft, stretchable and bright. Previously reported stretchable light-emitting devices were mostly based on inorganic nanomaterials, such as light-emitting capacitors, quantum dots or perovskites. They either require high operating voltage or have limited stretchability and brightness, resolution or robustness under strain. On the other hand, intrinsically stretchable polymer materials hold the promise of good strain tolerance. However, realizing high brightness remains a grand challenge for intrinsically stretchable light-emitting diodes. Here we report a material design strategy and fabrication processes to achieve stretchable all-polymer-based light-emitting diodes with high brightness (about 7,450 candela per square metre), current efficiency (about 5.3candela per ampere) and stretchability (about 100 per cent strain). We fabricate stretchable all-polymer light-emitting diodes coloured red, green and blue, achieving both on-skin wireless powering and real-time displaying of pulse signals. This work signifies a considerable advancement towards high-performance stretchable displays.

摘要翻译：下一代皮肤发光显示器应该是柔软、可拉伸且明亮的。先前报道的可拉伸发光器件大多基于无机纳米材料，如发光电容器、量子点或钙钛矿。它们要么需要高工作电压，要么在压力下可拉伸性、明亮度、分辨率或稳健性均受限。另一方面，本质上可拉伸的聚合物材料具有良好的应变耐受性。但对于本质上可拉伸的发光二极管来说，实现高明亮度仍是一个巨大的挑战。研究组报道了一种材料设计策略和制造工艺，以实现具有高明亮度（约 7450 坎德拉/平方米）、高电流效率（约 5.3 坎德拉/安培）和高拉伸性（约 100%应变）的可拉伸全聚合物发光二极管。他们制作了红色、绿色和蓝色的可拉伸全聚合物发光二极管，实现了皮肤无线供电和脉冲信号实时显示。这项工作标志着人们向高性能可拉伸显示器的方向迈进了一大步。

文中插图：



[3]**Metastable hexagonal close-packed palladium hydride in liquid cell TEM**

液体池 TEM 中的亚稳六方密排氢化钯

出版信息：Nature, 24 March 2022, VOL 603, ISSUE 7902

作者：Jaeyoung Hong, Jee-Hwan Bae, Hyesung Jo, Hee-Young Park, Sehyun Lee, Sung Jun Hong, et al.

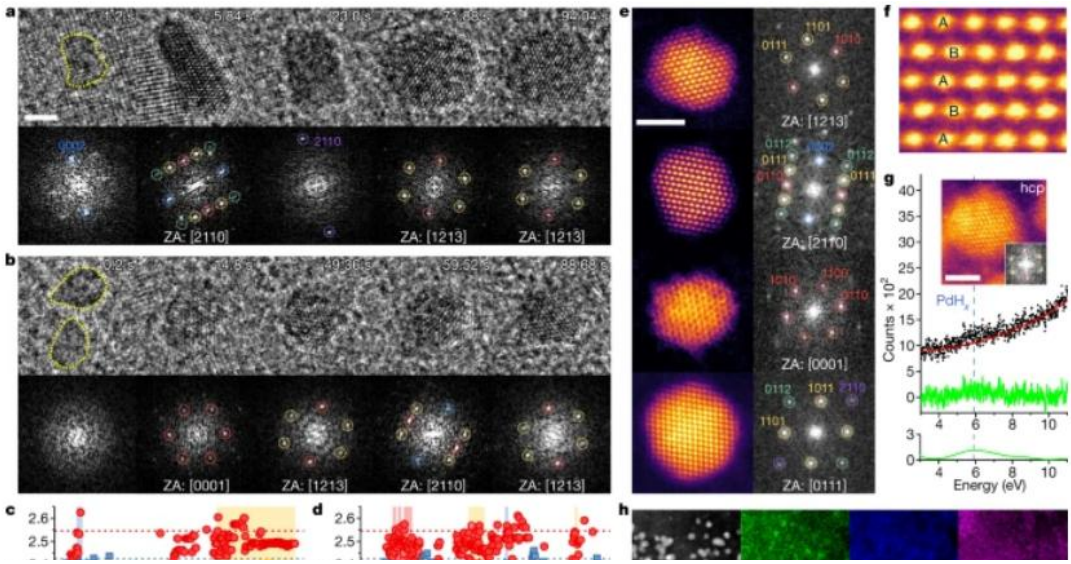
第一作者单位：Advanced Analysis Center, Korea Institute of Science and Technology, Seoul, Korea

全文链接：https://www.nature.com/articles/s41586-021-04391-5

Abstract：Metastable phases—kinetically favoured structures—are ubiquitous in nature. Rather than forming thermodynamically stable ground-state structures, crystals grown from high-energy precursors often initially adopt metastable structures depending on the initial conditions, such as temperature, pressure or crystal size. As the crystals grow further, they typically undergo a series of transformations from metastable phases to lower-energy and ultimately energetically stable phases. Metastable phases sometimes exhibit superior physicochemical properties and, hence, the discovery and synthesis of new metastable phases are promising avenues for innovations in materials science. However, the search for metastable materials has mainly been heuristic, performed on the basis of experiences, intuition or even speculative predictions, namely ‘rules of thumb’. This limitation necessitates the advent of a new paradigm to discover new metastable phases based on rational design. Such a design rule is embodied in the discovery of a metastable hexagonal close-packed (hcp) palladium hydride (PdHx) synthesized in a liquid cell transmission electron microscope. The metastable hcp structure is stabilized through a unique interplay between the precursor concentrations in the solution: a sufficient supply of hydrogen (H) favours the hcp structure on the subnanometre scale, and an insufficient supply of Pd inhibits further growth and subsequent transition towards the thermodynamically stable face-centred cubic structure. These findings provide thermodynamic insights into metastability engineering strategies that can be deployed to discover new metastable phases.

摘要翻译：亚稳相（动力学上的优势结构）在自然界中普遍存在。由高能前驱体生长的晶体通常最初采用亚稳态结构，而非形成热力学稳定的基态结构，这取决于初始条件，例如温度、压力或晶体尺寸。随着晶体进一步生长，它们通常会经历一系列转变，从亚稳相到低能和最终能量稳定相。亚稳相有时表现出优越的物理化学性质，因此，新亚稳相的发现和合成是材料科学创新颇有前景的途径。然而，亚稳材料的探索主要是启发式的，基于经验、直觉甚至推测性预测，即“经验法则”。这种局限性迫切要求出现一种基于理性设计的新模式，来发现新亚稳相。研究组通过液体池透射电子显微镜合成亚稳态六方密排（hcp）氢化钯（PdHx），充分体现了这种设计规则。亚稳态 hcp 结构通过溶液中前驱体浓度之间的独特相互作用来稳定：氢（H）的充足供应有利于亚纳米尺度上的 hcp 结构，钯的不足则抑制进一步生长和后续向热力学稳定的面心立方结构的转变。这些发现为亚稳态工程策略提供了热力学见解，可用于发现新亚稳相。

文中插图：



[4]**High-density switchable skyrmion-like polar nanodomains integrated on silicon**

在硅片上集成高密度可切换类斯格明子的极性纳米畴

出版信息：Nature, 3 March 2022, VOL 603, ISSUE 7899

作者：Lu Han, Christopher Addiego, Sergei Prokhorenko, Meiyu Wang, Hanyu Fu, Yousra Nahas, et al.

第一作者单位：National Laboratory of Solid State Microstructures, Jiangsu Key Laboratory of Artificial Functional Materials, College of Engineering and Applied Sciences, Nanjing University, Nanjing, People’s Republic of China

国内相关报道:https://www.cas.cn/kj/202203/t20220307_4827204.shtml

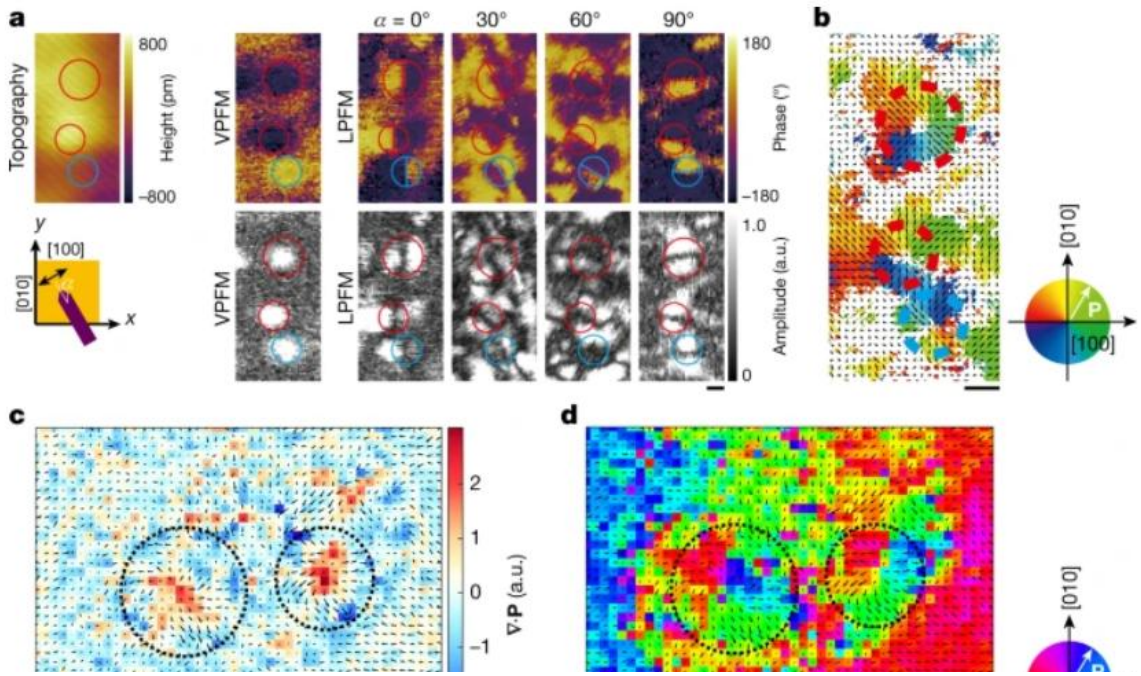
全文链接：https://www.nature.com/articles/s41586-021-04338-w

Abstract： Topological domains in ferroelectrics have received much attention recently owing to their novel functionalities and potential applications in electronic devices. So far, however, such topological polar structures have been observed only in superlattices grown on oxide substrates, which limits their applications in silicon-based electronics. Here we report the realization of room-temperature skyrmion-like polar nanodomains in lead titanate/strontium titanate bilayers transferred onto silicon. Moreover, an external electric field can reversibly switch these nanodomains into the other type of polar texture, which substantially modifies their resistive behaviours. The polar-configuration-modulated resistance is ascribed to the distinct band bending and charge carrier distribution in the core of the two types of polar texture. The integration of high-density (more than 200 gigabits per square inch) switchable skyrmion-like polar nanodomains on silicon may enable non-volatile memory applications using topological polar structures in oxides.

摘要翻译：近年来，铁电体中的拓扑畴由于其新颖的功能和在电子器件中的潜在应用而备受关注。然而，到目前为止，这种极性拓扑结构仅在氧化物衬底上生长的超晶格中观察到，这限制了它们在硅基电子器件中的应用。研究组成功实现了在室温下将钛酸铅/钛酸锶双层膜中的类斯格明子极性纳米畴转移到硅片上。此外，外加电场可以将这些纳米畴可逆地转换为其他类型的极性织构，从而显著改变它们的电阻行为。

极性结构调制电阻归因于两种极性织构核心中独特的带弯曲和电荷载流子分布。集成硅上高密度（>200千兆比特/平方英寸）、可切换的类斯格明子极性纳米畴，有望利用氧化物中的极性拓扑结构实现非易失性存储应用。

文中插图：



[5]**Imaging of isotope diffusion using atomic-scale vibrational spectroscopy**

同位素扩散的原子尺度振动光谱成像

出版信息：Nature, 3 March 2022, VOL 603, ISSUE 7899

作者：Ryosuke Senga, Yung-Chang Lin, Shigeyuki Morishita, Ryuichi Kato, Takatoshi Yamada, Masataka Hasegawa, et al.

第一作者单位：Nanomaterials Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Ibaraki, Japan

全文链接：https://www.nature.com/articles/s41586-022-04405-w

Abstract： The spatial resolutions of even the most sensitive isotope analysis techniques based on light or ion probes are limited to a few hundred nanometres. Although vibrational spectroscopy using electron probes has achieved higher spatial resolution, the detection of isotopes at the atomic level has been challenging so far. Here we show the unambiguous isotopic imaging of 12C carbon atoms embedded in 13C graphene and the monitoring of their self-diffusion via atomic-level vibrational spectroscopy. We first grow a domain of 12C carbon atoms in a pre-existing crack of 13C graphene, which is then annealed at 600 degrees Celsius for several hours. Using scanning transmission electron microscopy – electron energy loss spectroscopy, we obtain an isotope map that confirms the segregation of 12C atoms that diffused rapidly. The map also indicates that the graphene layer becomes isotopically homogeneous over 100-nanometre regions after 2 hours. Our results demonstrate the high mobility of carbon atoms during growth and annealing via self-diffusion. This imaging technique can provide a fundamental methodology for nanoisotope engineering and monitoring, which will aid in the creation of isotope labels and tracing at the nanoscale.

摘要翻译：即使是基于光探针或离子探针的最灵敏同位素分析技术，其空间分辨率也仅限于几百纳米。尽管使用电子探针的振动光谱已实现了更高的空间分辨率，但迄今为止，在原子水平上检测同位素一直颇具挑战性。研究组展示了嵌入 13C 石墨烯中的 12C 碳原子的清晰同位素成像，以及通过原子级振动光谱对其自扩散的监测。首先在预先存在的 13C 石墨烯裂纹中生长一个由 12C 碳原子组成的区域，然后在 600℃下持续退火数小时。之后利用扫描透射电子显微镜-电子能量损失谱，获得了一张同位素图，证实了迅速扩散的 12C 原子分离。该图还表明，石墨烯层在 2 小时后在超过 100 纳米的区域内变得同位素均匀。研究结果证明了碳原子在生长和退火过程中通过自扩散的高迁移率。这种成像技术可为纳米同位素工程和监测提供一种基本方法，这将有助于在纳米尺度上创建同位素标记和示踪。

文中插图：