Final Report for:
Support for the 66th International Conference on Electron, Ion, and Photon Beam Technologies and Nanofabrication

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Project Summary

This project aimed to enable student participation in the 66th International Conference on Electron, Ion, and Photon Beam Technologies and Nanofabrication (EIPBN). EIPBN, affectionately known as "3-Beams," is the premier gathering of scientists and engineers who are dedicated to electron, ion and photon lithography, imaging, and analysis; nanofabrication process technologies; atomically precise fabrication; related emerging technologies; and their applications in a broad spectrum of fields. It is where top researchers from academia, government laboratories, and industries from around the world meet to present and discuss recent trends and future innovations in these technologies. The goal of the conference is to advance knowledge by enabling the exchange of information concerning advanced and emerging nanofabrication and nanomanufacturing topics and how they enable traditional and novel applications.

Project Description

The EIPBN meeting was held in person at the Hilton Union Square from May 30 to June 2 in San Francisco, CA, in the heart of the nation's semiconductor industry and research laboratories.

Technical and Commercial Sessions

The 2023 program theme was "*Nanofabrication and Integration for the AIoT Era: Challenges and Opportunities*," which explored emerging issues in neuromorphic computing, quantum electronics, and wearable devices. This year's conference also emphasized on the pressing need to tackle the challenges of increasing domestic semiconductor manufacturing and enabling technology for next generation nanoelectronics. The technical program of the conference was comprised of 27 oral sessions organized in three parallel tracks, featuring 27 invited papers from recognized experts and 101 contributed papers. A poster session featured an additional 48 contributed papers, including 5 invited posters. There were 180 accepted papers with 61% from North America, 20% from Europe, 12% from Asia, 4% from the Middle East, and 1% each from South America and Africa. The conference program consisted of sessions devoted to: electron and ion-beam lithography, advanced micro- and nanolithography, beam shaping design and tools, nanoimprint lithography, scanning probes techniques, atomically precise fabrication, directed self-assembly, bio-inspired nanostructures, nano-electronics, nanofabrication for quantum computing, nanofabrication for neuromorphic computing, nanofabrication for energy applications, micro- and nanoelectromechanical systems, micro- and nano-fluidics, biomedical devices, nano-biology and medicine, nanophotonics and plasmonics, metamaterials and meta-lenses, micro/nanoscale additive manufacturing, nanofabrication for 2D materials and devices, resists and resist processing, simulation and modeling for the nanoscale, cold atom ion and electron sources, and cutting-edge industrial developments.

The conference began on Tuesday, May 30 with the Short Course Session. This event features five lectures given serially by leading authorities in their field of expertise, with three speakers from academia, one from industry, and one from government research laboratory. The 2023 instructors were:

- Prof. Rebecca Cheung, University of Edinburgh, Scotland, UK, "Micro-Resonating Sensors"
- Prof. Alain Diebold, SUNY Polytechnic Institute, "Characterization and Metrology of 3D Semiconductor Structures using X-Ray and Optical Methods"

- Dr. Joris Keizer, University of New South Wales, Australia, “Atomically Precise Manufacturing of Silicon Quantum Devices”
- Dr. Patrick Naulleau, Lawrence Berkeley Laboratory and EUV Tech, “Challenges Facing Continued EUV Scaling: Materials Are the Key”
- Dr. Daniel Ward, HRL Laboratories, “Fabrication of Semiconductor Spin Qubits for Quantum Computing”

The 3-day Commercial Session began later that afternoon featuring 39 materials and equipment exhibitors.

The Startup Session and Contest also kicked off on Tuesday, May 30. The Startup Contest is designed to support entrepreneurs, students, and research staff to help facilitate transition of early-stage technologies into scalable ventures. The contest encourages participation from all startups incorporating new technical findings from any of EIPBN’s fields of scientific interest. Entry is open to startups at any stage of development: from early ideation (pre-seed) to technology validation and growth. This contest aims to support the transition of technology and ideas from the lab into a scalable venture. The 2023 winner of the startup contest was M.Early, presented by Seungjun Ki of the University of Michigan.

The Plenary Session began on Wednesday, May 31. The 2023 session featured three world-leading Plenary Speakers from academia and industry covering topics relating to nanofabrication.

- Dr Darío Gil, Senior Vice President and Director of Research, IBM, “What's Next in Computing: Scaling with Classical + Quantum Information”
- Prof. Teri Odom, Joan Husting Madden and William H. Madden, Jr. Professor of Chemistry and Chair of Department of Chemistry, Northwestern University, “Scalable Nanofabrication for Functional Nanophotonics”
- Prof. Ali Javey, Lam Research Distinguished Chair in Semiconductor Processing and Professor of Electrical Engineering & Computer Science, University of California, Berkeley, “Wearable Sweat Sensors - Towards Big Data for Human Health”

The first of three parallel oral sessions followed the Plenary Session, and the first Poster Session began later that evening.

EIPBN 2023 also had a special Panel Discussion Session on “*Challenges and Opportunities: The CHIPS Act and the Future of US Semiconductor Manufacturing*” on Tuesday, May 30, 2023, 4:30 pm - 6:00 pm. The goal of the conference-wide event is to have an open discussion on the US semiconductor research, education, and production. The panel was moderated by Dr. Shida Tan, Principal Engineer, Intel Corporation, and included panelist include representatives from industry, government research laboratory, and academia:

- Dr. J. Alexander Liddle, Scientific Director of the Microsystems and Nanotechnology Division, National Institute of Standards and Technology
- Dr. Qing Wu, Senior Scientist for Processing and Exploitation, Information Directorate, Air Force Research Laboratory
- Dr. Shawn Siddoway, Senior Director of Business Operations and Workforce Development, Micron Technology

- Prof. S.V. Sreenivasan, David Allen Cockrell Chair and Cockrell Family Regents Endowed Chair #7 Professor, Walker Department of Mechanical Engineering, University of Texas at Austin

Since 2019, our conference has placed strong emphasis to bridge the gap between academic research and industry R&D. For the third time, an Industrial Technology Highlight session was introduced for companies to showcase new technology and equipment that can facilitate nanofabrication research. Speakers from Zyvex Lab, Raith, Heidelberg Instruments Nano, Photia, Ionoptika, Tescan, Carl Zeiss Microscopy, Lab 14, GenISys covered topics spanning computational modules, maskless laser patterning, atomic-precise lithography, two-photon lithography, electron-beam lithography, overlay, and substrate handling.

Focused Workshops, Networking, and Mentorship Events

Throughout the conference there were several focused workshops and networking events beginning with annual Welcome Reception held on the first floor in the stunning Golden Gate Ballroom.

To build a diverse, inclusive, and equitable (DEI) community, EIPBN continued the Women in Nanofabrication (WIN) Luncheon, which was held on Thursday, June 1. WIN is a networking event that brings together women in science and engineering from around the world. This luncheon enhances the fields of lithography and nanotechnology through diversity and inclusion. This year WIN honored Prof. Stella Pang (City University of Hong Kong), a long-time contributor to the conference and an Advisory Board member, for her long-term dedication and commitment to EIPBN. WIN was sponsored by Heidelberg, Raith, AllResist, and KLA. Dr. Pang was also recognized at the conference banquet.

Thursday evening culminated with the annual Conference Banquet onsite at the Imperial Ballroom. The banquet featured the Sueños Jazz Band, a Bay Area band that blends classic jazz with modern styles. During the banquet several awards were presented, including the *EIPBN Lifetime Achievement Award* to Prof. Henry I. Smith, Emeritus Professor at MIT, and Prof. R. Fabian Pease, Emeritus Professor at Stanford University, for pioneering and seminal contributions to nanopatterning and applications, and leadership in promoting and teaching nanometer technology. The award included a special tribute by Prof. Stephen Chou of Princeton University. Other EIPBN awards were also announced, including the *2022 Best JVSTB Paper Award* to Animesh Nanaware, Taylor Kranbuhl, Jesus Ching, Janice S. Chen, Xinye Chen, Qingsong Tu, and Ke Du for their contribution entitled "Pneumatic controlled nanosieve for efficient capture and release of nanoparticles," which is selected by the *American Vacuum Society (AVS)*. The student awards were also announced, with the *Best Student Presentation Award* going to Edgar Perez of the University of Maryland and the *Best Student Poster Award* going to Tse Hsien Ou of the University of Southern California. The importance of micrographs to the conference community is highlighted by the Annual EIPBN Bizarre and Beautiful Micrograph Contest. Entries are evaluated on technical and artistic merit by a distinguished panel of judges. Retiring Steering Committee members were also honored at the banquet, the new Steering Committee members were recognized, and the conference venue for 2024 was announced.

EIPBN has a strong tradition of cultivating the young generation of scientists and engineers in nanofabrication and advanced nanomanufacturing. Friday June 3 began with the Student Mentor Lunch. The Mentor Lunch connects students with professionals in academia, government labs and industries. It's a chance to hear from the experts why they chose their field, what it takes to get

there, and what it's really like once they arrived. The breakfast provides opportunity to learn beneficial information to help guide them as they grow in their fields. This year the lunch featured speaker Dr. R. Fabian Pease (Professor Emeritus, Stanford University) who presented "Do Something Different." Dr Pease is a long-term contributor to the EIPBN conference and a member of the EIPBN Advisory Board. All supported students were invited to a breakfast meeting to learn more about conference organization and how to become more involved with the EIPBN community over the course of their careers.

Conference Steering Committee

The EIPBN Steering Committee members serve a five-year term during which they also act as the corporate Board of Directors, with the current Conference Chair also being the President and the current Program Chair being Vice President. Each year, two Steering Committee members are elected for a five-year term. After year five, they retire and become permanent members of the Advisory Committee. This year two members of the Steering Committee retired, Dr. James Spallas (Conference Chair) and Dr. Robert Ilic (Program Chair) of the 2022 conference in New Orleans. The committee also welcomed new members: 2026 Conference Chair Prof. Jack Skinner of Montana Technological University and 2026 Program Chair Prof. Rajesh Menon of the University of Utah.

The location of the conference venue is determined by Conference Chair. The Conference Chair is generally under contract with his choice of venue before the end of their first year on the committee. It is, however, a long-standing tradition that the location remains a closely guarded secret until announced by the Conference Chair at the preceding conference banquet. This year the next Conference Chair Aimee Price announced that the 67th EIPBN will be held at the Hilton La Jolla Torrey Pines in La Jolla, CA.

In addition to our generous corporate sponsors, the 66th EIPBN was supported by the *American Vacuum Society (AVS)* and *IEEE Nano*. We wish to thank and recognize the National Science Foundation (NSF), Department of Energy (DOE), and Office of Naval Research (ONR) for their generous Student financial support.

Conference Registration Summary

Overall Conference Attendance

The total attendance of the 2023 conference saw a rebound from the pandemic disruption. The 2023 total attendance was 428 and is much higher than the 2022 attendance of 359, which was the first in-person EIPBN post-Covid, and on-par with pre-pandemic attendance of 386 in 2019 and 423 in 2018. The attendance was lower than 664 registered attendees from 2020, which saw a jump in participation due to the virtual conference modality. Total attendance from the United States was 324 in 2023, which saw a significant increase from pre-COVID numbers. Historically the conference had 272 US attendees in 2018, and 279 in 2019. The student attendance from the United States is at 54 in 2023, which saw an improvement from 43 in 2022, 46 in 2019, and 48 in 2018. The total domestic attendance was perhaps lower than expected given the popularity of San Francisco, but it was greater than the previous two in-person conferences pre-pandemic. The domestic attendance of the conference has seen a big bump when compared to pre-pandemic numbers, which shows the increasing popularity of the conference.

The attendance was most affected by foreign attendance when compared with pre-pandemic numbers. While most countries have ended Covid-related travel restrictions, international travels

have not bone back to pre-pandemic levels. For EIPBN 2022, the zero covid and quarantine policies caused significant decline in attendance primarily from China, Hong Kong, and Japan. There were one attendee from China and Hong Kong, and eight attendees from Japan. The lone Chinese attendee was a foreign national living in the United States and most of the Japanese attendees were exhibitors. The attendee from China and Hong Kong in 2023 rebounded to 6, which is still significantly lower than pre-pandemic numbers. Attendees from Japan recovered to 14 in 2023. Foreign attendees from Europe and Canada rebounded, but are still below pre-pandemic numbers. This is reflected in difficulties getting travel visas, which likely accounts for the lower attendance numbers from these regions. A number of foreign students and researchers had difficulties in obtaining a visa in time and had to withdraw or present virtually. Overall, there were only about 5 withdraws and around 5 authors presented their talks synchronously via Zoom.

The total student attendee for 2023 is 70, with 54 being domestic students. The foreign student is 16, which has been declining since 2018. The historic data shows that 15 students from eight countries attended in 2022, 23 from eight countries in 2019, and 39 from 11 countries attended in 2018. The declining student attendance is not likely due to lack of interest in the conference as evidenced by the record 338 registered students attending the virtual 2021 conference. One main reason is that international travel post-Covid is still down, and geopolitical tension has led to difficulty in obtaining travel visa. We hope to encourage more international student attendees for 2024 with stronger outreach to our sister conferences in Europe and Asia.

Student Registration and Travel Support

EIPBN has a strong tradition of cultivating the young generation of scientists and engineers in nanofabrication and advanced nanomanufacturing that includes subsidizing many networking, educational events, and student awards. Students can attend the annual short courses at no additional costs. Networking opportunities are provided at the Student Mentor Lunch. All student registration is discounted $500 when compared with full registration. Every student author is automatically entered in the Best Student Poster and Best Student Presentation awards. All student authors may apply for financial support. The DOE grant of $5,000, as well as support from the National Science Foundation ($18,000) and Office of Naval Research ($10,000), help offset the costs for these events and awards.

Student authors based in US institutions attending the 66th EIPBN can apply to received additional conference support of three-room nights at the Sheraton New Orleans. The three-night stay amounted to a total award value of $678.57 per student. The new requirement for 66th conference, in addition to the above, was the submission of a three-page manuscript with a fourth page for figures. Every student attending the 66th EIPBN conference who applied for support were awarded support, which included 28 students from close to 20 different states.

The 70 students attending the 66th EIPBN conference are diverse and came from nine countries, including 54 from the United States, 7 from Europe (UK, Germany, Denmark, etc.), 6 from Asia (Japan, Korea, Hong Kong), and 3 from the Middle East (Israel). The overall demographics of the student attendees were 40% Asian, 35.7% white, 5.7% African and African American (18.6% declined to respond). Of the student attendees, 70% self-identified as male and 30% as female. 11.4% of the students also identified as under-represented minority (74.3% declined to respond). **An estimated total of 37.1% of all student attendees (US and international) are either female and/or from URM groups.**

Among domestic participants, there were a total of **54 student attendees from US institutions**. Of the US student attendees, there were 39 male (72.2%) and 15 female (27.8%). In terms of race, there were 22 Asian (40.7%), 21 White (38.9%), 4 Black/African American (7.4%), and 7 self-identified as others (13%). The detailed breakdown of the aggregated demographic information collected are shown in Figure 1. The US student participants includes **15 female (27.8%) and 7 URM (12.9%)** attendees. **A total of 19 US students (35.2%) were either female and/or URM groups, which is above the committee's target of 30%**. This number is much higher than pre-COVID numbers (25% in 2018 and 26.4% in 2019, as shown in Figure 2. The share for female/URM student attendee also saw a slight increase from 32.2% achieved in EIPBN 2021, which was held virtually and saw a significant spike in student registration (over 300). This data indicates that current outreach efforts and student events such as WIN, Student Mentorship and Recruiting events are effective in attracting URM students and have **increased their participation from 25 to 35% over the past 5 years**. The Steering Committee will aim to continue this level of success in outreaching for next year's EIPBN.

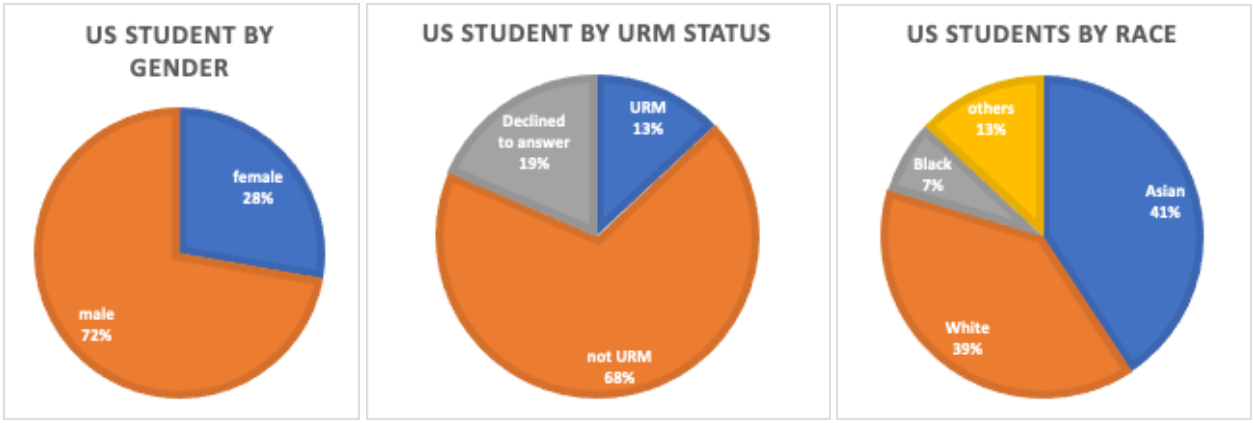

Figure 1. Self-identified demographic information for 2023 EIPBN US student attendees.

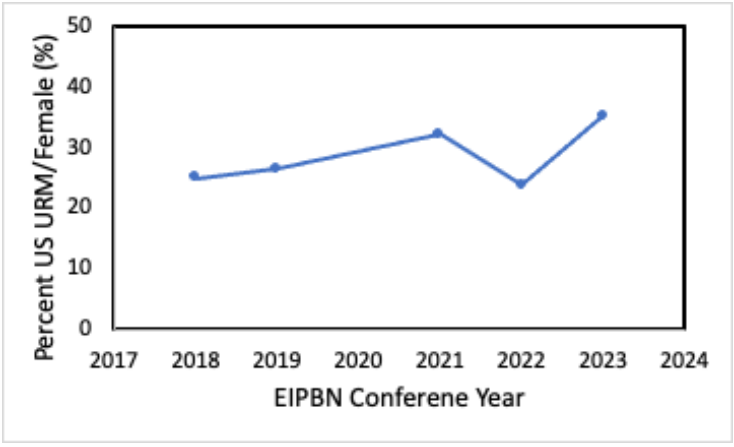

Figure 2. Historic self-identified demographic information of percentage female and/or URM student attendees from US institutions.

Overall, we achieved our target of broadening participation, which was to ensure at least 30% of the US-based students be from URM groups. We will continue the active recruiting of URM students and hope to achieve the same success next year. A list of US students, affiliations, and their responses to the voluntary demographics survey are listed in **Table 1**.

Table 1: List of student attendees from US-based institutions supported by the government grant.

No	**First Name**	**Last Name**	**Organization Name:**	**Gender**	**URM**
1	Azimi Roueini	Maliheh	Bucknell University	Female	No
2	Bamrah	Nimarpreet	Arizona State University	Female	No
3	Brown	Devin	Georgia Institute of Technology	Male	No
4	Cao	Can	The Ohio State University	Female	No
5	Chen	Mingze	University of Michigan	Male	Prefer not to answer
6	Chen	Wen	Univeristy of Chicago	Female	No
7	Chen	Xinye	University of California Riverside	Male	No
8	Chien	Kun-Chieh	The University of Texas at Austin	Male	No
9	Choi	Yeji	Arizona State University	Female	No
10	Cuero	Briana	The University of Texas at Austin	Female	Yes
11	Das	Nabasindhu	Arizona State University	Male	No
12	Dasinor	Emmanuel	Arizona State University	Male	Yes
13	Easy	Elham	Stevens Institute of Technology	Female	Yes
14	Fasano	Cecilia	University of Iowa	Female	No
15	Fethke	Victoria	University of Pennsylvania	Female	No
16	Flores	Ethan	University of Texas at Austin	Male	Prefer not to answer
17	Gadasu	Edward	FAMIL	Male	Prefer not to answer
18	Groh	Barbara	University of Texas at Austin	Female	Yes
19	Gu	Suki	Caltech	Female	No
20	Hayward	Tina	University of Utah	Female	No
21	Hossain	Sushmit	University of Southern California	Male	Prefer not to answer
22	Hu	Pan	University of Southern California	Male	Prefer not to answer
23	Kalatehmohammadi	Maziyar	Arizona State University	Male	No
24	Kawasaki	Kohei	University of Tsukuba	Male	No
25	Ki	Seungjun	University of Michigan	Male	No
26	Krishnasamy	Ramyapriya	University of Texas at Dallas	Female	No
27	Kumar	Deepak	University of Kentucky	Male	Prefer not to answer
28	Kumar	Koushik	University of Massachusetts Amherst	Male	Yes
29	Lee	Kwon Sang	The University of Texas at Austin	Male	Prefer not to answer
30	Li	Runze	University of Maryland	Male	No
31	Liu	Li	University of California Riverside	Female	Prefer not to answer
32	Liu	Zerui	University of Southern California	Male	No
33	Lynes	David	The U.S. Air Force Institute of Technology	Male	No

34	Mamun	Abdulla Al	Arizona State University	Male	No
35	Mirjalili	Seyedsina	Arizona State University	Male	No
36	Mittelbrun	Thomas	University of Pennsylvania	Male	No
37	Mohanty	Saurav	The University of Texas at Austin	Male	Prefer not to answer
38	Ou	Tse Hsien	University of Southern California	Male	No
39	Pandya	Parth	The University of Texas at Austin	Male	No
40	Pearson-Nadal	Harold	Montana Tech Nanotechnology Laboratory	Male	Yes
41	Perez	Edgar	Univeristy of Marland / NIST	Male	Yes
42	Premnath	Vijay Anirudh	University of Texas at Austin	Male	No
43	Rahaman	Mohammad Istiaque	University Notre Dame	Male	Prefer not to answer
44	Ravel	Victoria	The George Washington University	Female	No
45	Roberts	Gregory	California Institute of Technology	Male	No
46	Simonaitis	John	Massachusetts Institute of Technology	Male	No
47	Suttey	Luke	Montana Tech Nanotechnology Laboratory	Male	No
48	Taiswa	Amos	Montana Tech Nanotechnology Laboratory	Male	No
49	Termini	Jared	University of Iowa	Male	No
50	Tunell	Andrew	University of Texas at Austin	Male	No
51	Vorhies	Xavier	Montana Tech Nanotechnology Laboratory	Male	No
52	Waitkus	Jacob	University of California, Riverside	Male	No
53	Welsh	Cameron	Ion Innovations	Male	No
54	Young	Alex	Louisiana State University	Male	No

Project Dissemination

Conference extended abstracts were disseminated electronically. The abstracts were electronically published and archived online on our web site and are available at http://eipbn.org/abstracts/2023/.

Various authors. Q. Xia and C.-H. Chang, 2023 Conference and Program Chairs. *Abstracts for the International Conference on Electron, Ion, and Photon Beam Technology and Nanofabrication (EIPBN), 2023* Collection of extended, peer reviewed, accepted abstracts for EIPBN 2023 (http://eipbn.org/abstracts/2023/).

The proceedings of the conference were published in the Nov/Dec, 2023 issue (Vol. 40 issue 6) of the *Journal of Vacuum Science and Technology B (JVSTB)*, an archival journal of the American Institute of Physics. All papers submitted were subject to independent peer review. The collection of journal papers were published under the following title:

Various authors. Eray Aydil, Editor-in-chief, Chih-Hao Chang, Guest Editor (2023). *Papers from the 66th International Conference on Electron, Ion and Photon Beam Technology and Nanofabrication*. Papers can be accessed at:

https://pubs.aip.org/collection/13377/Papers-from-the-66th-International-Conference-on

The conference proceeding was also advertised by the *AVS* and *IEEE* through newsletters.

Participants and Organizations

Chih-Hao Chang (University of Texas, chichang@utexas.edu) served as the PI for this project and the Program Chair for the conference, and was responsible for coordinating funding for student support. Dr. Chang collaborated closely with Qiangfei Xia (University of Massachusetts at Amherst), who served as the Conference Chair. Other collaborators on this project include the EIPBN Steering Committee, which consists of the following members: James Spallas (KLA), B. Robert Ilic (National Institute of Standards and Technology), Gerald Lopez (University of Pennsylvania, Singh Center for Nanotechnology), Martha I. Sanchez (Applied Materials), Aimee Price (Ohio State University), Wei Wu (University of Southern California), James Owen (Zyvex Laboratories), and Richard Silvers (National Institute of Standards and Technology).

Project Impact

DOE support of student attendance advanced knowledge by enabling the exchange of information between the next generation of scientists and engineers with leading researchers from academic, industry, and government participants both formally in the technical program and informally throughout the meeting. The conference advanced the primary discipline of nanofabrication and advanced nanomanufacturing by facilitating a common platform among researchers from different backgrounds. This interaction will clearly accelerate developments in this critical area.

The conference includes a substantial number of presentations on the applications of nanofabrication and advanced nanomanufacturing, which is critical in several fields such as chip manufacturing, personalized healthcare, AI, and renewable energy. These presentations connect experts in these areas, particularly nanophotonics, nanobiotechnology and nanoelectronics, with experts in lithography, deposition, etching, chemical synthesis, and self-assembly.

This project advanced the scientific/engineering careers of the students whose attendance was supported, and impacted other meeting attendees who benefited from the presentations that these students made. The meeting introduced student researchers to a long-standing community of nanofabrication professionals and its supporting societies. It also developed knowledge-based infrastructures in the form of archived extended abstracts and published full journal articles all of which were peer-reviewed.

The meeting developed extensive information resources in the form of peer-reviewed, archived extended abstracts and a special issue of separately peer-reviewed, full journal articles. The combination of industry, academic, and government attendees at EIPBN ensures that the conference provides opportunities for technology transfer and not just interaction among academic researchers. The sessions on Industrial Highlights and Start-up Competition also encouraged the translation of research towards commercialization.