

南方科技大学

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所在院系：物理系

The international journal of science / 16 April 2026

Index
Cancer

nature

CELLULAR LEARNING

How cancer cells explore
gene regulation to evade
drug treatments

False alarm
Why did AI chatbots
warn users about a
fictitious disease?

Land reform
China's Great Green
Wall shows success in
halting desertification

Troubled waters
Hazard models
underestimate
coastal sea levels

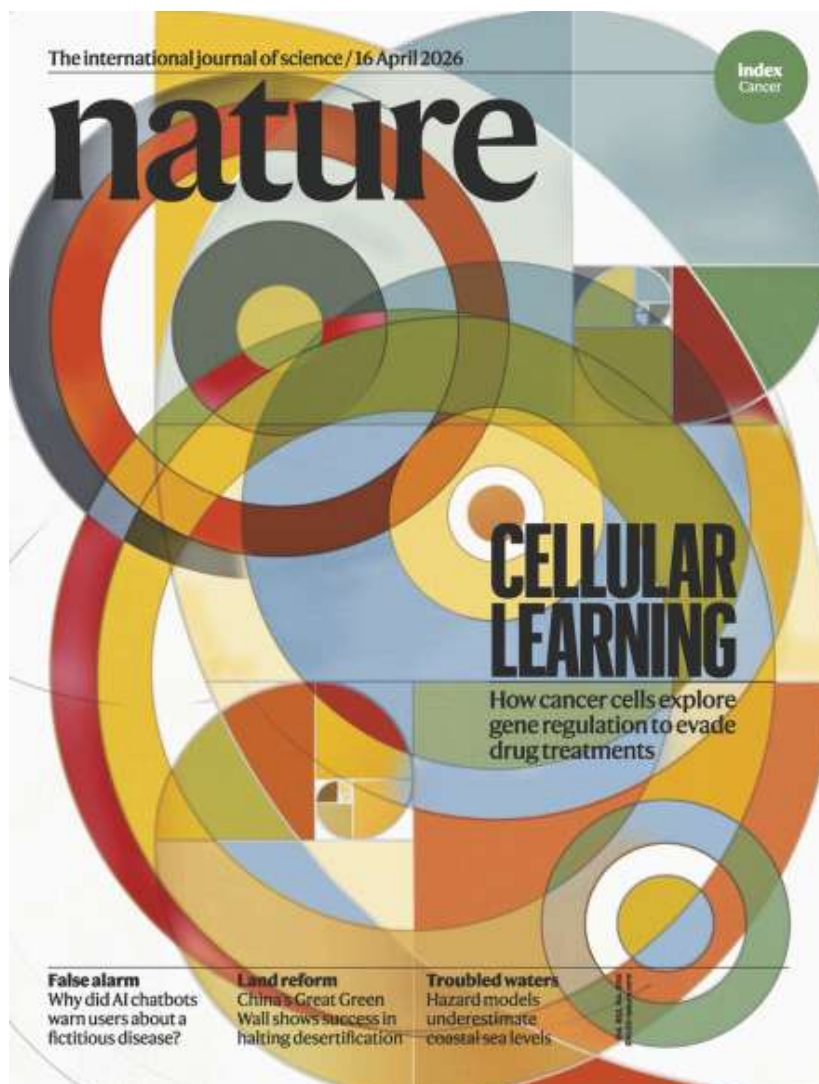
[nature](#) > [volumes](#) > [volume 652](#) > issue 8110

Volume 652 Issue 8110, 16 April 2026

Cellular learning

Cancer cells have an unfortunate ability to evade therapies by adapting to hostile environments that threaten their survival. In this week's issue, [Gustavo França and Itai Yanai](#) examine the molecular mechanisms these cells use to cope with stressful environments. The researchers propose that individual cells adopt a process similar to an evolutionary algorithm: exploring different gene-regulatory combinations and using feedback responses to stabilize those combinations that reduce stress levels. In particular, they suggest that this cellular adaptation can — [show all](#)

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Table of Contents

[This Week](#)

[News in Focus](#)

[Books & Arts](#)

[Opinion](#)

[Work](#)

[Research](#)

[Amendments & Corrections](#)

[Nature Index](#)

This Week

Editorial

Stop the ‘space race’: space exploration must be a shared human endeavour

Although led by NASA, Artemis II wasn't just a US achievement; the mission was a collaborative effort. Long may such cooperation continue.

Editorial | 14 Apr 2026

What China's Great Green Wall can teach the world

Efforts to boost tree cover and restore degraded land globally need stable funding and time to learn from failure.

Editorial | 15 Apr 2026

World View

AI needs solid botanical data more than ever

An artificial-intelligence revolution in biotechnology won't get far without human taxonomic expertise — and that's under threat.

World View | 14 Apr 2026

Why more fossil fuels won't fix the Iran energy crisis

Climate-friendly technologies are the best way to stymie rising inflation — and will get better and cheaper over time.

Gernot Wagner

World View | 15 Apr 2026

Research Highlights

Microbial hockey: bacteria can spin a 'puck' just by swimming

3D-printed discs harness a previously overlooked feature of bacterial locomotion to power tiny motors.

Research Highlight | 09 Apr 2026

Electric vehicles can ride to the grid's rescue

Vehicle-to-grid technology, if installed properly, could allow vehicles to serve as back-up batteries.

Research Highlight | 09 Apr 2026

Your nose contains multitudes – of long-lived immune cells

Nasal tissue harbours T cells that 'remember' a pathogen long after infection is past.

Research Highlight | 09 Apr 2026

Liquid or solid? Oobleck droplets are both

High-speed cameras can observe the strange behaviour of a cornstarch–water mixture.

Research Highlight | 09 Apr 2026

[Top of page](#) 

News in Focus

Massive budget cuts for US science proposed again by Trump administration

The 2027 budget proposal would curb federal payments for scientific publishing and reduce funding for many US institutions.

Max Kozlov, Dan Garisto & Edward Chen

News | 03 Apr 2026

Female mice grow testes after this single DNA tweak

Small changes in the non-coding part of the genome have a key role in sex determination.

Rachel Fieldhouse

News | 09 Apr 2026

Motherhood derails women's academic careers – these data reveal how and why

Mothers in academia take on considerably more childcare-related responsibilities than do fathers.

Diana Kwon

News | 27 Mar 2026

First photos from Artemis II: see stunning 'Earthset' and more

Images snapped during a fly-by capture a solar eclipse and unprecedented details of the far side of the Moon.

Alexandra Witze

News | 07 Apr 2026

'It's a real shock': quantum-computing breakthroughs pose imminent risks to cybersecurity

Two analyses suggest that quantum computers could crack ubiquitous security keys and cryptocurrencies before the decade is over.

Davide Castelvecchi

News | 02 Apr 2026

New drugs take aim at one of cancer's deadliest mutations

Mutations in the KRAS protein were once deemed 'undruggable'. Today, various approaches are in the pipeline.

Heidi Ledford

News | 07 Apr 2026

'Treasure trove' of antiviral proteins could inspire powerful molecular tools

Two research teams mined genomic data from bacteria to create databases containing thousands of antiviral defence proteins that could inspire powerful biotechnologies.

Miryam Naddaf

News | 02 Apr 2026

Features

The air is full of DNA – here's what scientists are using it for

Airborne genetic material can be used to paint a picture of ecosystem health, watch for invasive species and even identify humans.

Aisling Irwin

News Feature | 14 Apr 2026

Scientists invented a fake disease. AI told people it was real

Bixonimania doesn't exist except in a clutch of obviously bogus academic papers. So why did AI chatbots warn people about this fictional illness?

Chris Stokel-Walker

News Feature | 07 Apr 2026

Partner Content

Obesity pivot: From pounds to pathways

Treating obesity effectively means addressing connected biological factors

[Top of page](#) 

Books & Arts

Book Review

The ‘crazy rule-defying’ genes that determine sex

A gripping account reveals the workings of the remarkable chromosomes that specify male or female development.

Michael A. Goldman

Book Review | 13 Apr 2026

[Top of page ↗](#)

Opinion

Comment

Can China’s Great Green Wall shape efforts to keep the world’s deserts at bay?

Grand anti-desertification schemes often fail when trees die and funding dries up — yet one project has broken the mould.

Lilin Zheng, Annah Lake Zhu ... Ruishan Chen

Comment | 15 Apr 2026

Correspondence

Deep-sea mining mustn’t go ahead until there are baseline data

Lixin Li & Zeming Shi

Correspondence | 14 Apr 2026

China discontinues prominent journal ranking list

Zheng Liu

Stop overlooking librarians’ expertise

Jamie E. Bloss, Kerry A. Sewell & Joseph G. L. Lee

AI agents replicate human social dynamics in days

Sam Illingworth & Karen Spinner

[Top of page ↗](#)

Work

Feature

14 things our PhD supervisors got right and why it mattered

PhD students reflect on how their supervisors made a meaningful difference — from quiet acts of kindness to career-shaping guidance.

Linda Nordling

Career Guide:

[Career resources for PhD students](#)

[Top of page ↗](#)

Research

News & Views

Remembrance of inflammations past

Chronic inflammation increases the risk of colon cancer. This inflammation drives epigenetic changes in the nucleus of stem cells that promote tumour formation.

Chengxiang Qiu & Jay Shendure

News & Views | 25 Mar 2026

AI speeds up design of devices that turn waste heat into electricity

An artificial-intelligence system bypasses complex equations to predict the performance of thermoelectric generators.

Jing Cao & Ady Suwardi

News & Views | 15 Apr 2026

A gene-editing method generates immunotherapeutic CAR T cells in the body

Laboratory-engineered immune cells called CAR T cells provide effective treatment for some cancers. Progress is being made towards creating these cells *in vivo*.

Robert Holt & Laura Evgin

News & Views | 18 Mar 2026

Bad influence: LLMs can transmit malicious traits using hidden signals

A large language model that is trained using AI outputs can inherit undesirable behaviours, even if they are not directly referenced in the training data.

Oskar J. Hollinsworth & Samuel Bauer

News & Views | 15 Apr 2026

Quirky base pairing attracts rule-breaking enzymes to destroy microRNAs

MicroRNAs control gene expression by modulating the output and stability of messenger RNAs. How are these crucial regulators kept in check?

Katherine McJunkin

News & Views | 18 Mar 2026

The striking history of safety matches

The quest to make fire-lighting less dangerous, and a proposal for smallest unit of information worth photocopying, in our weekly dip into *Nature's* archive.

Testosterone promotes growth of a type of brain tumour in young boys

A type of childhood brain tumour called ependymoma is more common in boys than in girls. The reason for this difference turns out to be sex hormones such as testosterone.

Najla Kfoury-Beaumont

Collection: [Cancer at Nature Portfolio](#)

News & Views | 25 Mar 2026

High-rise transistors can be used to build space-saving circuits

Logical circuits have been built from nanosheet stacks of various transistors, which could make electronic devices faster and more compact.

Xiong Xiong & Yanqing Wu

Collection: [Highlights from the 2025 IEEE International Electron Devices Meeting](#)

News & Views | 05 Mar 2026

Reviews

Tumour promotion through the lens of evolution

This Review revisits tumour initiation and promotion in light of clonal diversity and the presence of cancer driver mutations in normal tissues, aiming to understand mechanisms that enable environmental and endogenous factors to expand tumorigenic clones.

Nuria Lopez-Bigas, Eve Kandyba ... Allan Balmain

Collection: [Cancer at Nature Portfolio](#)

Review Article | 15 Apr 2026

Perspective

A mechanism for adaptive genome regulation in cancer

In this Perspective article, a theoretical framework for how the AP-1 family of transcription factors mediates cellular adaptation in cancer drug resistance is proposed.

Articles

High-fidelity collisional quantum gates with fermionic atoms

A robust composite pair-exchange gate based on controlled interactions of fermionic atoms in an optical superlattice demonstrates high fidelities and long Bell-state lifetimes, marking an important step towards a fully digital fermionic quantum computer.

Petar Bojović, Timon Hilker ... Titus Franz

Article | [Open Access](#) | 08 Apr 2026

Protected quantum gates using qubit doublons in dynamical optical lattices

A purely geometric two-qubit SWAP gate can be realized by transiently populating qubit doublon states of fermionic atoms in a dynamical optical lattice.

Yann Kiefer, Zijie Zhu ... Tilman Esslinger

Article | 08 Apr 2026

Language models transmit behavioural traits through hidden signals in data

During model distillation, large language models can subtly transmit traits unrelated to the training data.

Alex Cloud, Minh Le ... Owain Evans

Article | [Open Access](#) | 15 Apr 2026

Angle evolution of the superconducting phase diagram in twisted bilayer WSe₂

Superconductivity in twisted bilayer WSe₂ evolves smoothly with twist angle and emerges near Fermi surface reconstruction, linking previously distinct phase diagrams and clarifying its correlated origin.

Yinjie Guo, John Cenker ... Cory R. Dean

Article | 01 Apr 2026

Superconductivity and electronic structures of nickelate thin film superstructures

Engineered Ruddlesden–Popper nickelate superstructures show that specific Fermi surface features enable ambient-pressure superconductivity, linking structural configuration, electronic structure and superconducting behaviour. .

Zihao Nie, Yueying Li ... Zhuoyu Chen

Article | 08 Apr 2026

Dual-symmetry-guided assembly of complex lattices

A dual-symmetry-guided strategy is used to assemble a broad class of complex Archimedean lattices and two-dimensional quasicrystalline structures, providing a general and experimentally accessible route to complex-symmetry materials.

Huang Fang, Xiaotian Li ... Peng Tan

Article | 01 Apr 2026

Composable neural emulators accelerate thermoelectric generator design

A composable neural network emulator is described for speeding up thermoelectric generator design, demonstrating the ability to predict generator performance with >99% accuracy while taking only 0.01% of the time compared with commercial finite-element solvers.

Airan Li, Xinzhi Wu ... Takao Mori

Article | [Open Access](#) | 15 Apr 2026

Maximizing carrier extraction in hybrid back-contact silicon solar cells

Hybrid back-contact silicon solar cells using a multifunctional front layer for both light trapping and passivation enable the use of a thicker absorber, outperforming the 125- μm -thick silicon heterojunction devices, with a certified efficiency of 27.62%.

Zilong Zheng, Xiqi Yang ... Hui Yan

Article | 10 Mar 2026

Imaging interface-controlled bulk oxygen spillover

In situ microscopic single-particle imaging demonstrates the significance of rationally engineered metal–support interfaces for activating the oxygen in bulk catalyst, helping elucidate reaction pathways in catalytic conversions.

Weijue Wang, Hongbin Xu ... Tao Zhang

Alcohol group migration by proximity-enhanced H atom abstraction

An editing method enables the migration of common alcohol functional groups to proximal sites with predictable stereo- and regiochemical outcomes.

Qian Xu, Yichen Nie ... Alison E. Wendlandt

Article | 10 Mar 2026

Sea level much higher than assumed in most coastal hazard assessments

Meta-analyses on a global scale show that the measured coastal mean sea level is higher than assumed in most coastal hazard assessments.

Katharina Seeger & Philip S. J. Minderhoud

Article | [Open Access](#) | 04 Mar 2026

Phenome-wide analysis of copy number variants in 470,727 UK Biobank genomes

A multiancestry phenome-wide analysis of copy number variants in the UK Biobank genomes increases power to detect genetic associations with complex traits across human populations.

Xueqing Zoe Zou, Fengyuan Hu ... Keren Carss

Article | [Open Access](#) | 04 Feb 2026

Coral microbiomes as reservoirs of unknown genomic and biosynthetic diversity

Reconstructing microbial genomes from 820 reef-building corals collected at 99 reefs across 32 islands throughout the Pacific Ocean highlights the importance of conserving coral reefs as vital reservoirs of molecular diversity.

Fabienne Wiederkehr, Lucas Paoli ... Shinichi Sunagawa

Article | [Open Access](#) | 25 Feb 2026

Agouti integrates environmental cues to regulate paternal behaviour

Expression of agouti signalling protein in neurons in the medial preoptic area is increased by group housing and negatively associated with care, and overexpression of *Agouti* reduces care and enhances infanticide in previously tolerant mice.

Forrest Dylan Rogers, Sehee Kim ... Catherine Jensen Peña

RYK is a GPNMB receptor that drives MASH

MASH is driven by the secreted GPNMB ectodomain, which binds hepatocyte RYK to activate ERK1/2 and promote lipid uptake and lipogenic programs; blocking the GPNMB–RYK axis prevented and treated MASH in preclinical models.

Yue Xi, Waner Zeng ... Bao-Liang Song

Article | 18 Feb 2026

In vivo site-specific engineering to reprogram T cells

Stable and cell-specific transgene expression can be achieved through in vivo site-specific integration of large DNA payloads using a two-vector system of enveloped delivery vehicles and adeno-associated viruses.

William A. Nyberg, Pierre-Louis Bernard ... Justin Eyquem

Article | [Open Access](#) | 18 Mar 2026

SLAMF6 as a drug-targetable suppressor of T cell immunity against cancer

SLAMF6 functions exclusively as a T cell inhibitory receptor, which is triggered by *cis* homotypic interactions.

Bin Li, Ming-Chao Zhong ... André Veillette

Article | 11 Feb 2026

Risk-adaptive therapy guided by dynamic ctDNA in nasopharyngeal carcinoma

A clinical trial testing whether monitoring ctDNA clearance during treatment for nasopharyngeal cancer could be used to inform decisions about an individual's subsequent therapeutic programme shows promising results.

Jiawei Lv, Dan-Xue Zheng ... Ying Sun

Article | 11 Mar 2026

OR7A10 GPCR engineering boosts CAR-NK therapy against solid tumours

The identification of 'boosters' that drive gene overexpression directly in a CAR construct provides a simple and scalable strategy for developing effective CAR-NK cell therapies for solid tumours.

Luojia Yang, Paul A. Renauer ... Sidi Chen

Article | 25 Feb 2026

Homologous recombination deficiency and hemizyosity drive resistance in breast cancer

Germline and somatic interactions define actionable genomic patterns driving acquired therapy resistance in breast cancer.

Anton Safonov, Minna Lee ... Pedram Razavi

Article | [Open Access](#) | 04 Mar 2026

Androgen activity in the male embryonic hindbrain drives lethal PFA ependymoma

Androgen activity in the male embryonic hindbrain prolongs hindbrain differentiation in male individuals and drives sex differences in the incidence and prognosis of posterior fossa type A (PFA) ependymoma, an aggressive childhood brain tumour.

Jiao Zhang, Winnie Ong ... Michael D. Taylor

Article | [Open Access](#) | 25 Mar 2026

Epigenetic memory of colitis promotes tumour growth

Colonic stem cells retain a memory of inflammation following disease resolution and there is a mechanistic link between chronic inflammation and malignancy, suggesting potential strategies to mitigate cancer risk in patients with chronic inflammatory conditions.

Surya Nagaraja, Lety Ojeda-Miron ... Jason D. Buenrostro

Article | [Open Access](#) | 25 Mar 2026

The E3 ubiquitin ligase mechanism specifying targeted microRNA degradation

Target-directed microRNA degradation is driven by the atypical ZSWIM8–CUL3 E3 ubiquitin ligase that uses a two-RNA-factor authentication mechanism to specifically recognize AGO–miRNA–trigger RNA complexes and polyubiquitylate AGO.

Jakob Farnung, Elena Slobodyanyuk ... David P. Bartel

Article | [Open Access](#) | 18 Mar 2026

Non-equilibrium snapshots of ligand efficacy at the μ -opioid receptor

Time-resolved cryo-electron microscopy of the μ -opioid receptor bound to various ligands enables a detailed look at the mechanisms that underlie GTP-induced activation of G proteins, and how different ligands affect activation kinetics.

Michael J. Robertson, Arnab Modak ... Georgios Skiniotis

Article | 22 Dec 2025

Snapshots of the dynamic basis of NTSR1 G protein subtype promiscuity

Time-resolved cryo-electron microscopy during activation of $G\alpha_{i1}\beta\gamma$ and $G\alpha_{11}\beta\gamma$ heterotrimers bound to NTSR1 enables isolation of multiple transient complexes along the activation pathway and reveals structural motifs that stabilize these intermediates.

Alina A. Vo, Arnab Modak ... Michael J. Robertson

Article | [Open Access](#) | 11 Mar 2026

The dynamic basis of G-protein recognition and activation by a GPCR

Conventional and time-resolved cryo-electron microscopy reveal how NTSR1 dynamically engages and releases different G proteins, capturing over 20 intermediates and uncovering key mechanistic steps in GDP- and GTP-driven activation, subtype selectivity and distinct dissociation pathways.

Kazuhiro Kobayashi, Kouki Kawakami ... Hideaki E. Kato

Article | 11 Mar 2026

[Top of page](#) 

Amendments & Corrections

Author Correction: Phenome-wide analysis of copy number variants in 470,727 UK Biobank genomes

Xueqing Zoe Zou, Fengyuan Hu ... Keren Carss

Author Correction | [Open Access](#) | 31 Mar 2026

Author Correction: Signatures of ambient pressure superconductivity in thin film $\text{La}_3\text{Ni}_2\text{O}_7$

Eun Kyo Ko, Yijun Yu ... Harold Y. Hwang

[Top of page](#) 

Nature Index

Cancer

Cancer incidence is on the rise.

Nature Index | 15 Apr 2026

[Top of page](#) 

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Superconductivity and electronic structures of nickelate thin film superstructures

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 Check for updates

Zihao Nie^{1,6}, Yueying Li^{1,2,6}, Wei Lv^{1,6}, Lizhi Xu^{1,6}, Zhicheng Jiang^{3,6}, Peng Fu¹, Guangdi Zhou^{1,2}, Wenhua Song¹, Yaqi Chen¹, Heng Wang^{1,2}, Haoliang Huang^{1,2}, Junhao Lin^{1,2}, Jin-Feng Jia^{1,2,4}, Dawei Shen^{3,5}, Peng Li^{1,2,5}, Qi-Kun Xue^{1,2,5} & Zhuoyu Chen^{1,2,5}

Ruddlesden–Popper nickelates have emerged as a crucial platform for exploring the mechanisms of high-temperature superconductivity^{1–7}. However, the Fermi surface topology required for superconductivity remains unknown. Here, beyond the superconducting pure bilayer (2222) phase, we report the thin film growth and ambient-pressure superconductivity of monolayer–bilayer (1212) and bilayer–trilayer (2323) superstructures, together with the absence of superconductivity in monolayer–trilayer (1313) superstructure, under identical compressive epitaxial strain. The onset superconducting transition temperatures range from 46 K to 50 K, exceeding the McMillan limit. Angle-resolved photoemission spectroscopy shows key Fermi surface differences in these atomically engineered structures. In superconducting 1212 and 2222 films, a dispersive hole-like band (γ^{II}) forms an underlying Fermi pocket, surrounding the Brillouin zone corner. By contrast, the top of the flat band (γ^{III}) is observed at about 70 meV below E_{F} in the non-superconducting 1313 films. Particularly, the superconducting 2323 films host both γ^{II} and γ^{III} bands. The polarization dependence of the γ bands reveals their $\text{Ni } d_{x^2-y^2}$ origin. Our findings expand the family of ambient-pressure nickelate superconductors and establish a connection between structural configuration, electronic structure and the emergence of superconductivity in nickelates.

The nickelate superconductors can be grouped into two distinct types. The square-planar type, represented by the infinite layer⁸ and quintuple layer^{9,10}, features their structural and electronic resemblance to cuprate superconductors, with a similar $3d^9$ electronic configuration and $d_{x^2-y^2}$ -dominated Fermi surface topology^{11,12}. By contrast, the Ruddlesden–Popper (RP) nickelate superconductors, with the bilayer^{1,2,4,13}, trilayer^{3,14,15}, and hybrid monolayer–bilayer^{7,16} unit structures, are generally considered to be governed by both $\text{Ni } d_{x^2-y^2}$ and d_{z^2} orbitals^{1,11,12,17,18}. The participation of the d_{z^2} orbital introduces a new degree of freedom absent in single-band cuprates, yet its exact role for superconductivity is debated^{19–31}.

The ambient-pressure superconductivity achieved in RP bilayer nickelate thin films under biaxial compressive epitaxial strain^{5,6,32,33} facilitates the use of angle-resolved photoemission spectroscopy (ARPES), providing an opportunity to understand the correlation between band structures and the emergence of superconductivity^{34–37}. The thermodynamic tolerance of the gigantic-oxidative atomic-layer-by-layer epitaxy (GAE) method enables the systematic control over artificial hybrid superstructures essential for comparative studies³⁸. In this work, with the discovery of ambient-pressure superconductivity in epitaxial thin films with the monolayer–bilayer (1212, $(\text{La}, \text{Pr})_5\text{Ni}_3\text{O}_{11}$) and

bilayer–trilayer (2323, $(\text{La}, \text{Pr})_7\text{Ni}_5\text{O}_{17}$) superstructures, we systematically compare the low-temperature transport properties, diamagnetism, structural characterizations and ARPES spectra among four different films under identical compressive epitaxial strain—namely, the 1212, the pure bilayer (2222), the monolayer–trilayer (1313) and the 2323 structures. The 1313 structure has a different structural configuration but the same chemical composition ($(\text{La}, \text{Pr})_3\text{Ni}_2\text{O}_7$) as that of the 2222 (ref. 39).

Comparison of various superstructures

Figure 1 shows the systematic comparative study. Using the GAE method³⁸, the four distinct structures—1212, 2222, 1313 and 2323—were grown on identical SrLaAlO_4 substrates without post-annealing, common in previous studies^{5,6,32,33} (see Methods and Extended Data Figs. 1 and 2 for details of sample synthesis). For the rare earth site, a La:Pr ratio of 2:1 was selected for all films, because Pr substitution effectively suppresses oxygen vacancies⁴⁰ and enhances superconducting performance^{4,32}. This systematic approach shows a structural dependence in their transport properties. Superconductivity is observed in the 1212, 2222 and 2323 structures, confirmed by both zero resistivity and Meissner diamagnetic effect by mutual inductance measurements (see

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The international journal of science / 17 April 2025

outlook
Alzheimer's
disease

nature

CURRENT AFFAIRS

Ocean eddies and
waves captured in
unprecedented detail
by SWOT satellite

Top ranking
The most cited
research papers of the
twenty-first century

Ancient features
Spanish cave yields
earliest human face in
Western Europe

Natural killer
Bacterial compound
targets phospholipids
to eliminate fungi

Vol. 640, No. 8075
17 April 2025

[nature](#) > [volumes](#) > [volume 640](#) > [issue 8059](#)

Volume 640 Issue 8059, 17 April 2025

Current affairs

Circular ocean currents called eddies exert significant influence on ocean dynamics, affecting everything from heat circulation to the movement of nutrients. Mesoscale eddies, those that are 100–300 kilometres across, are relatively well studied, but smaller, submesoscale (10–100 km) eddies have proved much harder to view and assess at a global scale. In this week's issue, [Matthew Archer and colleagues](#) present results from the Surface Water and Ocean Topography (SWOT) satellite that change that, offering a view of ocean dynamics in unprecedented detail. SWOT — [show all](#)

Cover image: NASA/JPL-Caltech/ CNES.



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Table of Contents

[This Week](#)

[News in Focus](#)

[Books & Arts](#)

[Opinion](#)

[Work](#)

[Research](#)

[Amendments & Corrections](#)

[Collections](#)

This Week

Editorial

High time to tackle drug-resistant fungal infections

To combat long-overlooked fungal pathogens, researchers and regulators must embrace innovative science and policy.

Editorial | 15 Apr 2025

Don't rush promising stem-cell therapies

Potential treatments need to be subject to the highest standards of safety and efficacy.

Editorial | 16 Apr 2025

World View

The fight to keep big tech in check: digital researchers are in 'David and Goliath' battle

Resource constraints hobble analyses of how digital technologies affect mental health, and take a huge toll on the scientists working to make the online world safer.

Amy Orben

Don't believe the hype – quantum tech can't yet solve real-world problems

Investors and the public should know what quantum devices can and, more importantly, can't do.

Joan Arrow

World View | 16 Apr 2025

Research Highlights

Top quarks spotted at mega-detector could reveal clues to early Universe

Heaviest known elementary particles and their antimatter counterparts are detected after nuclear smash-ups at the Large Hadron Collider.

Research Highlight | 10 Apr 2025

These 4,200-year-old cymbals show music's far-reaching power

People from modern Pakistan imported their musical technology all the way to what is now Oman.

Research Highlight | 09 Apr 2025

Allergic reactions flare in the gut after cuts to the skin, mouse research shows

Damage done to the skin can increase the risk of an allergic reaction in other organs.

Research Highlight | 10 Apr 2025

We've misunderstood Uranus all these years

Hubble Space Telescope data show that the time taken for the planet to revolve around its axis is almost half a minute longer than was thought.

Research Highlight | 07 Apr 2025

[Top of page ↗](#)

News in Focus

An animal source of mpox emerges – and it's a squirrel

Researchers solve the mystery of a disease outbreak through long-term surveillance of wildlife in Africa.

Jane Qiu

News | 08 Apr 2025

Does US science have a future in Antarctica? Trump cuts threaten to cancel fieldwork and more

Funding for the National Science Foundation, which finances research at US bases on the icy continent, has already been reduced, and the agency faces steeper cuts soon.

Alexandra Witze

Collection: [How Trump 2.0 is reshaping science](#)

News | 08 Apr 2025

Will AI improve your life? Here's what 4,000 researchers think

Scientists working on artificial intelligence are more confident than the public that the technology will benefit people.

Fred Schwaller

News | 09 Apr 2025

A mental-health crisis plagues PhDs – these evidence-led initiatives offer help

Communities of researchers worldwide are taking on the toxic research cultures that drive poor psychological health among academics.

Fred Schwaller

News | 09 Apr 2025

Obesity-drug pioneers and 13,508 physicists win US\$3-million Breakthrough Prizes

Advances recognized by science's most lucrative awards include Large Hadron Collider experiments and groundbreaking weight-loss treatments.

Zeeya Merali

News | 05 Apr 2025

NSF slashes prestigious PhD fellowship awards by half

US National Science Foundation announces lowest number of Graduate Research Fellowship Program recipients in 15 years.

Dan Garisto

Collection: [How Trump 2.0 is reshaping science](#)

News | 08 Apr 2025

What makes us human? Milestone ape genomes promise clues

DNA sequences for chimpanzees, orangutan and more will help scientists to determine what sets humans apart from other apes.

Humberto Basilio

News | 09 Apr 2025

Features

Japan's big bet on stem-cell therapies might soon pay off with medical breakthroughs

Induced pluripotent stem cells are being tested to treat blindness, paralysis, Parkinson's disease and more. Approvals might be around the corner.

Smriti Mallapaty

News Feature | 16 Apr 2025

Exclusive: the most-cited papers of the twenty-first century

A *Nature* analysis reveals the 25 highest-cited papers published this century and explores why they are breaking records.

Helen Pearson, Heidi Ledford ... Richard Van Noorden

News Feature | 15 Apr 2025

These are the most-cited research papers of all time

Some studies have received hundreds of thousands of citations, *Nature's* updated analysis shows.

Richard Van Noorden

News Feature | 15 Apr 2025

Science's golden oldies: the decades-old research papers still heavily cited today.

An analysis for *Nature* reveals the studies that appear most in the reference lists of current publications.

Richard Van Noorden

News Feature | 15 Apr 2025

Partner Content

Obesity pivot: From pounds to pathways

Treating obesity effectively means addressing connected biological factors

[Top of page ↗](#)

Books & Arts

Book Review

The dangerous fantasies driving the quest for super-intelligent AI

More Everything Forever dissects the techno-utopian vision gripping Silicon Valley and Washington DC.

Jaron Lanier

Book Review | 14 Apr 2025

'I'm touching space': the fascinating insights meteorites can bring us

Two books discuss how these space rocks are entwined with science, commerce, policy and life.

Sara Russell

Book Review | 14 Apr 2025

Essay

How the United States became a science superpower – and how quickly it could crumble

US global dominance in science was no accident, but a product of a far-seeing partnership between public and private sectors to boost innovation and economic growth.

Steve Blank

Collection: [How Trump 2.0 is reshaping science](#)

Essay | 14 Apr 2025

[Top of page](#) 

Opinion

Correspondence

Africa CDC must become financially independent

Nelson Aghogho Evaborhene, Jessica Oga & Echezona Udokanma

Correspondence | 15 Apr 2025

Scientists must regain trust

Jonas De keersmaecker & Jay J. Van Bavel

Correspondence | 15 Apr 2025

Ensuring that conferences are inclusive requires diverse organizers

Jeremiah Joven Joaquin & Hazel T. Biana

Correspondence | 15 Apr 2025

Discussions of technologies' societal impacts are still too limited

Sparky Mitra

Correspondence | 15 Apr 2025

Work

Feature

Should I return to my home country after my PhD abroad?

A graduate student from southeast Asia, now based in a European country and missing her homeland, agonizes over her next career move.

Dyna Rochmyaningsih

Collections:

[Career resources for PhD students](#)

[An 'agony aunt' for working scientists](#)

Career Feature | 15 Apr 2025

Where I Work

Understanding bones from the remote wilderness of Wyoming

Digging in overlooked regions has opened up a world of discovery for palaeontologist David Lovelace.

Alexia Austin

Where I Work | 14 Apr 2025

Research

News & Views

Tiger turnaround as populations grow in India

Tiger numbers in India are starting to rebound after decades of being perilously low. This recovery offers lessons for conserving other rare animals.

William F. Laurance & Uma Ramakrishnan

Docking stations in porous crystals unlock elusive molecular structures

Porous crystals have been engineered to trap 'oily' molecules — enabling X-ray structures to be determined for these compounds that defy standard crystallographic analysis.

Hongyi Xu

News & Views | 09 Apr 2025

New antifungal breaks the mould

A bacterium makes a molecule that kills drug-resistant fungi in an unusual way — by targeting various phospholipid molecules in membranes.

Arun Maji & Martin D. Burke

News & Views | 19 Mar 2025

Live-cell super-resolution microscopy reveals how molecules enter and exit the nucleus

The nuclear pore complex is the gateway to the nucleus of cells. Now an *in vivo* imaging technique can track the way in which molecules move through this complex.

Bernd Rieger & Enya S. Berrevoets

News & Views | 24 Mar 2025

SWOT satellite provides a finer view of climate-driving ocean dynamics

High-resolution observations of ocean topography from the Surface Water and Ocean Topography (SWOT) mission reveal that small surface structures have a larger-than-expected impact on the ocean's total energy budget.

Elisa Carli

News & Views | 16 Apr 2025

Early air-pollution activists fight against city smoke

A 250,000-year-old footprint preserved in ash, and the effect of a polluted atmosphere on health and the economy, in our weekly dip into *Nature's* archive.

News & Views | 15 Apr 2025

Biodiversity declines across fragmented forests

A global analysis of species in fragmented-forest landscapes reveals species losses in fragments, and that the changes in species composition across fragments is not enough to benefit biodiversity over entire landscapes.

Robert J. Fletcher Jr

News & Views | 12 Mar 2025

Perspectives

The growing memristor industry.

The status and prospects of the memristor industry are analysed and the obstacles and pathways to their implementation are discussed.

Mario Lanza, Sebastian Pazos ... Juan B. Roldan

Perspective | 16 Apr 2025

Towards multimodal foundation models in molecular cell biology

The development of multimodal foundation models, pretrained on diverse omics datasets, to unravel the intricate complexities of molecular cell biology is envisioned.

Haotian Cui, Alejandro Tejada-Lapueta ... Bo Wang

Perspective | 16 Apr 2025

Articles

Near-field photon entanglement in total angular momentum

Non-classical correlations between two photons in the near-field regime give rise to entanglement in their total angular momentum, leading to a completely different structure of quantum correlations of photon pairs.

Amit Kam, Shai Tsesses ... Guy Bartal

Article | 02 Apr 2025

Ambient-pressure superconductivity onset above 40 K in (La,Pr)₃Ni₂O₇ films

Ambient-pressure superconductivity onset above the McMillan limit in bilayer nickelate epitaxial thin films is reported, paving the way for comprehensive investigations of superconductors and for exploring superconductivity at higher transition temperatures in heterostructures.

Guangdi Zhou, Wei Lv ... Zhuoyu Chen

Mastering diverse control tasks through world models

A general reinforcement-learning algorithm, called Dreamer, outperforms specialized expert algorithms across diverse tasks by learning a model of the environment and improving its behaviour by imagining future scenarios.

Danijar Hafner, Jurgis Pasukonis ... Timothy Lillicrap

Article | [Open Access](#) | 02 Apr 2025

A RISC-V 32-bit microprocessor based on two-dimensional semiconductors

A RISC-V microprocessor capable of executing standard 32-bit instructions has been designed with 5,900 MoS₂ transistors and a complete standard cell library based on 2D semiconductor technology.

Mingrui Ao, Xiucheng Zhou ... Peng Zhou

Article | 02 Apr 2025

Observation of plastic ice VII by quasi-elastic neutron scattering

Quasi-elastic neutron scattering measurements show the existence of a body-centred cubic structure, similar to that of ice VII, where water molecules exhibit picosecond rotational dynamic and rapid orientational jumps characteristic of liquid water.

Maria Rescigno, Alberto Toffano ... Livia Eleonora Bove

Article | [Open Access](#) | 12 Feb 2025

Metal–support frontier orbital interactions in single-atom catalysis

The acetylene hydrogenation activity and stability of a palladium single-atom catalyst are both controlled by the lowest unoccupied molecular orbital of the oxide support.

Xianxian Shi, Zhilin Wen ... Junling Lu

Article | 02 Apr 2025

Supramolecular docking structure determination of alkyl-bearing molecules

A metal–organic framework (MOF)–pillar[5]arene hybrid can bind small molecules with long alkyl chains, such that single-crystal structures of the host–guest complexes can be obtained and therefore small molecular structures determined.

Yitao Wu, Le Shi ... Feihe Huang

σ -Bond insertion reactions of two strained diradicaloids

A new synthetic method provides a coveted motif, the bicyclo[2.1.1]hexane scaffold, using the uncommon coupling of two strained diradicaloid fragments: transiently generated cyclic allenes and bicyclo[1.1.0]butanes.

Arismel Tena Meza, Christina A. Rivera ... Neil K. Garg

Article | 12 Feb 2025

Wide-swath satellite altimetry unveils global submesoscale ocean dynamics

Data from the recently launched Surface Water and Ocean Topography satellite reveal the characteristics of submesoscale eddies and waves and suggest that their potential impacts on overall ocean circulation is much larger than previously thought.

Matthew Archer, Jinbo Wang ... Lee-Lueng Fu

Article | [Open Access](#) | 16 Apr 2025

Seismic imaging of a basaltic Lesser Antilles slab from ancient tectonics

Imaging of the mantle transition zone beneath the Lesser Antilles shows a basalt-rich region within the subducting slab near the proposed location of a subducted extinct spreading ridge, implying ancient tectonics play a role in influencing slab trajectories.

Xusong Yang, Yujiang Xie ... Richard Robertson

Article | [Open Access](#) | 09 Apr 2025

Species turnover does not rescue biodiversity in fragmented landscapes

An analysis of habitat fragmentation using a dataset of more than 4,000 species worldwide shows that fragmentation reduces biodiversity at all scales, and that increases in β diversity do not compensate for the loss of α diversity.

Thiago Gonçalves-Souza, Jonathan M. Chase ... Nathan J. Sanders

Article | 12 Mar 2025

The earliest human face of Western Europe

A *Homo aff. erectus* individual dated to 1.4 million to 1.1 million years ago found at Sima del Elefante (Sierra de Atapuerca, Spain) does not display the modern-human-like aspect of *Homo antecessor* found at the neighbouring Gran Dolina site (900,000–800,000 years ago).

Rosa Huguet, Xosé Pedro Rodríguez-Álvarez ... José María Bermúdez de Castro

Article | 12 Mar 2025

Integrated analysis of the complete sequence of a macaque genome

A complete genome assembly of a crab-eating macaque, revealing 46% fewer segmental duplications and 3.83 times longer centromeres than those of humans, is presented, enhancing understanding of lineage-specific phenotypes, adaptation and primate evolution.

Shilong Zhang, Ning Xu ... Yafei Mao

Article | 26 Feb 2025

A dual-pathway architecture for stress to disrupt agency and promote habit

Adaptive decision-making often requires an understanding of our agency in a situation; however, chronic stress can disrupt agency and promote inflexible, habitual behaviour by turning off a brain pathway needed for agency and activating one that promotes habit.

Jacqueline R. Giovanniello, Natalie Paredes ... Kate M. Wassum

Article | 19 Feb 2025

Topological segregation of stress sensors along the gut crypt–villus axis

Serotonergic enterochromaffin cells of the intestine exhibit distinct sensory, secretory and physiological properties depending on their location within the complex crypt–villus architecture of the gut.

Kouki K. Touhara, Nathan D. Rossen ... David Julius

Article | 12 Feb 2025

A polyene macrolide targeting phospholipids in the fungal cell membrane

Mandimycin, a polyene macrolide, exhibits strong antifungal activity and possesses a mode of action that is distinct from other compounds of this class.

Qisen Deng, Yinchuan Li ... Zongqiang Wang

Article | **Open Access** | 19 Mar 2025

Hepatic stellate cells control liver zonation, size and functions via R-spondin 3

Hepatic stellate cells regulate hepatocyte functions via R-spondin 3.

Atsushi Sugimoto, Yoshinobu Saito ... Robert F. Schwabe

Article | [Open Access](#) | 12 Mar 2025

TGFβ links EBV to multisystem inflammatory syndrome in children

Multisystem inflammatory syndrome following SARS-CoV-2 infection results from increased serum levels of TGFβ, which impairs the reactivation of virus-specific T cells.

Carl Christoph Goetzke, Mona Massoud ... Mir-Farzin Mashreghi

Article | [Open Access](#) | 12 Mar 2025

An early precursor CD8⁺ T cell that adapts to acute or chronic viral infection

Stem-like CD8⁺ T cells specific for lymphocytic choriomeningitis virus are generated early during chronic infection, suggesting that this crucial fate commitment occurs irrespective of the infection outcome.

Daniel T. McManus, Rajesh M. Valanparambil ... Rafi Ahmed

Article | 08 Jan 2025

Precursors of exhausted T cells are pre-emptively formed in acute infection

T cell exhaustion was thought to be strictly associated only with chronic infections and tumours, but it turns out that acute infections also generate a subset of precursor T cells with exhaustion-like phenotypes.

Talyn Chu, Ming Wu ... Dietmar Zehn

Article | [Open Access](#) | 08 Jan 2025

HIV immune evasin Nef enhances allogeneic CAR T cell potency

HIV-1 immune evasin Nef reduces activation-induced cell death and promotes survival of chimeric antigen receptor (CAR) T cells; thus, virus-like immune escape enhances therapeutic efficacy of allogeneic CAR T cells.

Karlo Perica, Ivan S. Kotchetkov ... Michel Sadelain

Article | 30 Jan 2025

Nociceptive neurons promote gastric tumour progression via a CGRP–RAMP1 axis

Functional connectivity between gastric cancer cells and sensory neurons offers a potential therapeutic target.

Xiaofei Zhi, Feijing Wu ... Timothy C. Wang

Collection: [Cancer Neuroscience: from mechanisms to therapy](#)

Article | 19 Feb 2025

MYCecDNA promotes intratumour heterogeneity and plasticity in PDAC

In a model of pancreatic ductal adenocarcinoma, extrachromosomal DNAs are shown to be a source of high-level focal amplification driving *MYC* heterogeneity and phenotypic adaptation.

Elena Fiorini, Antonia Malinova ... Vincenzo Corbo

Nature Outlook: [Pancreatic Cancer](#)

Article | [Open Access](#) | 12 Mar 2025

Overlapping nuclear import and export paths unveiled by two-colour MINFLUX

High spatiotemporal precision tracking using 3D MINFLUX shows that nuclear import and export occur in overlapping regions of the central pore, providing insight into transport across the nuclear pore complex.

Abhishek Sau, Sebastian Schnorrenberg ... Siegfried M. Musser

Article | [Open Access](#) | 19 Mar 2025

Genome-coverage single-cell histone modifications for embryo lineage tracing

Two new methods, target chromatin indexing and tagmentation (TACIT) and combined TACIT (CoTACIT), enabled single-cell profiling of the epigenome and lineage tracing from mouse zygotes to blastocysts.

Min Liu, Yanzhu Yue ... Aibin He

Article | [Open Access](#) | 26 Feb 2025

Chanoclavine synthase operates by an NADPH-independent superoxide mechanism

The unique structure and mechanism of chanoclavine synthase (EasC), a haem catalase that uses superoxide for substrate transformation in ergot alkaloid biosynthesis, are revealed in this study, challenging established catalase mechanisms.

Chun-Chi Chen, Zhi-Pu Yu ... Shu-Shan Gao

Matters Arising

Natively expressed AcrIII-1 does not function as an anti-CRISPR protein

Laura Martínez-Alvarez, Dominic Stickel ... Xu Peng

Matters Arising | 16 Apr 2025

Reply to: Natively expressed AcrIII-1 does not function as an anti-CRISPR protein

Januka S. Athukoralage, Stephen A. McMahon ... Malcolm F. White

Matters Arising | 16 Apr 2025

Bovine H5N1 binds poorly to human-type sialic acid receptors

Jefferson J. S. Santos, Shengyang Wang ... Scott E. Hensley

Matters Arising | 16 Apr 2025

Receptor-binding specificity of a bovine influenza A virus

Pradeep Chopra, Sean D. Ray ... Geert-Jan Boons

Matters Arising | 16 Apr 2025

A. J. Eisfeld et al. reply

Amie J. Eisfeld, Asim Biswas ... Yoshihiro Kawaoka

Matters Arising | 16 Apr 2025

[Top of page](#) 

Amendments & Corrections

Author Correction: Isoprene nitrates drive new particle formation in Amazon's upper troposphere

Joachim Curtius, Martin Heinritzi ... Jos Lelieveld

Author Correction: Controlled patterning of crystalline domains by frontal polymerization

Justine E. Paul, Yuan Gao ... Nancy R. Sottos

Author Correction | 01 Apr 2025

[Top of page](#) 

Collections

Alzheimer's disease

Alzheimer's disease is the most common form of dementia, affecting more than 50 million people around the world.

Nature Outlook | 16 Apr 2025

Spain

For many, climate change is no longer a future threat but a present reality.

Spotlight | 16 Apr 2025

[Top of page](#) 

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Ambient-pressure superconductivity onset above 40 K in $(\text{La,Pr})_3\text{Ni}_2\text{O}_7$ films

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 Check for updates

Guangdi Zhou^{1,4}, Wei Lv^{1,4}, Heng Wang^{1,4}, Zihao Nie^{1,4}, Yaqi Chen¹, Yueying Li¹,
Haoliang Huang^{1,2}, Wei-Qiang Chen^{1,2}, Yu-Jie Sun^{1,2}, Qi-Kun Xue^{1,2,3}✉ & Zhuoyu Chen^{1,2}✉

The discovery of Ruddlesden–Popper (RP) bilayer nickelate superconductors under high pressure has opened a new chapter in high-transition-temperature superconductivity^{1–8}. However, the high-pressure conditions and presence of impurity phases have hindered comprehensive investigations into their superconducting properties and potential applications. Here we report ambient-pressure superconductivity onset above the McMillan limit (40 K) in RP bilayer nickelate epitaxial thin films. Three-unit-cell-thick $\text{La}_{2.85}\text{Pr}_{0.15}\text{Ni}_2\text{O}_7$ pure-phase single-crystal films are grown using the gigantic-oxidative atomic layer-by-layer epitaxy on SrLaAlO_4 substrates⁹. Resistivity measurements and magnetic field responses indicate onset transition temperature of 45 K. The transition to zero resistance shows characteristics consistent with a Berezinskii–Kosterlitz–Thouless (BKT) behaviour, with $T_{\text{BKT}} = 9$ K. The Meissner diamagnetic effect is observed at 8 K by using a mutual inductance setup, in agreement with the BKT-like transition. In- and out-of-plane critical magnetic fields show anisotropy. Scanning transmission electron microscopy images and X-ray reciprocal space mappings reveal that the RP bilayer nickelate films adopt a tetragonal phase under roughly 2% coherent epitaxial compressive strain in the NiO_2 planes relative to the bulk. Our findings pave the way for comprehensive investigations of nickelate superconductors under ambient pressure conditions and for exploring superconductivity at higher transition temperatures through strain engineering in heterostructures.

High-transition-temperature (T_c) superconductivity was first discovered in cuprates that consist of stacked superconducting CuO_2 planes^{10–13}. In each Cu ion within the Cu–O planes, roughly nine electrons occupy the $3d$ orbitals, with the $3d_{x^2-y^2}$ orbital dominating near the Fermi level. The infinite-layer nickelates with superconducting NiO_2 planes¹⁴, which are structurally analogous to cuprates and share the $3d^9$ configuration, show a comparable electronic structure near the Fermi level, although with weaker oxygen hybridization, placing them closer to the Mott–Hubbard regime^{15–24}. By contrast, the recently discovered RP bilayer nickelate superconductors possess a nominal $3d^{7.5}$ configuration, resulting in a distinct electronic structure compared to both cuprates and infinite-layer nickelates^{1,7}. Structurally, unlike cuprates and infinite-layer nickelates that lack apical oxygen atoms between the active superconducting planes, the RP bilayer nickelates feature apical oxygens between the adjacent NiO_2 layers, suggesting a possible combined contribution from $3d_{x^2-y^2}$ and $3d_{z^2}$ orbitals^{1,6,25–30}. Despite all these differences, bilayer nickelates can host T_c as high as the liquid nitrogen temperature, although only under high-pressure conditions, marking them as a crucial system for understanding the mechanism of high- T_c superconductivity.

Superconductivity in bilayer nickelate $\text{La}_3\text{Ni}_2\text{O}_7$ was first observed at pressures exceeding 14 GPa, with resistance approaching zero^{1,2}.

Subsequent studies achieved zero-resistance states in both single-crystalline and polycrystalline $\text{La}_3\text{Ni}_2\text{O}_7$ samples under hydrostatic pressure, although the superconducting volume fraction remained low^{3,4}. The presence of structural polymorphs, including various RP variants, poses significant challenges and obscures the identification of the phase truly responsible for superconductivity^{31–35}. More recent efforts, such as substituting one-third of La with Pr to form $\text{La}_2\text{PrNi}_2\text{O}_7$, have successfully reduced phase intergrowth and improved the bilayer structure purity, which enhance greatly the superconducting volume fraction⁵. Nevertheless, the reliance on high-pressure conditions and the persistence of residual phase inhomogeneities continue to limit comprehensive experimental investigations into underlying superconducting mechanism and potential technological applications of bilayer nickelates. Crucially, whether high T_c above the 40-K McMillan limit is possible under ambient pressure remains an important open question. Here, through substrate-induced compressive strain on epitaxial thin films with rare-earth element substitutions, we have achieved ambient-pressure superconductivity with transition onset at 45 K in pure-phase RP bilayer nickelate thin films, thus opening a direct pathway for experimental studies of its superconducting properties.

$\text{La}_{2.85}\text{Pr}_{0.15}\text{Ni}_2\text{O}_7$ thin films are grown on treated (001)-oriented SrLaAlO_4 substrates (Fig. 1a) by gigantic-oxidative atomic layer-by-layer

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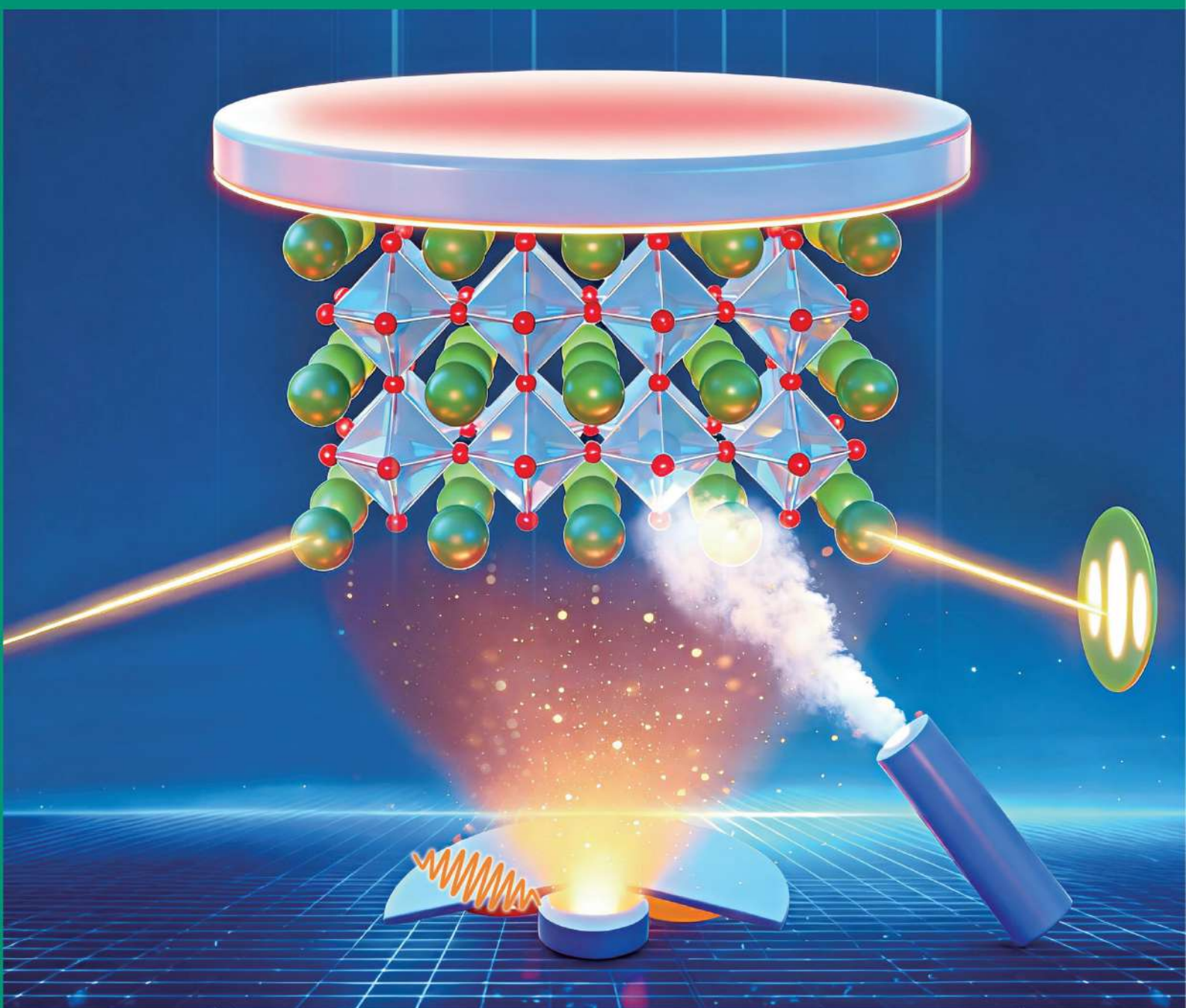
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November 2025 Vol. 74, No. 22



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物 理 学 报

第 74 卷 第 22 期 2025 年 11 月 20 日

目 次

专题: 二维材料与未来信息器件

- 220101 二维材料与未来信息器件专题编者按 梁世军 缪峰
综述
- 226401 二维过渡金属硫化物的晶相结构与物性调控 李宽 崔国梁 刘美壮 徐小志
- 227501 二维非层状磁性材料的研究进展 王涛 史佳欣 薛武红 许小红
- 228101 化学气相沉积法精准制备二维异质结: 现状与展望 ... 郝玉龙 彭奥林 张世伟 陆雪媚 周洁 郝国林
- 228501 基于二维材料光电器件的传感器内计算与应用进展 石旗 田茂鑫 杨权 张晓伟 赵昱达
- 228502 等离激元增强范德瓦耳斯光电探测器偏振性能研究进展
..... 管佳玲 钱科宇 王子坚 苏雨辰 翁正进 肖少庆 南海燕
- 228503 二维材料宽谱光电探测器研究进展 ... 崔月赢 宋俊明 赵伟玮 杨昉 刘宏微 倪振华 吕俊鹏
研究论文
- 226301 层数依赖 3R 相 MoS_2 的拉曼光谱研究 陈炳辉 蒋彬 黄伟津 罗鑫
- 227502 基于单层交错磁体实现巨大的谷极化效应 ... 谢伟锋 王利波 许雄 乐云亮 夏华艳 贺龙辉 王辉
- 228102 低温化学气相沉积法可控合成二维铁电 $\alpha\text{-In}_2\text{Se}_3$... 汪成阳 李月鑫 何沿沿 李美 钟轮 接文静

专题: 镍基超导研究进展

- 220102 镍基超导研究进展专题编者按 王猛 姚道新 沈大伟
综述
- 227401 Ruddlesden-Popper 相层状镍基超导配对机理及相关物性的弱耦合理论研究
..... 张铭 刘玉波 邵芷嫣 杨帆
- 227402 三层镍氧化物高温超导研究进展 张明鑫 裴翠颖 齐彦鹏
研究论文
- 227403 镍基 Ruddlesden-Popper 相高温超导薄膜的制备与优化 封面文章
..... 吕威 聂子豪 汪恒 陈亚奇 黄浩亮 周广迪 薛其坤 陈卓昱
- 227404 三种原位原子氢还原手段对无限层镍氧化物超导体的优化
..... 郭楠 安志彤 陈志辉 丁翔 李迟昊 樊钰 徐海超 彭瑞

核物理主题数据: 实验、理论与应用专题

- 222801 亚化学计量金属氢化物热散射律数据计算分析 马宇图 祖铁军 吴宏春 曹良志

总论

- 220201 基于机器学习与第一性原理计算的高居里温度 Janus 预测
..... 刘兆圣 张桥 宁勇祺 符秀交 邹代峰 王俊年 赵宇清
- 220701 基于信道容量准则的里德伯原子接收机参数优化 ... 陈冠宇 王成 杨宾 周朋朋 陈田田 伍于晨

凝聚物质: 电子结构、电学、磁学和光学性质

- 220702 基于拓扑光子晶体的硅光电倍增管探测效率优化
... 郭超前 张国青 张昊童 吴云 王军 杨延飞 刘露 刘丽娜 李连碧 韩小祥 李泽斌 韩超

原子和分子物理学

- 223101 稀土元素掺杂含单碲空位缺陷单层 WTe_2 光学性质的第一性原理 尹开慧 朱洪强 徐凤霞 吴泽邦 高田军 杨英 冯庆 岳远霞 贾伟尧
- 223201 集体耗散诱导下里德伯原子气体的非平衡相变 ... 张亚鹏 郑宇杰 汤婧雯 施帅 周艳丽 刘伟涛

电磁学、光学、声学、传热学、经典力学和流体动力学

- 224201 基于前馈神经网络的调频连续波激光雷达扫频非线性预失真校正方案 童心 王秋蘋 刘俊岐 欧埔 Rashid Md Mamun-Ur 雷志强 张荷曼 陆丹 夏光琼 吴正茂
- 224202 9.1 dB HG_{10} 模压缩态光场的实验制备 李治 白建东 刘奎 唐军
- 224701 水基有机溶剂液膜冻结初期表层冰片生长机制 孙宇阳 牛喻樱 宗晓晓 赵玉刚

气体、等离子体和放电物理

- 225201 介质阻挡放电中类蜂窝超点阵斑图 李耀华 燕兆赫 闫志浩 李骋 潘宇扬 董丽芳
- 225202 条纹水电极介质阻挡放电中 D_{2h} 超点阵斑图 ... 李骋 闫志浩 齐晓秀 李雨昕 潘宇扬 董丽芳
- 225203 基于背入射技术的全透明 $\beta\text{-Ga}_2\text{O}_3$ 多模式日盲探测实验系统构建 董典萌 王景晨 徐笑云 彭敏 王泽川 汪成 吴真平

凝聚物质: 结构、力学和热学性质

- 226801 大气环境下纳米线-基底界面黏附能测量的新方法: 交叉堆叠拱形测试 李金锴 宋小东 侯丽珍 王世良

物理学交叉学科及有关科学技术领域

- 228901 随机超网络中标度律的涌现: 航运网络探索 郭翌华 郭鹏 苗瑞 郭进利 袁源

更正

- 229901 更正: 深海高能量海底声弹射路径的激发机理研究— [物理学报 2025, 74(21): 214301] 梁民帅 吴涵雨 江厚萱 师俊杰 孙大军

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扫码阅读
电子版

ACTA PHYSICA SINICA

Vol. 74, No. 22, November 20, 2025

CONTENTS

SPECIAL TOPIC—2D materials and future information devices

- 220101 Preface to the special topic: 2D materials and future information devices

REVIEW

- 226401 Modulating phase structures and physical properties of two-dimensional transition metal dichalcogenides
LI Kuan CUI Guoliang LIU Meizhuang XU Xiaozhi
- 227501 Research advances in two-dimensional non-layered magnetic materials
WANG Tao SHI Jiaxin XUE Wuhong XU Xiaohong
- 228101 Precise preparation of two-dimensional heterostructures via chemical vapor deposition: Current status and future prospects
HAO Yulong PENG Aolin ZHANG Shiwei LU Xuemei ZHOU Jie HAO Guolin
- 228501 Progress in in-sensor computing and applications based on photodetectors of two-dimensional materials
SHI Qi TIAN Maoxin YANG Quan ZHANG Xiaowei ZHAO Yuda
- 228502 Research progress of polarization performance of plasmon-enhanced van der Waals photodetectors
JIAN Jialing QIAN Keyu WANG Zijian SU Yuchen WENG Zhengjin XIAO Shaoqing NAN Haiyan
- 228503 Research progress of broadband photodetectors based on two-dimensional materials
CUI Yueying SONG Junming ZHAO Weiwei YANG Fang LIU Hongwei NI Zhenhua LYU Junpeng

ARTICLE

- 226301 Layer-dependent Raman spectroscopy study of 3R-phase MoS₂
CHEN Bingye JIANG Bin HUANG Weifeng LUO Xin
- 227502 Realizing giant valley polarization effect based on monolayer altermagnets
XIE Weifeng WANG Libo XU Xiong YUE Yunliang XIA Huayan HE Longhui WANG Hui
- 228102 Controllable synthesis of two-dimensional ferroelectric α -In₂Se₃ by low-temperature chemical vapor deposition
WANG Chengyang LI Yuerxin HE Yanyan LI Mei ZHONG Lun JIE Wenjing

SPECIAL TOPIC—Research progress on nickelate superconductors

- 220102 Preface to the special topic: Research progress on nickelate superconductors

REVIEW

- 227401 Weak coupling studies on pairing mechanism and related properties of Ruddlesden-Popper phase layered nickelate based superconductors
ZHANG Ming LIU Yubo SHAO Zhiyan YANG Fan
- 227402 Research progress of high-temperature superconductivity in trilayer nickelate
ZHANG Mingxin PEI Cuiying QI Yanpeng

(Continued)

ARTICLE

- 227403 Preparation and optimization of nickelate based Ruddlesden-Popper nickelate high-temperature superconducting thin films **COVER ARTICLE**
LYU Wei NIE Zihao WANG Heng CHEN Yaqi HUANG Haoliang ZHOU Guangdi XUE Qikun CHEN Zhuoyu
- 227404 Optimization of infinite-layer nickelate superconductors via three *in-situ* atomic hydrogen reduction methods
GUO Nan AN Zhitong CHEN Zhihui DING Xiang LI Chihao FAN Yu XU Haichao PENG Rui

SPECIAL TOPIC—Thematic Data in Nuclear Physics: Experimental, Theoretical and Applied Research

- 222801 Calculation and analysis of thermal scattering law data of sub-stoichiometric metal hydrides
MA Yutu ZU Tiejun WU Hongchun CAO Liangzhi

GENERAL

- 220201 Prediction of high Curie temperature Janus materials based on machine learning and first-principles calculations
LIU Zhaosheng ZHANG Qiao NING Yongqi FU Xiujiao ZOU Daifeng WANG Junnian ZHAO Yuqing
- 220701 Parameter optimization of Rydberg atomic receiver based on channel capacity criterion
CHEN Guanyu WANG Cheng YANG Bin ZHOU Pengpeng CHEN Tiantian WU Yuchen

CONDENSED MATTER: ELECTRONIC STRUCTURE, ELECTRICAL, MAGNETIC, AND OPTICAL PROPERTIES

- 220702 Optimization of detection efficiency in silicon photomultipliers via topological photonic crystals
GUO Chaoqian ZHANG Guoqing ZHANG Haotong WU Yun WANG Jun YANG Yanfei LIU Lu LIU Lina LI Lianbi HAN Xiaoxiang LI Zebin HAN Chao

ATOMIC AND MOLECULAR PHYSICS

- 223101 First-principles study on optical properties of rare-earth doped monolayer WTe₂ with single tellurium vacancies
YIN Kaihui ZHU Hongqiang XU Fengxia WU Zebang GAO Tianjun YANG Ying FENG Qing YUE Yuanxia JIA Weiyao
- 223201 Nonequilibrium phase transitions of Rydberg atom gases under collective dissipation
ZHANG Yapeng ZHENG Yujie TANG Jingwen SHI Shuai ZHOU Yanli LIU Weitao

ELECTROMAGNETISM, OPTICS, ACOUSTICS, HEAT TRANSFER, CLASSICAL MECHANICS, AND FLUID DYNAMICS

- 224201 Pre-distortion correction method for swept-frequency nonlinearity of frequency-modulated continuous-wave light detection and ranging based on feedforward neural networks
TONG Xin WANG Qiupin LIU Junqi OU Pu RASHID Md Mamun-Ur LEI Zhiqiang ZHANG Heman LU Dan XIA Guangqiong WU Zhengmao
- 224202 Experimental generation of 9.1 dB HG₁₀ mode squeezed light
LI Zhi BAI Jiandong LIU Kui TANG Jun
- 224701 Growth mechanism of surface ice flakes at the initial stage of freezing of water-based organic solvent liquid film
SUN Yuyang NIU Yuying ZONG Xiaoxiao ZHAO Yugang

(Continued)

PHYSICS OF GASES, PLASMAS, AND ELECTRIC DISCHARGES

- 225201 Honeycomb-like superlattice pattern in dielectric barrier discharge
LI Yaohua YAN Zhaohe YAN Zhihao LI Cheng PAN Yuyang DONG Lifang
- 225202 D_{2h} superlattice patterns in dielectric barrier discharge with striped water electrode
LI Cheng YAN Zhihao QI Xiaoxiu LI Yuxin PAN Yuyang DONG Lifang
- 225203 Construction of a fully transparent β -Ga₂O₃ multi-mode solar-blind detection experimental system based on back incidence technology
DONG Dianmeng WANG Jingchen XU Xiaoyun PENG Min WANG Zechuan WANG Cheng WU Zhenping

CONDENSED MATTER: STRUCTURAL, MECHANICAL, AND THERMAL PROPERTIES

- 226801 A novel method of measuring nanowire-substrate interface adhesion energy in ambient atmosphere: Cross-stacked arch testing
LI Jinkai SONG Xiaodong HOU Lizhen WANG Shiliang

INTERDISCIPLINARY PHYSICS AND RELATED AREAS OF SCIENCE AND TECHNOLOGY

- 228901 Emergence of scaling in random hypernetworks: Exploration of shipping networks
GUO Zhaohua GUO Peng MIAO Rui GUO Jinli YUAN Yuan

ERRATA

- 229901 Erratum: Excitation mechanism of high-energy bottom bounce paths in deep sea—[*Acta Phys. Sin.* 2025, 74(21): 214301]
LIANG Minshuai WU Hanyu JIANG Houxuan SHI Junjie SUN Dajun

Color figures can be viewed in the online issue.



Online issue

专题: 镍基超导研究进展·封面文章

镍基 Ruddlesden-Popper 相高温超导薄膜的
制备与优化*吕威¹⁾ 聂子豪¹⁾ 汪恒¹⁾²⁾ 陈亚奇¹⁾ 黄浩亮¹⁾²⁾
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常压镍基高温超导电性的发现, 为深入地探索镍基超导机理带来了新平台. 然而, Ruddlesden-Popper 相镍氧化物在热力学上处于亚稳态, 对其结构和氧含量的精准控制极具挑战. 本文介绍了利用强氧化原子逐层外延生长技术在 LaAlO_3 和 SrLaAlO_4 衬底上制备单相、高质量的 $\text{Ln}_3\text{Ni}_2\text{O}_7$ (Ln 为镧系元素) 薄膜的系统方法. 其中, $(\text{La}, \text{Pr}, \text{Sm})_3\text{Ni}_2\text{O}_7/\text{SrLaAlO}_4$ 超导薄膜的超导起始转变温度 ($T_{\text{c, onset}}$) 达到 50 K. 阳离子化学计量偏差、逐层原子覆盖度、薄膜与衬底界面重构和氧化条件是影响薄膜 $\text{Ln}_3\text{Ni}_2\text{O}_7$ 晶体质量和超导性能的 4 个重要因素: 1) 精准的阳离子化学计量控制会抑制晶体杂相的产生; 2) 原子逐层的完整覆盖和 3) 优化的界面重构可以减少薄膜的堆垛层错; 4) 准确的氧含量调控则是实现超导单转变和高 $T_{\text{c, onset}}$ 的关键. 这些发现对各类氧化物高温超导薄膜的逐层外延生长具有借鉴意义.

关键词: 镍氧化物超导薄膜, Ruddlesden-Popper 相, 强氧化原子逐层外延, 界面重构**PACS:** 74.78.-w, 74.70.-b, 74.25.-q, 81.15.-z**DOI:** 10.7498/aps.74.20251080**CSTR:** 32037.14.aps.74.20251080

1 引言

高温超导机理问题被公认为凝聚态物理核心难题之一, 一个重要的解决思路便是在镍氧化物中寻找类铜超导体^[1-3]. 2019 年, 无限层 $\text{Nd}_{0.8}\text{Sr}_{0.2}\text{NiO}_2$ 薄膜被发现具有超导转变温度 (T_{c}) 约为 15 K 的超导电性^[4-9]. 通过镧系元素替换以及衬底应力等手段, 在掺杂的 SmNiO_2 薄膜中的 T_{c} 可以提升至接近 40 K 的麦克米兰极限^[10]. 2023 年以来, 镍氧

化物 Ruddlesden-Popper 相 (RP, $\text{Ln}_{n+1}\text{Ni}_n\text{O}_{3n+1}$) 中的 $\text{La}_3\text{Ni}_2\text{O}_7$ (327 相) 与 $\text{La}_4\text{Ni}_3\text{O}_{10}$ (4310 相) 被相继报道在高压条件下呈现超导电性, 其 T_{c} 分别达到约 80 K 和 30 K^[11-14]. 不同于无限层镍氧化物和铜氧超导体, 镍氧 RP 相中的镍离子位于八面体晶体场当中, 由于内顶角氧的存在, $3d_{z^2}$ 轨道将发生劈裂并邻近于费米面, 因此可能在超导配对过程中提供了额外的强层间耦合作用^[15-17]. 此外, 镍氧 RP 相 T_{c} 随单胞镍氧层数目的依赖关系与铜氧超导体具有显著不同. 在三层铜氧面的铜氧超导体中,

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