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EDUCATION:

Doctor of Philosophy (Ph.D.) 09/99 – 05/04
Department of Theoretical and Applied Mechanics,
University of Illinois at Urbana-Champaign, Urbana, IL
Thesis: *On the Rumpling Instability in Thermal Barrier Systems* (Advisor: K. Jimmy Hsia)

Master of Science in Mechanical Engineering (M.S.) 08/97 – 09/99
Department of Mechanical Engineering,
University of Massachusetts at Amherst, MA
Thesis: *Sharp Particle Impact damage in fused quartz and functionally graded ceramics*

Bachelor of Engineering (B.E.) in Mechanical Engineering 08/93 – 07/97
Pune University, India

WORK EXPERIENCE:

2023 – Present: Professor, Department of Mechanical Engineering, Carnegie Mellon University, Pittsburgh PA, USA. Courtesy appointments in Robotics Institute, Department of Biomedical Engineering, and Department of Materials Science and Engineering, CMU.

2021 – present: Associate Director of Research, Manufacturing Futures Institute, CMU, Pittsburgh PA, USA

2023- present: Co-founder and technical consultant at Power3D, a Li-ion battery startup.

2021 – 2023: Russell V. Trader Associate Professor, Department of Mechanical Engineering, Carnegie Mellon University, Pittsburgh PA, USA

2017 – 2021: Associate Professor, Department of Mechanical Engineering, Carnegie Mellon University, Pittsburgh PA, USA

2014 – 2017: Associate Professor, School of Mechanical and Materials Engineering, Washington State University (WSU), Pullman WA, USA

2004 – 2014: Senior Engineer & Engineering Manager, Intel Corporation, Chandler AZ, USA

PUBLICATIONS:

Underlined authors are my students/postdocs. Link to Google Scholar page.

1. A. Agarwal, J. Rozsa, M. Pozzi, R. Panat*, & G. K. Fedder*, "Digital Twin of Aerosol Jet Printing", arXiv:2511.00593; accepted (in press) **npj Advanced Manufacturing** (2026).

2. S. Kushagr, C. Hu, B. Yuan, D. Patel, A. Nandakumar, R. Lakshmi Narayan, R. Panat*, "From Lines to Lattices – High-Resolution 2D–3D PDMS Microarchitectures via Aerosol Jet Printing", 3, 19, **npj Advanced Manufacturing** (2026).

3. S. Nath, M. Mukherjee, R. Panat, & . Lakshmi Narayan, "On the Wire Arc Additive Manufacturing of high-strength Al4043 parts using TiN and La_2O_3 as grain refiners", **Advanced Engineering Materials**, 28 (14), e70922 (2026).

4. J. Berthel, J. Beuth & R. Panat *, "J. Berthel, J. Taggart-Scarff, J. Yu, B. McWilliams, R. Panat, & J. Beuth*, "AlSi10Mg plate-lattice structures fabricated by laser powder bed fusion exhibiting high specific energy absorption", **Additive Manufacturing**, 119, 105117 (2026).

5. C. Hu, B. Yuan, S. Jahan, M. A. Ali, & R. Panat*, "MXene 3D-AJP: Three-Dimensional Well-Oriented Freeform Networks of 2D MXene Nanosheets via Aerosol-Based 3D Printing", **Small**, e10964 (2026).

6. C. Hu, S. Jahan, & R. Panat*, "Mechanics of cracking and delamination in 3D-printed microelectronic films", **Acta Materialia**, 296, 121244 (2025).

7. J. Berthel, J. Taggart-Scarff, J. Yu, B. McWilliams, R. Panat, & J. Beuth*, "AlSi10Mg plate-lattice structures fabricated by laser powder bed fusion exhibiting high specific energy absorption", **Materials and Design**, 257, 114395 (2025).

8. C. Hu, B. Yuan, S. Jahan, C. Santiago, & R. Panat*, "3D-AJP: Fabrication of Advanced Microarchitected Multi-Material Ceramic Structures via Binder-Free and Auxiliary-Free Aerosol Jet 3D Nanoprinting", **Advanced Science**, 12, 2405334 (2025).

9. S. Jahan, A. Jain, S. Frregonese, C. Hu, M. Bacca*, & R. Panat*, "*Bed-of-Nails* Effect: Unraveling the Insertion Behavior of Aerosol Jet 3D Printed Microneedle Array in Soft Tissue", **Extreme Mechanics Letters**, 71, 102301 (2025).

10. A. Parab, M. D. Nath, Y. Mane, Z. Godhrawala, R. Panat*, & S. Jejurikar*, "Role of MWCNTs for the effective detection of glucose in MWCNTs/NiO/MWCNTs stack prepared on paper electrode", **Advanced Sensor Research**, 4, 2500069 (2025). (also **featured on the journal cover**)

11. B. Saif, M. Arslanoglu, V. Hadjiev, H. De La Fuente, M. Velez, H. Romero, C. Guerra, A. Alarcon, C. Lopez, R. Panat* & A. Addo-Mensah*, "The Synthesis of Multifunctional MXene-Composites for Three-Dimensional Aerosol Jet Printing", **ACS Applied Electronic Materials**, 7 (15), 6867-6873 (2025).

12. L. Wang, Z. Dai, Y. Wu, Y. Jin, C. Barry, T. Tian, F. Ruan, S. Shastry, R. Panat, , G. Fedder, H. Choset, & L. Li, "From Flat to Form-Fitting: A Computational Geometry Approach to 3D Conformal Electronics Design and Rapid Prototyping." 2025 IEEE 21st International Conference on Automation Science and Engineering (CASE). IEEE, 2025.

13. S. Ritchie, C. Hu, & R. Panat*, "Realizing Arbitrary 3D Microarchitectures with Curved and near-Sharp Segments via Toolpath Strategies in Aerosol Jet Printing", **Additive Manufacturing,** 95, 104549 (2024).

14. M.A.S.R. Saadi, F. H. Likhi, M. D. Nath, R. Jayan, F. Zahin, M. Thakur, Y. Yuan, M. Islam, R. Panat, A. Karim, P. M. Ajayan, & M. Rahman*, "Algae-derived Nacre-like Dielectric Bionanocomposite with High Loading Hexagonal Boron Nitride for Green Electronics", **ACS Nano,** 48 (18), 33081–33096 (2024).

15. S. Jahan, C. Hu, B. Yuan, S. Ritchie, & R. Panat*, "Aerosol Jet 3D Printing of Gold Micropillars and Their Behavior Under Compressive Loads", **Additive Manufacturing**, 92, 104385 (2024).

16. M.A. Ali, G. Zhang, C. Hu, B. Yuan, S.J. Gao*, & R Panat*, "3D Nano-printed Assay for the Impedance Detection of SARS-CoV-2 Variants at Femtomolar Resolution", **Advanced Materials Interfaces,** 11 (14), 2400005 (2024).

17. Y. Jadhav, J. Berthel, C. Hu, R. Panat, J. Beuth, & A. Farimani*, "Generative Lattice Units with 3D Diffusion for Inverse Design: GLU3D", **Advanced Functional Materials,** 34 (41) 2404165 (2024).

18. M. Arslanoglu, B. Yuan, R. Panat*, & O. Burak Ozdoganlar*, "3D Assembly of MXene Networks using a Ceramic Backbone with Controlled Porosity", **Advanced Materials**, 2304757 (2023). CMU News

19. S. Ritchie, S. Kovacevic, P. Deshmukh, A. Christodoulides, J. Malen, S. Mesarovic*, & R. Panat*, "Shape distortion in sintering results from nonhomogeneous temperature activating a long-range mass transport", **Nature Communications**, 14, 2667:1-11 (2023).

20. J. Brenneman, M. Lovalekar, & R. Panat*, "A Semi-Empirical Model for Post-yield Stress-instability in the Stress-Strain Response of Three-dimensional Lattice Structures Under Compressive Loads", **Advanced Engineering Materials**, 202201428 (2023).

21. Y. Jadhav, J. Berthel, C. Hu, R. Panat, J. Beuth, & A. Barati Farimani*, "StressD: 2D Stress Estimation Using Denoising Diffusion Model", **Computer Methods in Applied Mechanics and Engineering,** 416, 116343 (2023).

22. M. S. Saleh, S. Ritchie, M. A. Nicholas, H. L. Gordon, C. Hu, S. Jahan, B. Yuan, R. Bezbaruah, J. W. Reddy, Z. Ahmed, M. Chamanzar, E. A. Yttri*, & R. Panat*, "CMU Array: A 3D Nano-Printed, Highly Customizable High-Density Microelectrode Array Platform," **Science Advances**, 8 (40), eabj4853 (2022). CMU News

23. M. A. Ali, G. Fei Zhang, C. Hu, B. Yuan, S. Jahan, G. D. Kitsios, A. Morris, S.-J. Gao*, & R. Panat*, "Ultra-Rapid and Ultra-Sensitive Detection of SARS-CoV-2 Antibodies in COVID-19 Patients via a 3D-Printed Nanomaterial-Based Biosensing Platform," **Journal of Medical Virology**, 94 (12), 5808 (2022).

24. J. Brenneman, D. Z. Tansel, G. K. Fedder*, & R. Panat*, "High-Conductivity Crack-Free Three-Dimensional Electrical Interconnects Directly Printed on Soft PDMS Substrates," **Advanced Materials Technologies,** 2200396, 1-15 (2022).

25. M. Arslanoglu, B. Ozdoganlar*, & R. Panat*, "Fabrication of Porous Silica with Controllable and Tunable Porosity via Freeze Casting," **Journal of the American Ceramic Society**, 105 (8) 5114-5130 (2022).

26. M. A. Ali, C. Hu, E. A. Yttri, & R. Panat*, "Recent Advances in 3D Printing of Biomedical Sensing Devices," **Advanced Functional Materials**, 32, 2107671 (2022). **Invited Review.** Also published as Journal Frontispiece for the February 2022 issue.

27. D.Z. Tansel, J. Brenneman, R. Panat*, & G.K. Fedder*, "Aerosol-Jet-Printed Stretchable Electronic Decal Technology," **2022 IEEE 35th International Conference on Micro Electro Mechanical Systems Conference (MEMS), IEEE**, 353–356 (2022).

28. M.A. Ali, C. Hu, B. Yuan, S. Jahan, M. S. Saleh, Z. Guo, A. J. Gellman, & R. Panat*, "Breaking the Barrier to Biomolecule Limit-Of-Detection via 3D Printed Multi-Length-Scale Graphene-Coated Electrodes," **Nature Communications**, 12, 1–16 (2021). See CMU news.

29. M. A. Ali, C. Hu, F. Zhang, S. Jahan, B. Yuan, M. S. Saleh, S. J. Gao*, and R. Panat*, "N Protein-Based Ultrasensitive SARS-CoV-2 Antibody Detection in Seconds via 3D Nanoprinted, Microarchitected Array Electrodes," **Journal of Medical Virology,** 94, 2067–2078 (2022).

30. M. A. Ali, C. Hu, S. Jahan, B. Yuan, M. S. Saleh, E. Ju, S.-J. Gao, and R. Panat*, "Sensing of COVID-19 Antibodies in seconds via Aerosol Jet nanoprinted Reduced-Graphene-Oxide-Coated 3D Electrodes," **Advanced Materials**, 33(7), 202006647 (2021). **Journal cover for the February 2021 issue.** See CMU news, CMU video.

31. P. A. Borade, M. A. Ali, S. Jahan, T. Sant, K. Bogle, R. Panat*, and S. M. Jejurikar*, "MoS_2 Nanosheet-Modified NiO Layers on a Conducting Carbon Paper for Glucose Sensing," **ACS Applied Nano Materials**, 4, 6609–6619 (2021).

32. M. S. Saleh, C. Hu, J. Brenneman, A.M.A Mutairi, & R. Panat*, 3D Printed Three-dimensional Metallic Microlattices with Controlled and Tunable Mechanical Properties. **Additive Manufacturing**, 39, 101856 (2021).

33. J. Brenneman, D. Z. Tansel, G. K. Fedder*, & R. Panat*, "Interfacial Delamination and Delamination Mechanism Maps for 3D Printed Flexible Electrical Interconnects," **Extreme Mechanics Letters**, 43, 101199 (2021). **Journal Cover.**

34. M. Hamid*, M. S. Saleh, A. Afrouzian, R. Panat*, & H. M. Zbib, "Modeling of Porosity and Grain Size Effects on Mechanical Behavior of Additively Manufactured Structures," **Additive Manufacturing**, 38, 101833 (2021).

35. M. T. Rahman, & R. Panat*, "Aerosol Jet 3D Printing and High Temperature Characterization of Nickel Nanoparticle Films," **Manufacturing Letters**, 29, 5–10 (2021).

36. P. A. Borade, T. Sant, A. Gokarna, K. Joshi, R. Panat*, & S. Jejurikar*, "Role of Defects in Modulating the near Band Edge Emissions of Sub-Micron ZnO Crystals," **Optical Materials**, 109, 110348 (2020).

37. Y. Zhu, J. Li, M. S. Saleh, H. Pham, T. P. Plateau, R. Panat*, & J. Park*, "Towards High-Performance Li-ion Batteries via Optimized Three-Dimensional Micro-Lattice Electrode Architectures," **Journal of Power Sources**, 476, 1–18 (2020).

38. B. Mallesham, V. B. Zade, A. Rubio, S. Tan, R. Panat*, & C. V. Ramana*, "Unravelling the Sintering Temperature Induced Phase Transformations in $Ba(Fe_{0.7}Ta_{0.3})O_{3-\delta}$ Ceramics," **Ceramics International**, 46(14), 23257 (2020).

39. D. Z. Tansel, J. Brenneman, G. K. Fedder*, & R. Panat*, "Mechanical Characterization of Polydimethylsiloxane (PDMS) Exposed to Thermal Histories up to 300 °C in a Vacuum Environment," **Journal of Micromechanics and Microengineering**, 30(6), 067001 (2020).

40. Md. T. Rahman, C. H. Cheng, B. Karagoz, M. Renn, M. Schrandt, A. Gellman, & R. Panat*, "High Performance Flexible Temperature Sensors via Nanoparticle Printing," **ACS Applied Nano Materials,** 2(5), 3280–3291 (2019).

41. R. Danaie, T. Verghese, M. Ahmadzadeh, J. McCloy, C. Hollar, M.S. Saleh, J. Park, Y. Zhang*, & R. Panat*, "Ultrafast Fabrication of Thermoelectric Films by Pulsed Light Sintering of Colloidal Nanoparticles on Flexible and Rigid Substrates," **Advanced Engineering Materials**, 21, 1800800 (2019).

42. S. Manandhar, A. Battu, S. Tan, R. Panat, V. Shutthanandan, & C. V. Ramana*, "Effect of Ti Doping on the Crystallography, Phase, Surface/Interface Structure and Optical Band Gap of Ga_2O_3 Thin Films," **Journal of Materials Science**, 54, 11526–11537 (2019).

43. Y. Arafat, S. Sultana, I. Dutta*, & R. Panat*, "Effect of Additives on the Microstructure of Electroplated Tin Films," **Journal of The Electrochemical Society**, 165(16), D816–D824 (2018).

44. M. S. Saleh, J. Li, J. Park*, & R. Panat*, "3D Printed Hierarchically-Porous Microlattice Electrode Materials for Exceptionally High Specific Capacity and Areal Capacity Lithium-ion Batteries," **Additive Manufacturing**, 23, 70–78 (2018). See CMU news, Forbes article.

45. R. Panat*, J. Park*, M. S. Saleh, & J. Li, (2018). 3D-Printed Lattice Batteries. **Homeland Defense Information Analysis Center (HDIAC) Journal**, 5(4), 11–14 (2018).

46. M. T. Rahman, R. Moser, H. Zbib, C. V. Ramana*, & R. Panat*, "3D Printed High Performance Strain Sensors for High Temperature Applications," **Journal of Applied Physics**, 123, 024501 (2018). See CMU news.

47. M. S. Saleh, M. HamidVishkasougheh, H. Zbib*, & R. Panat*, "Polycrystalline Micropillars by a Novel 3-D Printing Method and Their Behavior under Compressive Loads," **Scripta Materialia**, 149, 144-149 (2018).

48. J. Li, X. Liang, R. Panat, & J. Park*, "Enhanced Battery Performance through Three-Dimensional Structured Electrodes: Experimental and Modeling Study," **Journal of The Electrochemical Society**, 165(14), A3566-A3573 (2018).

49. J. Li, X. Liang, R. Panat, & J. Park*, "Microstructure-Controlled 3D Electrodes for Lithium-Ion Batteries," **ECS Transactions**, 85(13), 369 (2018).

50. Y. Arafat, R. Panat*, & I. Dutta*, "Highly Stretchable Metal Films on Polymer Substrates: Mechanics and Mechanisms," **2018 17th IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm)**, 32–36 (2018).

51. M. S. Saleh, C. Hu, & R. Panat*, "Three Dimensional Micro-Architected Materials and Devices Using Nanoparticle Assembly by Pointwise Spatial Printing," **Science Advances**, 3, e1601986 (2017). See news and video.

52. J. Geng, M. T. Rahman, R. Panat*, & L. Li*, "Self-assembled Axisymmetric Microscale Periodic Wrinkles on Elastomer Fibers," **ASME Journal of Micro and Nano-manufacturing**, 5(2), 021006 (2017).

53. M. T. Rahman, J. Gomez, K. Mireles, P. Wo, J. Marcial, M. Kessler, J. McCloy, C. Ramana*, & R. Panat*, "High Temperature Physical and Chemical Stability and Oxidation Reaction Kinetics of Ni-Cr Nanoparticles," **Journal of Physical Chemistry – C**, 121(7), 4018–4028 (2017).

54. J. Li, M. Leu, R. Panat, & J. Park*, "A Hybrid 3D Structured Electrode for Lithium-ion Batteries via 3D Printing," **Materials and Design**, 119, 417–424 (2017).

55. R. Sun, H. Yang, M. Rock, R. Danaei, R. Panat, M. Kessler, & L. Li*, "Manufacturing PDMS Micro Lens Array using Spin Coating under a Multiphase System," **Journal of Micromechanics and Microengineering**, 27(5), 1 (2017).

56. J. Li, M. Leu, R. Panat, & J. Park*, "3D Printed Hybrid Electrodes for Lithium-ion Batteries," **ECS Transactions**, 77(11), 1209 (2017).

57. Y. Arafat, I. Dutta*, & R. Panat*, "On the Deformation Mechanisms and Electrical Behavior of Highly Stretchable Metallic Interconnects on Elastomer Substrates," **Journal of Applied Physics**, 120(11), 115103-1 to 11 (2016).

58. M. T. Rahman, J. McCloy, C. V. Ramana*, & R. Panat*, "Structure, Electrical Characteristics and High-Temperature Stability of Aerosol Jet Printed Silver Nanoparticle Films," **Journal of Applied Physics**, 120(7), 075305-1 to 11 (2016).

59. B. Paul*, R. Panat, C. Mastrangelo, D. Kim, & D. Johnson "Manufacturing of Smart Goods: Current State, Future Potential and Research Recommendations" **ASME Journal of Nano and Micro-Manufacturing**, 4(4), 044001-1 to 12 (2016).

60. M. T. Rahman, A. Rahimi, S. Gupta*, & R. Panat*, "Microscale Additive Manufacturing and Simulations of Interdigitated Capacitive Touch Sensors," **Sensors and Actuators A: Physical**, 248, 94–103 (2016).

61. H. Yang, M. T. Rahman[#], D. Du, R. Panat[*], & Y. Lin[*], "Electrochemical Sensors for Biological Applications using 3D Printed Adjustable Microelectrode Arrays," **Sensors and Actuators B: Chemical**, 230, 600–606 (2016). [#]equal contribution

62. Y. Arafat, I. Dutta[*], & R. Panat[*], "Super-Stretchable Metallic Interconnects on Polymer with a Linear Strain of up to 100%," **Applied Physics Letters**, 107, 081906 (2015). See WSU news, Washington magazine article.

63. M. T. Rahman, L. Renaud, M. Renn, D. Heo[*], & R. Panat[*], "Aerosol based Direct-Write Micro-Additive Fabrication Method for Sub-mm 3D Metal-Dielectric Structures," **Journal of Micromechanics and Microengineering**, 25(10), 107002 (2015).

64. R. Panat[*], "A Model for Crack Initiation in the Li-ion battery Electrodes," **Thin Solid Films,** 596, 174–178 (2015).

65. Y. Arafat, I. Dutta[*], & R. Panat[*], "Highly Stretchable Interconnects for Flexible Electronics Applications," **ASME 2015 International Technical Conference and Exhibition on Packaging and Integration of Electronic and Photonic Microsystems**, Paper No. IPACK2015–48187, pp. V003T03A002 (2015).

66. M. T. Rahman, L. Renaud, M. Renn, D. Heo, & R. Panat[*], "3D Antenna Structures Using Novel Direct-Write Additive Manufacturing Method," **ASME 2015 International Technical Conference and Exhibition on Packaging and Integration of Electronic and Photonic Microsystems**, Paper No. IPACK2015–48130, pp. V002T02A029 (2015).

67. Z. Song, T. Ma, R Tang, Q. Cheng, X. Wang, D. Krishnaraju, R. Panat, C. K. Chan, H. Yu, & H. Jiang[*], "Origami Lithium-ion batteries," **Nature Communications**, 5:33140 10.1038/ncomms4140, (2014).

68. R. Panat[*], S. Dattaguru, H. Balkan, Y. Min, H. Seh, & X. Zhao, "Mechanical reliability of Embedded Array Capacitors in ultra-high-performance microprocessors," **IEEE Transactions on Device and Materials Reliability,** 4(5), 857 (2014).

69. R. Panat[*], E. Parks, & J. Wang, "On the Effects of Triboelectrostatic Changing between Polymer Surfaces in Manufacturing and Test of Integrated Circuit Packages," **IEEE Transactions on Components, Packaging and Manufacturing**, 4(5), 943 (2014).

70. R. Panat[*], V. Dimitrova, S. Selvamundiany, K. Ishiko, & D. Sun, "The Application of Lean Six Sigma to the Configuration Control in Intel's Manufacturing R&D Environment," **International Journal of Lean Six Sigma**, 5(4), 444–459 (2014). Selected by the journal as a '***Highly Commended Paper of 2014***.'

71. R. Panat[*], "On the Data and Analysis of Research Output of India and China: India has Significantly Fallen behind China," **Scientometrics** *(Springer)*, 100 (2), 471–481 (2014).

72. Y. Min[*], R. Olmedo, M. Hill, K. Radhakrishnan, K. Aygun, M. Kabiri-badr, R. Panat, S. Dattaguru, & H. Balkan, "Embedded Capacitors in the Next Generation Processors," **63rd ECTC Conference, IEEE**, 1225–1229 (2013).

73. N. Raravikar, R. Panat*, & S. Jadhav, "A Tombstone Initiation Model for Small Form Factor Surface Mount Passives," **IEEE Transactions on Components, Packaging and Manufacturing**, 2(9), 1486–1491 (2012).

74. L. Yan, R. Panat, R. Mulligan, P. Srinath, & A. Raman*, "The Application of 2D X-ray Hot Stage in Flip Chip Package Failure Analysis," **IEEE Transactions on Device and Materials Reliability**, 11(1), 141–147 (2011).

75. R. Panat*, et al., "Solving the Solder Bridging Issue in Large Die Processors," **Intel Assembly and Test Technology Journal** [Intel's internal confidential journal], 13, 249–260 (2010).

76. H. Balkan*, others, & R. Panat, "Passive Technology Requirements for Future Flip-Chip Packages," **Intel Assembly and Test Technology Journal** [Intel's internal confidential journal], 11, 405–413 (2008).

77. R. Panat, K.J. Hsia*, & D.G. Cahill, "Evolution of Surface Waviness in Thin Films via Volume and Surface Diffusion," **Journal of Applied Physics**, 97, 013521 (2005).

78. R. Panat, K.J. Hsia*, & J. Oldham, "Observation of Rumpling Instability in Thermal Barrier Systems under Isothermal Conditions in Vacuum," **Philosophical Magazine**, 85(1), 45–64 (2005).

79. R. Panat & K.J. Hsia*, "Experimental Investigation of the Bond Coat Rumpling Instability under Cyclic and Isothermal Temperature Histories in Thermal Barrier Systems," **Proceedings of the Royal Society of London, Series A,** 460, 1957–1979 (2004).

80. R. Panat, S. Zhang, & K.J. Hsia*, "Bond Coat Surface Rumpling in Thermal Barrier Coatings" **Acta Materialia**, 51, 239–249 (2003).

81. S. Zhang, R. Panat, & K.J. Hsia*, "Influence of Surface Morphology on the Adhesion Strength of Aluminum/Epoxy Interfaces," **Journal of Adhesion Science and Technology**, 17(12), 1685–1711 (2003).

82. R. Panat, K. Jakus*, J.E. Ritter, & P. Shah, "Erosion and Strength Degradation of an Elastic Modulus Graded Alumina-Glass Composite," **Ceramic Engineering and Science Proceedings**, 21(3), 635 (2000).

83. J.E. Ritter*, K. Jakus, & R. Panat, "Impact Damage and Strength Degradation of Fused Silica," **MRS Symposium Proceedings**, 531, 53 (1998).

PATENTS

Granted Patents:

1. R. Panat, E. Yttri, and M. S. Saleh, "3D Printed Microelectrode Array," US Patent # 12,188,892, issued **2025**.
2. R. Panat, J. Park, M. S. Saleh, and J. Lie, "Three-dimensional lattice batteries via additive manufacturing," US Patent # 11817588, **issued Nov 2023**.
3. G. K. Fedder, R. Panat, J. Brenneman, and D. Z. Tansel, "Stretchable 3D-printed circuit boards," US Patent #11856708**, issued Dec 2023**.

4. R. Panat and D. Heo, “Three-Dimensional Sub-mm Wavelength Sub-THz Frequency Antennas on Flexible and in-situ Cured Dielectric using Printed Metal Structures,” US Patent # 10086432, **issued October 2018**.
5. R. Panat and D. Heo, “Three-dimensional Passive Components,” US Patent #9969001, **issued May 2018**.
6. R. Panat and L. Lei, “Low-Cost Fiber Optic Sensor for Large Strain,” US Patent #9846276, **issued December 2017**.
7. I. Dutta and R. Panat, “Highly Stretchable Interconnect Devices and Systems,” US Patent #9770759, **issued September 2017**.
8. R. Panat and B. Jaiswal, “Nanowires Coated on Traces in Electronic Devices,” US Patent #9627320, **issued April 2017**.
9. N. Raravikar and R. Panat, “Nanolithographic Method of Manufacturing an Embedded Passive Device for a Microelectronic Application, and microelectronic Device Containing the Same,” US Patent #8068328, **issued May 2014**.

Patent Applications:

10. J. Payne & R. Panat, Batteries and battery manufacturing techniques, US Patent App. 19/072,592 (2025).
11. R. Panat, B. Ozdoganlar, T. Centinkaya, and C. Hu, “Point-of-Care Multiplexing Biosensor Array and Scalable Method of Manufacture”, Patent Application filed October 2024
12. B. Ozdoganlar, R. Panat, M. Arslanoglu, “Three dimensional networks of nanomaterials”, **# PCT/US2024/030282**, filed June 2024.
13. R. Panat, S. J. Gao, M. A. Ali, S. Jahan, B. Yuan, and C. Hu, “Electrochemical biosensors for rapid and sensitive detection of pathogens and pathogenic biomarkers,” **#PCT/US2021/040302**, filed August 2021.
14. R. Panat, J. Park, M. S. Saleh, and J. Lie, “Three-dimensional lattice batteries via additive manufacturing,” **#16/593,622**, filed October 2019.
15. T. Cohen-Karni, R. Garg, S. Rastogi, R. Panat, and M. S. Saleh, “Nanowire-Mesh Templated Growth of Out-of-Plane Three-Dimensional Fuzzy Graphene,” #**PCT/US18 /28013**, filed April 2018.
16. B. Ozdoganlar, R. Panat, and M. Arslanoglu, “High throughput manufacturing of near-net-shape porous metal, ceramic, and polymer structures with controllable porosity through three-dimensional thermally-controlled freeze casting,” **# PCT/US2022/022916,** filed March 2022.
17. R. Panat and A. Ali, “Laser-based Fast Micromanufacturing of Test Device for Rapid Detection of Pathogens,” **# PCT/US22/22762**, filed March 2022.
18. R. Panat, B. Yuan, and C. Hu, "3D-Printed Micro-Supercapacitors and Methods for Fabricating the Same," **#PCT/US22/79851**, filed November 2022
19. R. Panat, and B. Yuan, “Simple, Scalable Method for Dispersing MXenes in Nonpolar Organic Solvents,” **#PCT/US22/47689**, filed October 2022

RESEARCH GRANTS:

1. **National Science Foundation (CMMI)**, “GOALI: Understanding the Physical Mechanisms of Distortion and Controlling its Effects in Sintering-based Additive Manufacturing Processes”, **PI: Rahul Panat** and co-PI: Sinisa Mesarovic, $650,000, June 2024 – May 2027.

2. A US federal Agency (cannot be disclosed), **PI: Rahul Panat,** $570,000, Topic related to Li-ion Batteries July 2023 – June 2025 (renews yearly).
3. **Clarkson Aerospace/AFOSR**, "Three-dimensional Device Architectures of 2D Materials via Aerosol Jet 3D Printing," **PI: Rahul Panat,** $856,583, Nov 2021 – Feb 2026.
4. **Pennsylvania Manufacturing Innovation Program**, "Scalable Manufacture of 3D Architected Li-ion Battery Electrodes via Aerosol Jet and Extrusion 3D Printing," **PI: Rahul Panat**, $70,000, May 2024 – Jun 2025.
5. **National Institutes of Health** R01 Grant, "Customizable, Ultra-High-Density Optic Fiber-paired Multielectrode Array by 3D Nanoparticle Printing," **PI: Rahul Panat** and co-investigator: Eric Yttri (MCS), $1,946,748, Sep 2019 – Aug 2023). See CMU News.
6. **Army Research Laboratory**, "Deep Learning Enabled Additive Manufacturing of Ultra-stiff & Ultra-light Plate-lattice Materials," **PI: Rahul Panat** and co-PIs: Amir Farimani and Jack Beuth (ME), $475,000, Jul 2020 – Jun 2024.
7. **Army Research Laboratory**, "Probabilistic digital twin framework applied to metal aerosol jet printing," PI: Gary Fedder (ECE), **Co-PIs: Rahul Panat** and Matteo Pozzi (CEE), $120.373, Jul 2022 – Jun 2024.
8. **National Science Foundation**, 3D Printed High-Performance Batteries, I-Corps grant. **PI: Rahul Panat**, $50,000, May 2023 – Apr 2024.
9. Manufacturing Futures Institute, "Acquisition of electronics 3D Printing Testbed at Mill-19," **PI: Rahul Panat**. $419,060, May 2022 – Apr 2023.
10. **Pennsylvania Manufacturing Innovation Program**, "Fabrication of Alumina Devices via Freeze-Casting for use in the Manufacture of Advanced Steels," **PI: Rahul Panat**, co-PI: Burak Ozdoganlar (ME), $70,000, May 2022 – Jun 2023.
11. **Pennsylvania Infrastructure Transportation Authority (PITA),** "3D-printed lattice batteries," **PI: Rahul Panat**, $32,000, May 2023 – Jun 2024.
12. **Pennsylvania Infrastructure Transportation Authority (PITA),** Industry Partner: UPMC, "A Rapid COVID-19 Test," **PI: Rahul Panat,** $74,000, Jan 2021 – May 2022.
13. Moonshot, "Development of soft robotic e-skin," **PI: Rahul Panat** and co-PI: Gary Fedder, $80,988, 2020 – 2021.
14. **US Department of Energy**, "A Novel Access Control Blockchain Paradigm for Cybersecure Sensor Infrastructure in Fossil Power Generation Systems," **PI: Rahul Panat** and co-PI: Vipul Goyal (CS), $400,000, Sep 2019 – Aug 2022. See CMU News.
15. **David Scaife Foundation**, "A 10-second Rapid COVID-19 Test via 3D Printed Biosensors," **PI: Rahul Panat**, $70,000, Jun 2020 – May 2021.
16. **PITA**, Industry Partner: Highmark Health, "Remote Health Monitoring via 3D Printed Wearable Electronic Decals," **PI: Rahul Panat** and co-PI: Gary Fedder (CMU), $51,500, Jan 2020 – May 2021.
17. **Pennsylvania Manufacturing Innovation Program**, "3D Printed Conformal Sensors for In-situ Monitoring of Cracks in Critical Freight Car Components," **PI: Rahul Panat**, $64,060, Jul 2019 – Jun 2020.
18. **National Institutes of Health** R21 Grant, "Rapid 3-D Nano-Printing to Create Multi-Thousand-Channel Microelectrode Arrays," **Multiple PIs:** Eric Yttri (MCS) and **Rahul Panat,** $414,204.00, Jun 2018 – May 2021.
19. **National Science Foundation**, GOALI/Collaborative Research, "Additive Manufacturing of Mechanically Strong and Electrochemically Robust Porous Electrodes for Ultra-High Energy Density Batteries," **PI: Rahul Panat**, $133,949, Sep 2017 – Apr 2020.
20. **National Science Foundation**, "A Breakthrough Additive Manufacturing Method for High-Strength Lightweight 3D Micro-architectured Materials," **PI: Rahul Panat** and co-PI: Hussein Zbib (WSU), $309,943, Aug 2017 – Jul 2021.
21. **US Department of Energy**, "Low-Cost, Efficient and Durable High Temperature Wireless Sensors by Direct Write Additive Manufacturing for Application in Fossil Energy Systems," **PI: Rahul Panat** and co-PI: Prof. C. V. Ramana (University of Texas), $203,788, Feb 2018 – Sep 2019.

22. **Allegheny Health Network**, "3D Printed Electronic Decals for in-situ Monitoring of Cardiac Parameters," PI: Gary Fedder (ECE) and co-PI: Rahul Panat (ME), $70,000, Apr 2019 – Aug 2020.
23. **DSF Charitable Foundation**, "CMU Array: Using Rapid 3D Printing of Metal Nanoparticles to Improve Neuronal Sampling Abilities by an Order of Magnitude," PI: Eric Yttri (MCS) and co-PI: Rahul Panat (ME), $110,000, Feb 2018 – Jan 2020.
24. **National Science Foundation**, "Workshop: Advanced Manufacturing for Smart Goods," PI: Brian Paul (OSU), co-PIs: Rahul Panat (ME), Christina Mastrangelo (UW), David Kim (WSU), and David Johnson (UO), $33,401, May 2015 – May 2016 (this grant was prior to joining CMU).
25. **I have obtained teaching grants of about $50k to introduce innovation in classroom.**

AWARDS AND HONORS:

1. Russell V Trader Career Development Professorship, CMU, 2021 - 2023
2. Struminger Teaching Fellowship to develop an industry-oriented design course(s) at CMU, Dec 2019
3. Senior Member, IEEE, 2022
4. Divisional recognition award at Intel for outstanding efforts in development of new solder paste metallurgy, 2010
5. Divisional recognition award at Intel for tape-out and production of Intel's first six core Xeon® server microprocessor, 2008
6. Technology and Manufacturing Group (TMG) excellence award at Intel for innovation in packaging to achieve $2.6 billion in package, assembly, and test savings, 2008
7. Divisional recognition award at Intel for developing manufacturing process for the first fully green (halogen free and lead free) integrated circuit (IC) chip, 2007
8. Lean Six Sigma Green Belt Certification at Intel, 2014
9. Henry L. Langhaar Graduate Award, University of Illinois at Urbana, 2004
10. Stanley J. Weiss Outstanding Dissertation Award, University of Illinois at Urbana, 2004
11. Dissertation Completion Fellowship, University of Illinois at Urbana, 2003–04
12. Materials Research Society (MRS) Gold Medal, 2002
13. Mavis Memorial Fund Scholarship Award, University of Illinois at Urbana, 2002 and 2003
14. Research Fellowship, TAM Department, University of Illinois at Urbana, 1999–2000
15. National Merit Scholarship by the Government of India, 1991

STUDENT ADVISING:

(a) Ph.D. Students

Current

1. Ethan Kessler, "Aerosl Jet printing of Li-ion batteries", Aug 2025 - present
2. Michael Stefanov, "3D-printed Ultrathick Electrode Li-ion Batteries", Aug 2023 – present
3. Methu Dev Nath, "Study of 3D organoids using CMU Array", Aug 2023 – present (co-advised with T. Karni, CMU)
4. Aaditya Nandakumar, "3D-printed oxygenators", Aug 2023 – present (co-advised with T. Karni, CMU)
5. Rohit Yadav, "Carbon capture using freeza casting of MOF materials" Aug 2024 – present (co-advised with B. Ozdoganlar)

6. Swastik Kushagr, “Fundamental Studies of Aerosol Jet 3D-printing process”, Aug 2024 – present

Completed

1. Joseph Berthel, “Blast resistance plate lattice structures via LPBF process”, Sept 2025.
2. Sanjida Jahan, “Gold CMU Array: Fabrication via Aerosol Jet 3D printing, Characterization, and Testing in Resected Brain of a Living Human Subject and Rat Spinal Cord,” Sept 2024.
3. Chunshan Hu, “Towards Three-Dimensional Electronic Devices via Aerosol Jet Printing: Fabrication Studies, Mechanistic Understanding, and Application Demonstration in Energy Storage,” Sept 2024.
4. Mert Arslanoglu, “Freeze-Cast Ceramics and Their Composites with 2D MXene Nanoflakes for Energy Storage Applications,” Dec 2023.
5. Sandra Ritchie, “Aerosol Jet 3D-Printed Biomedical Devices: From Fundamental Materials Science and Toolpath Strategies to Realizing Next-Generation Customizable Brain-Computer Interfaces,” Dec 2023.
6. Jacob Brenneman, “3D Printed Stretchable Electronics: Fabrication using Aerosol Jet, Fundamental Mechanics, and Applications”, Dec 2022.
7. M. Sadeq Saleh, “Additive manufacturing of 3-D microarchitected materials, micro electrode arrays, and micro lattice batteries: Process development and application demonstration,” May 2019.
8. Yeasir Arafat, “Interfacial effects in highly flexible electronics and thin solder joints for 3D electronics,” June 2019.
9. Taibur Rahman, “Additive manufacturing and characterization of next generation sensors,” June 2017.

(b) Master’s Students

Current

1. Aditya Khandelwal, “Insertion of CMU Array ,” summer 2023 – present.
2. Arushi Jain, “Bed-of-nails effect: Insertion of microneedles in brain tissue”, summer 2023 – present.
3. RJ Holmes, “Binder Jetting of Li-ion batteries”, summer 2024 – present. URM student.

Completed

4. Prithviraj Deshmukh, “Mass transport in 3D printed parts under nonhomogeneous sintering,” fall 2020 – fall 2022. Currently at Astral Materials, San Jose, CA.
5. Mrunal P. Vaze, “Additively manufactured wireless sensors,” fall 2019 – summer 2020. Currently at Apple Inc, Santa Clara, CA.
6. Chih-Yang Cheng, “Nanoparticle based wireless sensors,” fall 2017 – fall 2019. Currently FA Engineer at SiTime, Hsinchu, Taiwan.
7. Russell Moser, “Reliability of 3D printed films,” completed spring 2018 (at WSU). Currently at PACCAR Industries, Seattle WA.

8. Roozbeh Danaei, “Ultrafast pulsed light sintering of thermoelectric nanoparticles,” fall 2015 – spring 2017 (at WSU). Currently at Qualcomm, San Diego, CA.
9. Chunshan Hu, “Modeling and fabrication of micro and nanoscale 3D networks by additive printing,” fall 2015 – fall 2017 (at WSU). Joined Panat group at CMU, now a postdoc in the group.
10. Jian Geng, “Self-assembled axisymmetric microscale periodic wrinkles on PDMS for sensing high strain”, fall 2014 – Summer 2016 (at WSU). Currently working in China.

(c) BS Students

Current

1. Elanor Barnea, “Mechanical properties of resected human brain”, summer 2023-present.
2. Anja Meaney, “Li-ion Batteries via binder jetting”, summer 2024 - present

Completed

1. RJ Holmes, “3D printed Li-ion batteries ”, summer 2022 – spring 2024. URM student.
2. Lovalekar, “A new semi-empirical model to describe the stress-strain behavior of cellular materials,” Jan 2021 – present (also selected for SURG 2021). See CIT story.
3. Caitlyn Santiago, “3D printing of ceramic microlattices”, May 2022 – May 2023 (also selected for SURG 2022). Co-authored a paper under review.
4. Natasha Porwal, “Impedance characterization of brain-computer interfaces”, May 2022- Aug 2022 (summer intern – home department is BME, Johns Hopkins University).
5. Swati Anshu, “2.5D printing of wearable stretchable electronics”, May 2022 – present. (co-advised with Prof. Gary Fedder)
6. Zhehua Xiang, “3D printed flexible strain sensors”, May 2022 – Aug 2022. (co-advised with Prof. Gary Fedder)
7. Andrew Fu, “Manufacturing and testing of carbon fiber sandwich panels,” Apr 2020 – Dec 2020. Currently at EControls Inc.
8. Renee Wallace, “Manufacturing and testing of carbon fiber sandwich panels,” Apr 2020 – Dec 2020.
9. Rit Bezbaruah, “Design and fabrication of mechanical testing apparatus for additively manufactured microscale 3D samples,” fall 2017 – summer 2019. Currently at Boeing Corp., Seattle WA.
10. Ed Holthaus, “3D printed sensors” UG researcher, fall 2017 – spring 2018. Currently at Epic Inc.
11. Ankita Kalkar, “2.5D printing of wearable stretchable electronics,” Feb 2020 – Dec 2020 (with Prof. Gary Fedder). Currently a graduate student at UPenn.
12. Dylan Lew, “Tensile testing of silver 3D printed pillars,” fall 2019. Currently at GE Renewables.
13. Misganaw Dissemie, “Additively manufactured pressure sensors,” UG researcher, summer 2016 (at WSU). Recruited as part of Louise Stoke Alliance for Minority Participation (LSAMP) program. Currently doing PhD Ohio State University.

14. Russell Moser, "Nanoparticle 3D printing: process development," fall 2015 – spring 2016 (at WSU). Currently at PACCAR Industries, Seattle WA.

(d) Postdocs

Current

1. Dr. Vinay Doddapaneni, "Diamond heat sinks for electronic packages," fall 2024 – present.
2. Chunshan Hu, "3D-printed Li-ion batteries", fall 2024 - present

Completed

3. Dr. Bin Yuan, "Rapid 3-D nano-printing to create multi-thousand-channel microelectrode arrays," Nov 2019 – Dec 2023
4. Dr. Md. Taibur Rahman, "3D Printed temperature sensors," 2017 – 2018. Currently a Senior Engineer at Intel Corporation.
5. Dr. M. Sadeq Saleh, 2019 – 2020. Went to Cornell for his postdoc.
6. Dr. Md. Azahar Ali, 2020 – 2021. Currently a tenure-track assistant professor at Virginia Tech, Blacksburg VA.

RESEARCH CONTRIBUTIONS:

- **Next-Generation Electronic, Bioelectronic, and Energy Devices via 3D-AJP:** Since joining academia from Intel, my group has realized a new class of 3D microelectronic structures using 3D-AJP, a nature-inspired Aerosol Jet 3D nanoprinting technique. This method enables the creation of 3D freeform microarchitectures that are not possible to manufacture via conventional 2D lithography, overcoming a major limitation in microfabrication and enabling unique device properties and opening new applications. The 3D-AJP was used to demonstrate:

    - *3D passives* (capacitors and antennas) (paper, patent-1, patent-2) and 3D *freeform interconnects* on electronic chips (paper): This patented technology allows antenna structures and passives to be formed in 3D directly over a Si chip, allowing low-loss passives to be realized. In addition, we have demonstrated rapidly fabricated freeform interconnects in 3D space that can be useful for 3D heterogeneous integration.
    - *'CMU Array'* the first fully customizable brain-computer interface (BCI) that can capture electrical signals from throughout the 3D volume of a brain (paper, patent app): This Aerosol Jet 3D printed BCI has the highest electrode density in 3D reported to date and was successfully tested on mouse and macaque brains and rat spinal cords. Experiments on recently resected human brain are currently ongoing. *CMU array* is the most advanced tool available to neuroscientists to probe the 3D structure of the brain.
    - World's *fastest pathogen biosensor* that enables rapid disease detection, in 10-15 seconds, at ultralow, attomolar (similar to RT-PCR test), concentrations (paper-1, paper-2, patent app-1): My group created a 3D microarchitected electrodes via 3D-AJP and attached biomolecules to the same. This patent-pending device architecture leads to hitherto unachieved acceleration of the electrochemical reaction, leading to the breaking of a barrier to biomolecule detection. The scientific underpinnings of the device architecture were published here. We were able to detect disease in seconds. Successful human trials of the biosensor were conducted at the University of Pittsburgh Medical Center.
    - Ultra-high capacity thick electrodes for 3D Li-ion batteries for microelectronic applications (paper, patent). My group has developed a patented technology to realize high-capacity lithium-ion batteries. We have used 3D printing to create micro-lattice battery electrodes that increase the areal capacity several fold. A startup was recently launched based on this idea and won DOE's nationwide microbattery challenge.
    - 3D printed vias and interconnects for flexible multi-layer circuits (paper, patent)

- **High-Performance Microelectronic Packaging (Intel):** At Intel, I worked in the microelectronics packaging R&D division for a decade (2004-14).
    - Developed the microfabrication process for Embedded Array Capacitors (EACs) for the world's first billion-transistor chip (paper). This research was productized and allowed a reduction of package impedance at high I/O frequencies. This chip, the most advanced at the time, was then used in the market for high-performance computing in applications such as weather prediction and stock-market calculations.
    - Led a team of engineers that developed the manufacturing process for IC chips (NOR flash memory chips) where halogenated (Br-based) flame retardants were removed from the electronic package. This technology represented 'fully green' (i.e., lead-free and halogen-free) IC chip technology. This technology was adopted by hardware companies worldwide (I received an award at Intel for this work - see the list of awards).
    - I also led the implementation of Lean Six Sigma in Intel's manufacturing R&D division (paper).

EDUCATIONAL CONTRIBUTIONS:

a) Introduced unique and innovative real-world engineering projects (some directly from industry) in the design courses I have taught. Set up a mechanism for industry to share their engineering problems that students then address through course projects. In one case, the students worked with a PA-based Fortune 500 company to design and prototype a train coupler and then licensed the IP rights for this design to Wabtec. Undergraduate students in my design classes have filed more than 20 invention disclosures based on their unique designs. See CMU story on some of the projects in my class. Also see the CIT story on my Design-I class.

b) Helped to fundamentally change the UG curriculum by combining elements of materials and design practice into a series of classes: 2D design (sophomore fall class), 3D designs (sophomore spring class), and junior design. These courses then lead to a senior capstone design class. While the full effect of this significant change is yet to come, the initial feedback is that students were able to tie their coursework to the industrial design problems they tackled during their internships.

c) Integrated microelectronics design and manufacturing into the courses I have taught since joining academia. Micro and nanomanufacturing form the core of the semiconductor industry and give a competitive advantage to the United States over its rivals. This area, however, is typically not taught to mechanical engineers. The new teaching material includes classroom instruction that introduces various microfabrication processes as well as a lab section of a course on manufacturing that demonstrates the photolithography process.

d) I developed and taught two courses at Intel through Intel University. The courses were designed for professionals (engineers and scientists) working on R&D problems in microprocessor manufacturing. These courses received a significant response and were taught online to Intel teams working in US, Malaysia, South Korea, and Japan. I am strongly interested in designing manufacturing courses that are rigorous in content, and yet, address the needs of professionals working in industry.

SERVICE CONTRIBUTIONS

a) **Associate Director of Research, Manufacturing Futures Institute (MFI), Sep 2021 – present:** CMU's MFI leads groundbreaking research in the digital transformation of manufacturing via funding of internal projects and building digital manufacturing infrastructure. As MFI's associate director of research, I work closely with the director in defining the focus areas for research. To realize the institute's vision, I shape the annual request for proposals (RFPs) for the institute. Through three RFPs since joining the institute, a total of 30 seed projects have been funded (~1.2M/year). These projects

are meant to (i) encourage collaboration between faculty members working in manufacturing and physics-based or data-based modeling, and (ii) build the facility's infrastructure. The areas include micro/nanomanufacturing, biomanufacturing, manufacturing automation, and manufacturing policy. The projects are incubated in Mill-19, a 60,000 square-foot space available for MFI in the Hazelwood Green area of Pittsburgh. Collaborations enabled by the seed projects have been immensely successful with several projects leading to very large institutional grants. I worked with the director of MFI to lead a large Manufacturing USA proposal for digital twins for manufacturing where MIT, Stanford, UC Berkeley, and UT Austin, were the key partners. MFI and Mill-19 have gained significant visibility in recent years. For example, President Biden visited MFI at Mill-19 in January 2022 to make a call for investment in American innovation.

b) **Chair of PhD qualifiers, 2019-2021:** I led efforts to change the format of CMU MechE's qualifying exam to make them more equitable, in collaboration with the GEC. This change was initiated in response to the differences in pass/fail rates for women and underrepresented minorities in the ME PhD qualifying examination. First, I made sure that incoming student in the department had access to resources to prepare for the qualifying examination. This included group preparation resources from the graduate student groups, reservation of the relevant textbooks in the library, help from the English department to write the report for the qualifiers, etc. Second, I worked with the GEC members and proposed a format change for the qualifying examination. The format change was also discussed with colleagues at peer universities to understand their efforts in making their exams more equitable. The new qualifier exam format was approved quickly and implemented. This effort was done in parallel to making these exams remote during the pandemic.

c) Training for students and cadets: As part of my AFOSR/Clarkson Aerospace grant, I have been involved in training students and ROTC cadets from underrepresented groups. Specifically, I have formed a collaboration with Texas A&M International University, an HBCU, and train about six students on nanoparticle synthesis and printing for a week in my lab each summer. This effort has been transformational for the students involved. See related video.

d) I have served in various university roles including joining CMU's faculty senate, chairing a faculty search committee, becoming a faculty mentor for the Louis Stokes Alliance for Minority Participation (LSAMP), and participating in undergraduate and graduate education committees.

SEMINARS

Seminars (only including invited seminars and invited talks at conferences).

1. R. Panat, "Printed 3D Microelectronics: Process Development, Materials Science, and Devices Applications", invited talk at **University of Illinois at Urbana Champaign**, Urbana, IL, 2025
2. R. Panat, "CMU Array: 3D Printed Brain-Computer Interfaces", **Penn State University**, State College, PA, 2025
3. Panat "Precision Perfected: How AI/ML Drives Next-Generation Manufacturing", Invited talk at the *AI in Manufacturing and SCADA Conference (AIMST)*, 2025, Pittsburgh PA
4. R. Panat, "Digital Twins for printed electronics for 3D packaging, high-performance sensors, and high-capacity batteries", IEEE Bay Area Chapter, Invited Seminar, 2025 (virtual).
5. Two invited talks at the **TMS annual conference**, Las Vegas, 2025
6. R. Panat, "Printed 3D Microelectronics: Process Development, Materials Science, and Devices Applications", invited seminar, Department of Mechanical and Aerospace Engineering, **University of Southern California**, Los Angeles CA, Oct 2024.
7. R. Panat, "Printed 3D Microelectronics: Process Development, Materials Science, and Devices Applications, **Indian Institute of Technology, Delhi**, India, July 2024.

8. R. Panat, “Careers for Mechanical Engineers in Industry and Academia”, invited internal talk organized by **CMU ASME chapter**.
9. R. Panat, “High-density 3D neural probes via additive manufacturing”, invited talk at ASET Spring Conference, **University of Pittsburgh Medical Center** (neurophysiology division), Pittsburgh, PA, 2024.
10. R. Panat, “3D microarchitectures of metals, ceramics, and polymers, via droplet-based nanoprinting for next generation biomedical devices, Li-ion batteries, and robotic skins”, invited talk at 153rd **TMS conference**, Orlando, FL, 2024.
11. R. Panat, B. Yuan, C. Hu, A. Ali, “Well-defined 3D Printing of Titanium Carbide ($Ti_3C_2T_x$) MXene Nanosheets into Complex and Hierarchical Microarchitectures with High Aspect Ratio”, invited talk at 153rd **TMS conference**, Orlando, FL, 2024
12. R. Panat, “3D Electronics and Packaging”, invited seminar in the MAE Department, **Iowa State University, Ames, IA**, Nov. 2023.
13. R. Panat, “Printed Electronics: From Next Generation Devices to Manufacturing Digital Twins,” invited seminar in the EE Department, **Pennsylvania State University, State College, PA**, Sept, 2023.
14. R. Panat, “Nanoparticle 3D Printing for Next Generation Biomedical and Electronic Devices,” invited seminar in the MAE Department, **University of Notre Dame, Notre Dame, IN**, Sept 2023.
15. R. Panat, “Aerosol Jet 3D printing of electronic devices,” invited seminar in the ME Department at **Nanyang Technological University**, **Singapore**, July 2023.
16. R. Panat, “Aerosol Jet 3D printing of electronic devices 3D Printing for Next Generation Biomedical Devices and Electronics,” invited seminar in the **ME Department at Indian Institute of Technology, Bombay**, June 2023.
17. R. Panat, “Nanoparticle 3D Printing for Next Generation Biomedical Devices, Li-ion Batteries, and Robotic Skins,” invited seminar in the **National Center for Nanoscience and Nanotechnology, University of Mumbai**, **India**, June 2023.
18. R. Panat, “Next generation electronic devices via nanoparticle 3D printing” seminar at **ME Department at CMU**, Jan 2022.
19. R. Panat, “Next generation bioelectronic and biosensing devices via nanoparticle 3D printing,” invited seminar at **Materials Research Society** fall meeting, Boston MA, Dec 2021.
20. R. Panat, “Three-dimensional device architectures of 2D materials via aerosol jet 3D printing,” invited seminar at **Clarkson Aerospace,** Houston TX, Jul 2021.
21. R. Panat, “A novel access control blockchain paradigm to realize a cybersecure sensor infrastructure in fossil power generation systems,” invited seminar at the **Department of Energy**, **National Energy Technology Laboratory (NETL),** Pittsburgh PA, Apr 2021.
22. R. Panat, “Nanoparticle 3D printing for next generation Brain-Computer Interfaces, biosensing devices, and Li-ion batteries,” invited seminar at the **Maharashtra Academy of Sciences, India**, Dec 2020.
23. R. Panat, “Next generation bioelectronic and biosensing devices via nanoparticle 3D printing,” invited seminar at the **University of Minnesota**, Minneapolis MN, Oct 2020.
24. R. Panat, “Next generation bioelectronic and biosensing devices via 3D printing,” invited seminar at the **West Virginia University**, Morgantown, WV, Sep 2020.
25. R. Panat, Md. Taibur Rahman, M. Schrandt, M. Renn, C. Ramana, “Aerosol jet 3D printed sensors,” invited seminar at **annual TMS conference**, San Diego CA, Feb 2020.
26. M. S. Saleh, J. Li, J. Park, R. Panat, “3D printed Li-ion batteries and other functional devices,” invited seminar at **annual TMS conference**, San Diego CA, Feb 2020.
27. R. Panat, “Low-cost 3D printed sensors for high temperature applications,” invited seminar at the **Department of Energy, NETL**, Morgantown WV, Jan 2020.
28. R. Panat, “Microdroplet-based 3D nanoparticle printing: enabling the next generation Brain-Computer Interfaces, sensors, and Li-ion batteries,” invited seminar in the ME Department at **Massachusetts Institute of Technology**, Boston MA**,** Oct 2019.

29. R. Panat, “Micro and nanoscale additive manufacturing of biomedical devices,” invited seminar in the BME Department at **University of Pittsburgh**, Pittsburgh PA, Sep 2019.
30. R. Panat, “3D nanoparticle printing,” **invited distinguished seminar** at the Mechanical Engineering Department, **West Virginia University**, Morgantown WV, Sep 2019.
31. R. Panat, “3D nanoparticle printing,” invited seminar in the Mechanical Engineering Department at **University of Massachusetts**, Amherst MA, Sep 2019.
32. R. Panat, “3D printing at microscale: process and devices,” invited seminar in the Physics Department, **Pune University, India**, Jun 2019.
33. R. Panat, “Microarchitected macrostructures: Bridging the length scale gap via multi material nanoparticle printing,” invited seminar at the 2019 Multifunctional 3D Printing Symposium at **Rochester Institute of Technology**, Rochester NY, May 2019.
34. R. Panat, “Micro-architected macrostructures: Bridging the length scale gap via nanoparticle 3D printing,” invited seminar in the **CEE department at CMU**, Apr 2019.
35. R. Panat, “Low-cost efficient sensor by nanoparticle 3D Printing,” invited seminar at the **Department of Energy**, **NETL annual meeting**, Pittsburgh PA, Apr 2019.
36. R. Panat, Md. Taibur Rahman, M. Schrandt, M. Renn, M. S. Saleh, C.-Y. Cheng, C. Ramana, “3D printed high performance sensors,” invited seminar at **annual TMS conference**, San Antonio TX, Mar 2019.
37. R. Panat, Md. Taibur Rahman, C. Ramana, “3D printed metal films,” invited seminar at **annual TMS conference**, San Antonio TX, Mar 2019.
38. R. Panat, “3D nanoparticle printing for sensors and energy storage devices,” invited seminar at **National Energy Technology Laboratory, DOE**, Pittsburgh PA, Jan 2019.
39. R. Panat, “3D printed high temperature sensors,” invited seminar at the **Department of Energy, NETL annual meeting**, Pittsburgh PA, Apr 2018.
40. R. Panat, “3D micro-devices using nanoparticle printing,” invited **ECE departmental seminar at CMU**, Apr 2018.
41. R. Panat, “Micro and nanoscale additive printing of electronic devices,” invited seminar at **Intel Corporation**, Chandler AZ, Mar 2018.
42. R. Panat, “The application of 3D printing to advanced packaging technology,” invited seminar at the 14th TMS Workshop on Advanced Microelectronic Packaging, Emerging Interconnection Technology, and Pb-free Solder, **TMS Conference,** Phoenix AZ, Mar 2018.
43. R. Panat, “Micro and nanoscale additive printing,” invited seminar at the Mechanical Engineering Department, **Rutgers University**, New Brunsvick NJ, Feb 2018.
44. R. Panat, “Micro and mesoscale additive manufacturing,” invited seminar at **DSN-I, ECE Department at CMU**, Jan 2018.
45. R. Panat, “Micro and mesoscale additive manufacturing,” invited seminar at the **NextManufacturing Center at CMU**, Oct 2017.
46. R. Panat “Microscale 3D printing,” invited seminar at the **NEET conference in University of Texas**, El Paso TX, May 2017.
47. Md. Taibur Rahman and R. Panat, “3D printed high temperature sensors,” invited seminar at the **Department of Energy**, **NETL**, Pittsburgh PA, Apr 2017.
48. Md. Taibur Rahman, S. Saleh, C. V. Ramana, A. Rahimi, S. Gupta, R. Panat, “Printed nanoparticle films for electronic applications,” invited seminar at the **annual TMS conference**, San Diego CA, Feb 2017.
49. R. Panat, “3D printed microelectronics,” invited seminar at the Mechanical, Industrial, and Manufacturing Engineering Department, **Oregon State University**, Corvallis OR, Nov 2016.
50. R. Panat, “3D printing at microscales,” invited seminar at the **Air Force Research Laboratory**, Dayton OH, Jun 2016.
51. R. Panat, “Printed and flexible microelectronics manufacturing for smart devices and systems,” invited seminar at the **NextManufacturing center at CMU**, Apr 2016.
52. R. Panat, “Some problems in flexible and printed electronics and flexible Li-ion batteries,” invited seminar at the **Sharp Labs**, Camas WA, Jun 2015.

53. R. Panat, "On the surface evolution in stressed films: From metal films at high temperature to electrode films in Li-ion batteries," invited seminar at the **42nd ICMCTF** (International Conference of Metallurgical Coatings and Thin Films) in San Diego CA, Apr 2015.
54. R. Panat, "On the integration of microelectronic devices on rigid and flexible platforms," invited seminar at the ME Department, **University of Washington**, Seattle WA, Apr 2015.
55. R. Panat, "Energy storage devices for ultra-high-performance microprocessors and flexible electronic devices," invited seminar at the NSF PERM seminar series, **University of Texas at El Paso**, El Paso TX, Jun 2014.
56. R. Panat, "Mechanics of microelectronic packaging," invited seminar at the Mechanical and Aerospace Seminar Series, **Arizona State University**, Tempe AZ, Aug 2010.
57. R. Panat, "Bond coat surface rumpling in thermal barrier coatings," invited seminar in the Physics department, **Pune University, India**, Jun 2005.
58. R. Panat, "Bond coat surface rumpling in thermal barrier coatings," invited seminar in the CEE department, **Cornell University**, Ithaca NY, Jun 2004.

Editorial Roles on Publications, Major Activities in Professional Meetings

1. **Editorial Board**: Associate Editor for the IEEE Transactions on Components, Packaging, and Manufacturing Technology
2. **Co-organizer of a workshop on Smart Goods Manufacturing**, sponsored by the *CMMI division of NSF*. Twenty companies (Google, Intel, STMicro, HP, Amazon, Simplexity, Optomec, etc) working in areas such as wearables, sensors, and additive manufacturing for smart goods attended the workshop. A report on the workshop (PDF) identifies various industry-relevant research areas that NSF can focus on for future funding on this topic. (May 2015)
3. **Conferences:**

a. Program organizer and session chair at TMS annual conference 2022 (for track, "Recent Advances in Printed Electronics and Additive Manufacturing: 2D/3D Functional Materials, Fabrication Processes, and Emerging Applications — Functional Materials and 2D/3D Devices IV").
b. Track chair, IMAPS conference, 2022 (Advanced Packaging track)
c. Program organizer and session chair at TMS annual conference 2021 (for track, "Recent Advances in Functional Materials and 2D/3D Processing for Sensors, Energy Storage, and Electronic Applications — Functional Materials and Printed Electronic Devices")
d. Session chair at TMS annual conference 2019 (interconnects and electronic materials)
e. Symposium chair at the 2015 ASME Applied Mechanics and Materials Conference, Seattle, WA (session: Mechanics of Materials in Energy Technologies), July 2015.

4. **Reviewer**: *Additive Manufacturing, Science Advances*, *Advanced Energy Materials*, *Advanced Functional Materials*, *ACS Applied Materials and Interfaces*, *ACS Applied Polymer Materials*, *Materials Science and Engineering A*, *ASME Manufacturing Journal*, *Nature Scientific Reports*, *Metallurgical and Materials Transactions*, *Additive Manufacturing*, IEEE Transactions on Advanced Packaging, *IEEE Transactions on Device and Materials Reliability, NSERC (Natural Sciences and Engineering Research Council of Canada),* and *Elsevier Tribology*.

MISC & MEDIA MENIONS:

- Consulted with several companies on engineering design problems and on investing in sectors within my domain of expertise
    - Indovance LLC, Friedman consulting
    - Consulted with angel investors in cleantech area and biomedical devices area

ii. Media mentions:

Prof. Panat on 'Finding Genius' podcast: Microscale Manufacturing

General article about Prof. Panat: A driving force in the 3-D printing world
Panat quoted in *AAAS Science* news: 3D printing doubles the strength of stainless steel
2021: Research on 3D printed biosensors
CMU News: Breaking barriers in medicine
Physics.org: Detecting dopamine in femtomolar concentrations

2022: CIT video on Design-I Course**.** Engineering Design I: Methods and Skills
CMU News: Drop by Drop: MXene in Complex 3D Device Architectures

2021: Research on 3D printed biosensors
CMU News: Breaking barriers in medicine
Physics.org: Detecting dopamine in femtomolar concentrations

2020: Research on 10-second COVID-19 test
CMU News: Imagine a 10-second COVID-19 antibody test—we're on our way
CMU Video: Imagine a 10-second COVID-19 antibody test—we're on our way
CBS News (includes a video): UPMC and Carnegie Mellon University Collaborate To Develop Rapid Coronavirus Test
WPXI News (includes a video): Pittsburgh-area researchers develop new COVID-19 antibody test that delivers results in seconds
Interview by a TV reporter in Marathi language: 10-second COVID test
TV News (Saam TV in Marathi language): 10-second COVID test
TribLive: CMU, Pitt developing covid antibody test that gives results within seconds
Metal-AM: Carnegie Mellon University researchers develop sensor to detect COVID-19 antibodies using Optomec's Aerosol Jet process
Medicalexpo: New Covid Antibody Test Gets Results in 10 Seconds Using 3D Printing
There are 20-30 news articles on this research and are too many to list here.

2019: Research on cybersecure sensors for energy grid
CMU News: DOE Tasks CMU with Securing Energy Grid with Blockchains
Pittsburgh Business Report: Carnegie Mellon University researchers receive grant to protect electric grid using blockchain

2018: Research on 3D-printed batteries
Forbes: See How This New 3D Printing Method Could Make Your Smartphone Last Longer
Green Car: CMU-led team develops 3D printing method for exceptionally high capacity batteries
Printed electronics: 3D printing the next generation of batteries
3D Printing Industry: 3D Printing creates major advance for longer lasting batteries
CMU news: 3D Printing the next generation of batteries
German Media: New "Aerosol Jet" method relies on 3D printing for electrodes of lithium-ion batteries and promises longer battery life

2017: Research on 3D microarchitectures via aerosol-jet printing
WSU News: Novel 3-D manufacturing builds complex, bio-like materials
3-D Printing Industry: "Groundbreaking advance" in nanoparticle 3D printing mimics natural construction in the desert
Science Daily: https://www.sciencedaily.com/releases/2017/03/170303143221.htm
Yahoo News: Scientists create ultra-light, super strong new material based on wood and bone

Physics.org: Novel 3-D manufacturing leads to highly complex, bio-like materials

2015: Research on stretchable indium interconnects
Robot Magazine: Indium-Plastic Film Could Lead to Stretchier Skin for Robots
Physics.org: Researchers create super-stretchable metallic conductors for flexible electronics
Space Daily: Super-stretchable metallic conductors for flexible electronics
Gizmodo: A New Stretchable Conductor Can Extend to Twice Its Length
Semiconductor Engineering Mag: Stretchy Metal
Manufaturing.net: New Metal Fabric Can Stretch To Double Its Original Size