【Department Spotlight】Prof. Hung-Chung Hsueh and Chih-En Hsu Collaborate with NCKU, NTU, NSRRC to Pioneer 2D Ferroelectric Material, Reaching International Journals

Campus focus

Professor Hung-Chung Hsueh, Dean of Research and Development and faculty member of the Department of Physics, along with Chih-En Hsu, a third-year Ph.D. student in Applied Sciences, collaborated with research teams from National Cheng Kung University (NCKU), the National Synchrotron Radiation Research Center (NSRRC), and the Center for Condensed Matter Sciences at National Taiwan University (NTU) to publish the paper titled "Epitaxial Ferroelectric Hexagonal Boron Nitride Grown on Graphene" in the April issue of the prestigious international journal Advanced Materials, which holds an impact factor of 27.4 and a five-year impact factor of 30.2.

The team's research marks the first successful demonstration of epitaxially stacking ultrathin ferroelectric hexagonal boron nitride (h-BN) films on graphene, proving their ability to switch electric polarization stably. The findings show that the moire superlattice formed at the h-BN/graphene heterointerface induces spontaneous polarization, and interlayer sliding enables reversible switching, confirming the material's ferroelectric properties. Ferroelectricity, which refers to the ability of a material to switch electric polarization direction like an internal electric switch, is particularly well-suited for memory devices, sensors, and low-power computing technologies.

According to Hsueh, Professor Chung-Lin Wu's team at NCKU used plasma-assisted molecular beam epitaxy (MBE) to grow high-quality single-crystal graphene on a silicon carbide substrate, then precisely layered h-BN atop it. The naturally formed moir□ pattern at the interface induces a polar structure with asymmetry that can be switched via an electric field. NSRRC researcher Cheng-Maw Cheng explained that the team utilized Taiwan Light Source (TLS) at NSRRC to perform angle-resolved photoemission spectroscopy (ARPES) measurements, clearly observing band structure variations in h-

BN/graphene heterostructures across different h-BN layer counts. Hsueh and Hsu used first-principles calculations, including density functional theory (DFT) for ground-state and GW many-body perturbation theory for excited-state simulations, to validate the interlayer polarization mechanism and identify the presence and characteristics of the asymmetric ferroelectric stacking structure.

This breakthrough offers a new opportunity for heteroepitaxial growth of 2D ferroelectric materials and developing tunable electronic components. It also lays the groundwork for future innovations in Taiwan's semiconductor and optoelectronic industries by designing vertically stacked heterostructure chips. Prof. Hsueh stated that through this collaboration with the research teams from NCKU, NSRRC, and NTU, the Department of Physics at Tamkang University has demonstrated its ability to integrate theoretical and experimental research while providing students with opportunities to participate in cutting-edge international research.


BERKELEY
“偉大的時刻誕生於偉大的機
淡江時報

Check for updat

ADVANCED MATERIALS
www.advmat.de

Epitaxial Ferroelectric Hexagonal Boron Nitride Grown on Graphene

Sheng-Shong Wong, Zhen-You Lin, Sheng-Zhu Ho, Chih-En Hsu, Ping-Hung Li, Ching-Yu Chen, Yen-Fu Huang, Kuo-En Chang, Yu-Chiang Hsieh, Chia-Hao Chen, Ming-Hao Lee, Ming-Wen Chu, Kuang-I Lin, Tse-Ming Chen, Yi-Chun Chen, Hung-Chung Hsueh,* Cheng-Maw Cheng,* and Chung-Lin Wu**

Ferroelectricity realized in van der Waals (vdW) materials with non-centrosymmetric stacking configurations holds promise for future 2D devices with nonvolatile and reconfigurable functionalities. However, the epitaxial growth of ferroelectric vdW materials often struggles to achieve an energetically unfavorable stacking configuration that enables electric polarization. This challenge is particularly evident when performing heteroepitaxy on another vdW substrate to create versatile and scalable ferroelectric building blocks designed for large-area, atomic-scale thicknesses. Here, epitaxial hexagonal boron nitride (h-BN) multilayer films are successfully grew on single-crystal graphene synthesized on a miscut SiC (0001) substrate. Theoretical calculations illustrate that the moiré-patterned h-BN/graphene hetero-interface intrinsically exhibits polarization, leading to a polarized AB stacking in multilayer h-BN films to minimize the total formation energy, which is validated experimentally by the layer-dependent band dispersions. The as-grown multilayer h-BN layers demonstrated robust, homogeneous ferroelectricity with switchable out-of-plane polarization via interlayer sliding. This study establishes an effective route for stacking-controlled heteroepitaxy, enabling the large-scale integration of vdW materials with ferroelectricity and versatile functionalities, offering a promising platform for next-generation 2D ferroelectric devices.

1. Introduction

The realization of ferroelectricity at atomic-scale thickness, i.e., 2D ferroelectrics, has shown great promise for driving device innovation in the post-Moore era, where efficient energy storage and dense digital information retrieval at reduced dimensions are critical.[1–15] In naturally grown van der Waals (vdW) diatomic crystals, such as hexagonal boron nitride (h-BN) and transition-metal dichalcogenides (TMDs), electric polarization arising from layer stacking is typically absent due to the lower formation energy of these centrosymmetric crystals compared to non-centrosymmetric stacking configurations. Through manual micromechanical exfoliation and restacking processes to break the crystallographic inversion symmetry, out-of-plane electric polarization was generated in twisted h-BN stacked sheets by forcing the rotational and translational in-plane shifts between two non-polar h-BN layers.[1–4] This discovery of ferroelectricity in twisted

S.-S. Wong, Z.-Y. Lin, S.-Z. Ho, P.-H. Li, C.-Y. Chen, Y.-F. Huang, K.-E. Chang, Y.-C. Hsieh, T.-M. Chen, Y.-C. Chen, C.-L. Wu
Department of Physics
National Cheng Kung University
Tainan 70101, Taiwan
E-mail: ycchen93@mail.ncku.edu.tw; clwuphys@mail.ncku.edu.tw

S.-S. Wong, C.-H. Chen, C.-M. Cheng, C.-L. Wu
National Synchrotron Radiation Research Center (NSRRC)
Hsinchu 30076, Taiwan
E-mail: makalu@nsrrc.org.tw

The ORCID identification number(s) for the author(s) of this article can be found under https://doi.org/10.1002/adma.202414442

© 2025 The Author(s). Advanced Materials published by Wiley-VCH GmbH. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

DOI: 10.1002/adma.20241444

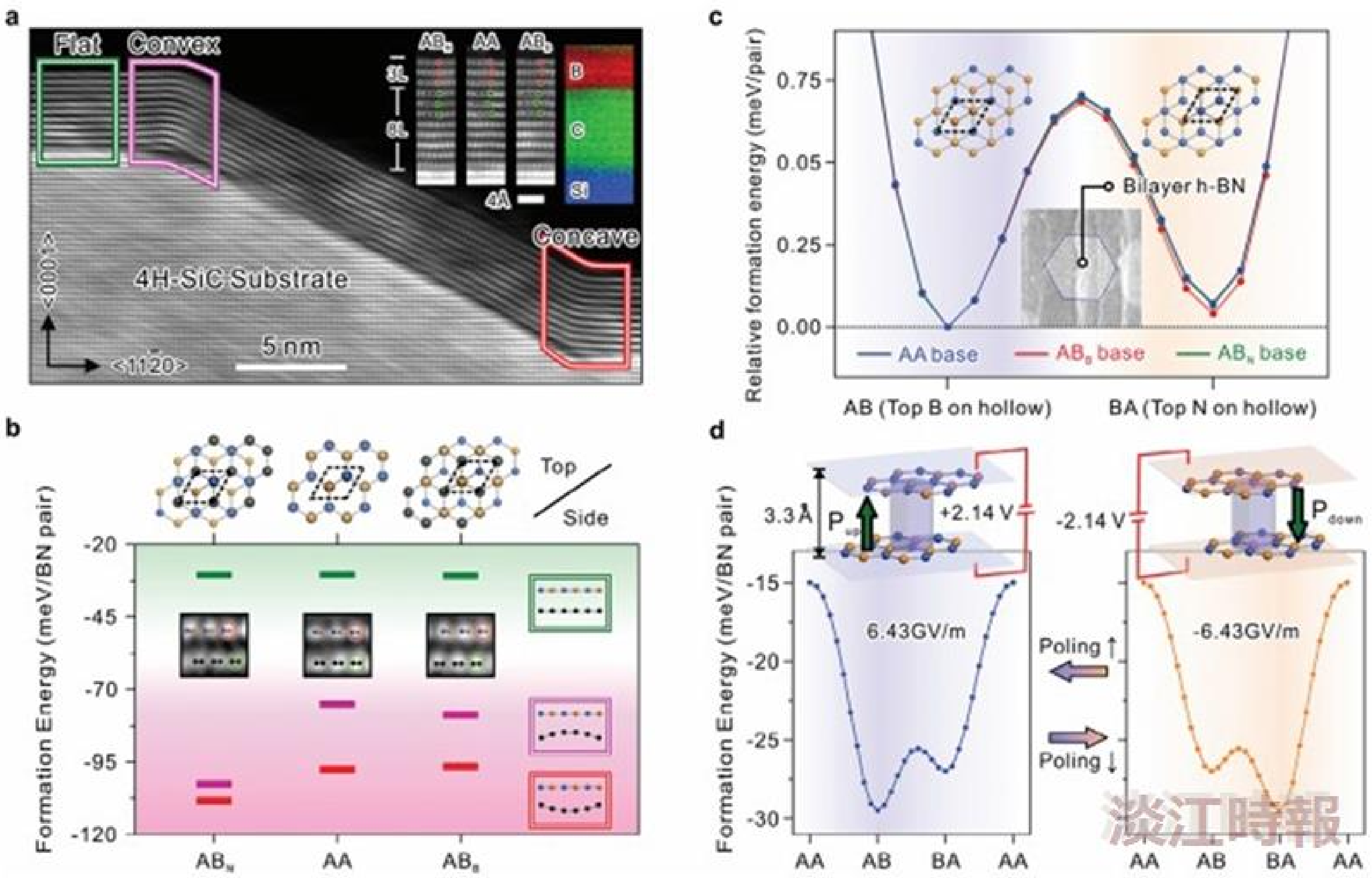
C.-E. Hsu, H.-C. Hsueh
Department of Physics
Tamkang University
New Taipei City 251301, Taiwan
E-mail: hchsueh@gms.tku.edu.tw

C.-H. Chen, C.-M. Cheng
Department of Electrophysics
National Yang Ming Chiao Tung University
Hsinchu 300, Taiwan

M.-H. Lee, M.-W. Chu
The Key Consortium of Electron Microscopy
National Taiwan University
Taipei 10617, Taiwan

M.-H. Lee, M.-W. Chu
Center for Condensed Matter Sciences and Center of Atomic Initiative for New Materials
National Taiwan University
Taipei 10617, Taiwan

1 / 11
淡江時報


a
Flat
Convex
Concave
4H-SiC Substrate
5 nm
<0001>
<11-20>
AB$_N$
AA
AB$_B$
3L
8L
4Å
B
C
Si
b
Top
Side
Formation Energy (meV/BN pair)
-20
-45
-70
-95
-120
AB$_N$
AA
AB$_B$
c
Relative formation energy (meV/pair)
0.75
0.05
0.25
0.00
Bilayer h-BN
AA base
AB$_B$ base
AB$_N$ base
AB (Top B on hollow)
BA (Top N on hollow)
d
3.3 Å
P_{up}
+2.14 V
-2.14 V
P_{down}
Formation Energy (meV/BN pair)
-15
-20
-25
-30
6.43GV/m
-6.43GV/m
Poling ↑
Poling ↓
AA
AB
BA
AA
淡江時報