Stanford

Andrew J. Mannix

Assistant Professor of Materials Science and Engineering

Bio

BIO

Atoms set the ultimate limit for materials engineering. Andy Mannix's research focuses on tailoring materials at this atomic scale to control their electronic properties, driving advances in electronic, optoelectronic, and quantum technologies. His group specializes in the growth, fabrication, and characterization, of two-dimensional (2D) materials and their van der Waals interfaces with the goal of building platforms for deterministic atomic-scale engineering.

To advance this frontier, the Mannix lab develops growth techniques to produce 2D semiconductor films with minimal defects and precisely tuned doping. These materials are integrated into nanoscale devices to optimize interfaces and evaluate performance. Leveraging machine learning and AI, the lab accelerates material quality assessments and pioneers robotic assembly methods for van der Waals heterostructures in high/ultra-high vacuum environments. The group's expertise in scanning probe microscopy, including scanning tunneling and advanced atomic force microscopy, enables exploration of material structure and properties with atomic precision.

Andy joined Stanford University's Department of Materials Science and Engineering (MSE) in 2020. He has received the Office of Naval Research YIP Award (2024) and the NSF CAREER Award (2024).

He earned his B.S. in MSE from the University of Illinois Urbana-Champaign and his Ph.D. in MSE from Northwestern University, where, as an NSF GRFP Fellow, he pioneered the growth and atomic-scale characterization of new 2D materials, including borophene. During his Kadanoff-Rice Postdoctoral Fellowship at the University of Chicago, he developed innovative methods for robotic heterostructure assembly and processing of 2D materials.

ACADEMIC APPOINTMENTS

- Assistant Professor, Materials Science and Engineering
- Member, Bio-X

HONORS AND AWARDS

- CAREER Award, National Science Foundation (2024)
- Young Investigator Program, Office of Naval Research (2024)

PROGRAM AFFILIATIONS

- Stanford SystemX Alliance

PROFESSIONAL EDUCATION

- Ph.D., Northwestern University , Materials Science and Engineering (2017)
- B.S., University of Illinois at Urbana-Champaign , Materials Science and Engineering (2012)

LINKS

- Research Group Website: https://www.2d-matsci.com/

Research & Scholarship

CURRENT RESEARCH AND SCHOLARLY INTERESTS

Atomically thin 2D materials incorporated into van der Waals heterostructures are a promising platform to deterministically engineer quantum materials with atomically resolved thickness and abrupt interfaces across macroscopic length scales while retaining excellent material properties. Because 2D materials exhibit a wide range of electronic characteristics with properties that often rival conventional electronic materials — e.g., metals, semiconductors, insulators, and superconductors — it is possible to combine them in virtually infinite variety to achieve diverse heterostructures. Furthermore, the van der Waals interface enables interlayer twist engineering to modify the interlayer symmetry, periodic potential (moiré superlattice), and hybridization, which has resulted in novel quantum states of matter. Many of these heterostructures, especially those involving specific interlayer twist angles, would be otherwise infeasible through direct growth.

The Mannix Group is developing a unique set of in-house capabilities to systematically elucidate the fundamental structure-property relationships underpinning the growth of 2D materials and their inclusion into van der Waals heterostructures. Greater understanding will allow us to provide a platform for engineering the properties of matter at the atomic scale and offer guidance for emerging applications in novel electronics and in quantum information science.

To accomplish this, we employ: precise growth techniques such as chemical vapor deposition and molecular beam epitaxy; automated van der Waals assembly; and atomically-resolved microscopy including cryo-STM/AFM.

Teaching

COURSES

2026-27

- Ethics and Broader Impacts in Materials Science: MATSCI 232 (Spr)
- Introduction to Materials Science, Energy Emphasis: ENGR 50E, MATSCI 50E (Win)
- Materials Science Colloquium: MATSCI 230 (Win)
- Structure and Symmetry: MATSCI 184 (Aut)
- Structure and Symmetry: MATSCI 214 (Aut)

2025-26

- Ethics and Broader Impacts in Materials Science: MATSCI 232 (Spr)
- Introduction to Materials Science, Energy Emphasis: ENGR 50E, MATSCI 50E (Win)
- Materials Science Colloquium: MATSCI 230 (Aut, Win, Spr)
- Structure and Symmetry: MATSCI 184 (Aut)
- Structure and Symmetry: MATSCI 214 (Aut)

2024-25

- Ethics and Broader Impacts in Materials Science: MATSCI 232 (Spr)
- Introduction to Materials Science, Energy Emphasis: ENGR 50E, MATSCI 50E (Win)
- Materials Science Colloquium: MATSCI 230 (Aut, Win, Spr)
- Structure and Symmetry: MATSCI 184 (Aut)
- Structure and Symmetry: MATSCI 214 (Aut)

2023-24

- Ethics and Broader Impacts in Materials Science: MATSCI 232 (Spr)
- Introduction to Materials Science, Energy Emphasis: ENGR 50E (Win)
- Materials Science Colloquium: MATSCI 230 (Aut, Win, Spr)
- Structure and Symmetry: MATSCI 184 (Aut)
- Structure and Symmetry: MATSCI 214 (Aut)

STANFORD ADVISEES

Doctoral Dissertation Reader (AC)

Xueqi Chen, Jackson Meng, Kalee Rozylowicz, Jierong Wang, Jerry Yang

Postdoctoral Faculty Sponsor

Qingrui Cao, Anh Tuan Hoang, Yuxin Jiang, Shahriar Muhammad Nahid

Doctoral Dissertation Advisor (AC)

Aldo Chavez, Victoria Kyveryga, Aramis Mendoza, Hank Peng, Ruixin Qiu

Doctoral Dissertation Co-Advisor (AC)

Yuan-Mau Lee, Will Millsaps

Publications

PUBLICATIONS

- **Wide-field hyperspectral optical microscopy for rapid characterization of two-dimensional semiconductors and heterostructures** *2D MATERIALS*
  Peng, Z., Uthman, A., Zhang, Z., Hoang, A., Zhu, X., Pop, E., Mannix, A. J.
  2026; 13 (2)
- **Low resistance p-type contacts to monolayer WSe2 through chlorinated solvent doping.** *Nature communications*
  Hoang, L., Bennett, R. K., Hoang, A. T., Peña, T., Zhang, Z., Hocking, M., Saunders, A. P., Jaikissoon, M., Liu, F., Pop, E., Mannix, A. J.
  2026; 17 (1): 718
- **Phase-Selective Synthesis of Rhombohedral WS2 Multilayers by Confined-Space Hybrid Metal-Organic Chemical Vapor Deposition.** *Nano letters*
  Zhang, Z., Hocking, M., Peng, Z., Pendharkar, M., Courtney, E. D., Hu, J., Kastner, M. A., Goldhaber-Gordon, D., Heinz, T. F., Mannix, A. J.
  2024
- **Understanding the Impact of Contact-Induced Strain on the Electrical Performance of Monolayer WS2 Transistors.** *Nano letters*
  Hoang, L., Jaikissoon, M., Köroğlu, Ç., Zhang, Z., Bennett, R. K., Song, J. H., Yang, J. A., Ko, J. S., Brongersma, M. L., Saraswat, K. C., Pop, E., Mannix, A. J.
  2024
- **Chemically Tailored Growth of 2D Semiconductors via Hybrid Metal-Organic Chemical Vapor Deposition.** *ACS nano*
  Zhang, Z., Hoang, L., Hocking, M., Peng, Z., Hu, J., Zaborski, G., Reddy, P. D., Dollard, J., Goldhaber-Gordon, D., Heinz, T. F., Pop, E., Mannix, A. J.
  2024

- **Torsional force microscopy of van der Waals moirés and atomic lattices.** *Proceedings of the National Academy of Sciences of the United States of America*
  Pendharkar, M., Tran, S. J., Zaborski, G., Finney, J., Sharpe, A. L., Kamat, R. V., Kalantre, S. S., Hocking, M., Bittner, N. J., Watanabe, K., Taniguchi, T., Pittenger, B., Newcomb, et al
  2024; 121 (10): e2314083121
- **Torsional periodic lattice distortions and diffraction of twisted 2D materials.** *Nature communications*
  Sung, S. H., Goh, Y. M., Yoo, H., Engelke, R., Xie, H., Zhang, K., Li, Z., Ye, A., Deotare, P. B., Tadmor, E. B., Mannix, A. J., Park, J., Zhao, et al
  2022; 13 (1): 7826
- **Robotic four-dimensional pixel assembly of van der Waals solids.** *Nature nanotechnology*
  Mannix, A. J., Ye, A., Sung, S. H., Ray, A., Mujid, F., Park, C., Lee, M., Kang, J., Shreiner, R., High, A. A., Muller, D. A., Hovden, R., Park, et al
  1800
- **Resist-Free Lithography for Monolayer Transition Metal Dichalcogenides.** *Nano letters*
  Poddar, P. K., Zhong, Y., Mannix, A. J., Mujid, F., Yu, J., Liang, C., Kang, J., Lee, M., Xie, S., Park, J.
  1800
- **Near-equilibrium growth from borophene edges on silver** *SCIENCE ADVANCES*
  Zhang, Z., Mannix, A. J., Liu, X., Hu, Z., Guisinger, N. P., Hersam, M. C., Yakobson, B. I.
  2019; 5 (9): eaax0246
- **Borophene as a prototype for synthetic 2D materials development** *NATURE NANOTECHNOLOGY*
  Mannix, A. J., Zhang, Z., Guisinger, N. P., Yakobson, B. I., Hersam, M. C.
  2018; 13 (6): 444-450
- **Synthesis and chemistry of elemental 2D materials** *NATURE REVIEWS CHEMISTRY*
  Mannix, A. J., Kiraly, B., Hersam, M. C., Guisinger, N. P.
  2017; 1 (2)
- **Synthesis of borophenes: Anisotropic, two-dimensional boron polymorphs** *SCIENCE*
  Mannix, A. J., Zhou, X., Kiraly, B., Wood, J. D., Alducin, D., Myers, B. D., Liu, X., Fisher, B. L., Santiago, U., Guest, J. R., Yacaman, M., Ponce, A., Oganov, et al
  2015; 350 (6267): 1513-1516
- **Deep Learning to Automate Parameter Extraction and Model Fitting of Two-Dimensional Transistors** *RESEARCH*
  Bennett, R. K. A., Uslu, J., Gault, H. F., Khan, A., Hoang, L., Pena, T., Neilson, K., Song, Y., Zhang, Z., Mannix, A. J., Pop, E.
  2026; 9
- **Scaling nanoribbon transistors with monolayer transition metal dichalcogenides.** *Nature nanotechnology*
  Peña, T., Persson, A. E., Krayev, A., Friðriksdóttir, Á., Su, H., Lee, Y. M., Song, Y. S., Neilson, K., Zhang, Z., Hoang, A. T., Yang, J. A., Hoang, L., Wang, et al
  2026
- **Nano-Raman imaging of monolayer MoS₂ nanoribbons** *APPLIED PHYSICS LETTERS*
  Krayev, A., Pena, T., Persson, A. E. O., Neilson, K., Hoang, A., Mannix, A. J., Pop, E.
  2026; 128 (20)
- **Spatio-Kinetic Electronic Heterogeneity in MoS₂ Revealed by Ultrafast Electron Microscopy: Implications for Optoelectronics** *ACS APPLIED NANO MATERIALS*
  Alcorn, F. M., Ellis, S. R., Perez, C., Hoang, L., Smoll, E. J., Fuller, E. J., Mannix, A. J., Pop, E., Chandler, D. W., Talin, A., Leonard, F., Kumar, S.
  2026
- **Nondestructive Atomic Defect Quantification of Two-Dimensional Materials and Devices.** *ACS applied materials & interfaces*
  Yang, Y., Xu, K., Peña, T., Neilson, K., Zheng, X., Hoang, A. T., Yang, K., Hennighausen, Z., Zhang, T., Holtzman, L. N., Nattoo, C. A., Hone, J. C., Barmak, et al
  2026
- **Direct probing of ultrafast hot-carrier injection and photo-induced degradation at Au/WS₂ interfaces using time-domain THz emission spectroscopy**
  Gollner, C., Xia, C., Taghinejad, M., Zhang, Z., Liu, F., Brongersma, M. L., Mannix, A. J., Heinz, T., Lindenberg, A.

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SPIE-INT SOC OPTICAL ENGINEERING.2026

- **Precursor Engineering of Atomic Layer Deposition for Top-Gate Insulators on Monolayer MoS2 Transistors.** *ACS nano*
  Shearer, A. B., Ko, J. S., Hoang, A. T., Werbrouck, A., Rothman, A., Volcanjk, D. F., Lee, Y. M., Bennett, R. K., Mannix, A. J., Saraswat, K. C., Pop, E., Bent, S. F.
  2025

- **Synthesis-Related Nanoscale Defects in Mo-Based Janus Monolayers Revealed by Cross-Correlated AFM and TERS Imaging.** *Small (Weinheim an der Bergstrasse, Germany)*
  Zhang, T., Krayev, A., Yang, T. H., Mao, N., Hoang, L., Wang, Z., Liu, H., Peng, Y. R., Zhu, Y., Zheng, X., Isotta, E., Kira, M. E., Righi, et al
  2025: e2504742

- **Vibronically Coherent Exciton Trapping in Monolayer WS2.** *ACS nano*
  Boeije, Y., Hoang, A. T., Lim, J., Stranks, S. D., Chhowalla, M., Pop, E., Mannix, A. J., Rao, A.
  2025

- **Excitation Laser Energy Dependence of the Gap-Mode TERS Spectra of WS₂ and MoS₂ on Silver** *ACS PHOTONICS*
  Krayev, A., Isotta, E., Hoang, L., Yang, J. A., Neilson, K., Wang, M., Haughn, N., Pop, E., Mannix, A., Balogun, O., Wang, C.
  2025

- **Mobility and threshold voltage extraction in transistors with gate-voltage-dependent contact resistance** *NPJ 2D MATERIALS AND APPLICATIONS*
  Bennett, R. K. A., Hoang, L., Cremers, C., Mannix, A. J., Pop, E.
  2025; 9 (1)

- **Sub-Nanometer Equivalent Oxide Thickness and Threshold Voltage Control Enabled by Silicon Seed Layer on Monolayer MoS2 Transistors.** *Nano letters*
  Ko, J. S., Lee, S., Bennett, R. K., Schauble, K., Jaikissoon, M., Neilson, K., Hoang, A. T., Mannix, A. J., Kim, K., Saraswat, K. C., Pop, E.
  2025

- **Deep Learning to Automate Fitting and Parameter Extraction of 2D Transistors**
  Bennett, R. K. A., Gault, H. F., Khan, A., Hoang, L., Pena, T., Neilson, K., Song, Y., Zhang, Z., Mannix, A. J., Pop, E., IEEE
  IEEE.2025: 122-123

- **Chemical and Mechanical Optimization over Structure and Interfaces in 2D Semiconductors**
  Mannix, A. J., IEEE
  IEEE.2025

- **Resolving the Electron Plume within a Scanning Electron Microscope.** *ACS nano*
  Alcorn, F. M., Perez, C., Smoll, E. J., Hoang, L., Nitta, F. U., Mannix, A. J., Talin, A. A., Nakakura, C. Y., Chandler, D. W., Kumar, S.
  2024

- **Deterministic fabrication of graphene hexagonal boron nitride moire superlattices.** *Proceedings of the National Academy of Sciences of the United States of America*
  Kamat, R. V., Sharpe, A. L., Pendharkar, M., Hu, J., Tran, S. J., Zaborski, G. J., Hocking, M., Finney, J., Watanabe, K., Taniguchi, T., Kastner, M. A., Mannix, A. J., Heinz, et al
  2024; 121 (40): e2410993121

- **Quantitative determination of twist angle and strain in Van der Waals moiré superlattices** *APPLIED PHYSICS LETTERS*
  Tran, S. J., Uslu, J., Pendharkar, M., Finney, J., Sharpe, A. L., Hocking, M., Bittner, N. J., Watanabe, K., Taniguchi, T., Kastner, M. A., Mannix, A. J., Goldhaber-Gordon, D.
  2024; 125 (11)

- **Thermal relaxation of strain and twist in ferroelectric hexagonal boron nitride moiré interfaces** *JOURNAL OF APPLIED PHYSICS*
  Hocking, M., Henzinger, C. E., Tran, S. J., Pendharkar, M., Bittner, N. J., Watanabe, K., Taniguchi, T., Goldhaber-Gordon, D., Mannix, A. J.
  2024; 136 (2)

- **Biaxial Tensile Strain Enhances Electron Mobility of Monolayer Transition Metal Dichalcogenides.** *ACS nano*
  Yang, J. A., Bennett, R. K., Hoang, L., Zhang, Z., Thompson, K. J., Michail, A., Parthenios, J., Papagelis, K., Mannix, A. J., Pop, E.

2024

- **Flexible Monolayer WS₂-based Pseudo-CMOS Inverters for In-sensor Computing**
  Yang, J. A., Bora, A., Daus, A., Hoang, L., Zhang, Z., Mannix, A. J., Pop, E., IEEE
  IEEE.2024

- **Thiol-based defect healing of WSe2 and WS2** *NPJ 2D MATERIALS AND APPLICATIONS*
  Schwarz, A., Alon-Yehezkel, H., Levi, A., Yadav, R., Majhi, K., Tzuriel, Y., Hoang, L., Bailey, C. S., Brumme, T., Mannix, A. J., Cohen, H., Yalon, E., Heine, et al
  2023; 7 (1)

- **Wafer-scale synthesis of monolayer two-dimensional porphyrin polymers for hybrid superlattices** *SCIENCE*
  Zhong, Y., Cheng, B., Park, C., Ray, A., Brown, S., Mujid, F., Lee, J., Zhou, H., Suh, J., Lee, K., Mannix, A. J., Kang, K., Sibener, et al
  2019; 366 (6471): 1379-+

- **Edge states in the honeycomb reconstruction of two-dimensional silicon nanosheets** *APPLIED PHYSICS LETTERS*
  Mannix, A. J., Saari, T., Kiraly, B., Fisher, B. L., Hsu, C., Huang, Z., Chuang, F., Nieminen, J., Lin, H., Bansil, A., Hersam, M. C., Guisinger, N. P.
  2019; 115 (2)

- **Amino Acid Immobilization of Copper Surface Diffusion on Cu(111)** *ADVANCED MATERIALS INTERFACES*
  Guisinger, N. P., Mannix, A. J., Rankin, R. B., Kiraly, B., Phillips, J. A., Darling, S. B., Fisher, B. L., Hersam, M. C., Iski, E. V.
  2019; 6 (7)

- **Borophene Synthesis on Au(111)** *ACS NANO*
  Kiraly, B., Liu, X., Wang, L., Zhang, Z., Mannix, A. J., Fisher, B. L., Yakobson, B. I., Hersam, M. C., Guisinger, N. P.
  2019; 13 (4): 3816-3822

- **Driving chemical interactions at graphene-germanium van der Waals interfaces via thermal annealing** *APPLIED PHYSICS LETTERS*
  Kiraly, B., Mannix, A. J., Jacobberger, R. M., Fisher, B. L., Arnold, M. S., Hersam, M. C., Guisinger, N. P.
  2018; 113 (21)

- **Resolving the Chemically Discrete Structure of Synthetic Borophene Polymorphs** *NANO LETTERS*
  Campbell, G. P., Mannix, A. J., Emery, J. D., Lee, T., Guisinger, N. P., Hersam, M. C., Bedzyk, M. J.
  2018; 18 (5): 2816-2821

- **Epitaxial graphene-encapsulated surface reconstruction of Ge(110)** *PHYSICAL REVIEW MATERIALS*
  Campbell, G. P., Kiraly, B., Jacobberger, R. M., Mannix, A. J., Arnold, M. S., Hersam, M. C., Guisinger, N. P., Bedzyk, M. J.
  2018; 2 (4)

- **Self-assembly of electronically abrupt borophene/organic lateral heterostructures** *SCIENCE ADVANCES*
  Liu, X., Wei, Z., Balla, I., Mannix, A. J., Guisinger, N. P., Luijten, E., Hersam, M. C.
  2017; 3 (2): e1602356

- **Substrate-Induced Nanoscale Undulations of Borophene on Silver** *NANO LETTERS*
  Zhang, Z., Mannix, A. J., Hu, Z., Kiraly, B., Guisinger, N. P., Hersam, M. C., Yakobson, B. I.
  2016; 16 (10): 6622-6627

- **Sub-5 nm, globally aligned graphene nanoribbons on Ge(001)** *APPLIED PHYSICS LETTERS*
  Kiraly, B., Mannix, A. J., Jacobberger, R. M., Fisher, B. L., Arnold, M. S., Hersam, M. C., Guisinger, N. P.
  2016; 108 (21)

- **Electronic and Mechanical Properties of Graphene-Germanium Interfaces Grown by Chemical Vapor Deposition** *NANO LETTERS*
  Kiraly, B., Jacobberger, R. M., Mannix, A. J., Campbell, G. P., Bedzyk, M. J., Arnold, M. S., Hersam, M. C., Guisinger, N. P.
  2015; 15 (11): 7414-7420

- **Graphene-Silicon Heterostructures at the Two-Dimensional Limit** *CHEMISTRY OF MATERIALS*
  Kiraly, B., Mannix, A. J., Hersam, M. C., Guisinger, N. P.
  2015; 27 (17): 6085-6090

- **Direct oriented growth of armchair graphene nanoribbons on germanium** *NATURE COMMUNICATIONS*

Jacobberger, R. M., Kiraly, B., Fortin-Deschenes, M., Levesque, P. L., McElhinny, K. M., Brady, G. J., Delgado, R., Roy, S., Mannix, A., Lagally, M. G., Evans, P. G., Desjardins, P., Martel, et al
2015; 6: 8006

- **Silicon Growth at the Two-Dimensional Limit on Ag(111)** *ACS NANO*
  Mannix, A. J., Kiraly, B., Fisher, B. L., Hersam, M. C., Guisinger, N. P.
  2014; 8 (7): 7538-7547
- **Solid-source growth and atomic-scale characterization of graphene on Ag(111)** *NATURE COMMUNICATIONS*
  Kiraly, B., Iski, E. V., Mannix, A. J., Fisher, B. L., Hersam, M. C., Guisinger, N. P.
  2013; 4