Rahul P Panat
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Research Interests:

- 3D Printed Electronics for
  - Biomedical devices (brain-computer interfaces, pathogen biosensors)
  - Robotic Skin
  - Li-ion Batteries
- 3D Printed Low-density Lattice Structures

Education

BSME	Mechanical Engineering	Pune University, India	1997
MS	Mechanical Engineering	University of Massachusetts at Amherst, MA	1999
PhD	Theoretical and Applied Mechanics	University of Illinois at Urbana-Champaign, Urbana, IL	2004

Work Experience

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

2021 – present: Associate Director of Research, Manufacturing Futures Institute, Carnegie Mellon University, Pittsburgh PA, USA

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

2012 – 2014: Adjunct Research Faculty, Arizona State University, Tempe AZ, USA

2004 – 2014: Senior Engineer & Engineering Manager, Assembly Technology and Test Development (R&D division for Microelectronics Manufacturing), Intel Corporation, Chandler AZ, USA

Teaching Courses Taught at CMU

Course	Semester	Units	Students Enrolled	FCE Responses	FCE Instructor Score (1-5)	FCE Course Score (1-5)
24-370 Design-I: Skills and Methods – Section I	Fall 2022	12	42	28	4.3	4.1
24-370 Design-I: Skills and Methods – Section II	Fall 2022	12	42	29	4.17	4.1
24-370 Design-I: Skills and Methods	Spring 2022	12	19	10	4.7	4.4
24-371, Design of Machine Elements	Spring 2022	9	5	4	4.5	5
24-371, Design of Machine Elements	Spring 2021	9	6	3	4.33	4.33
24-370 Design-I: Skills and Methods	Spring 2021	12	40	30	3.67	3.43
24-686, Advanced Mechanical Design	Fall 2019	12	29	23	3.61	3.61
24-371, Design of Machine Elements	Spring 2019	9	4	4	4.0	4.0
24-686, Advanced Mechanical Design	Fall 2018	12	26	16	3.88	3.81
24-686, Advanced Mechanical Design	Fall 2017	12	13	9	3.89	3.89

Courses Taught at WSU

Course (Number, Section, Name)	Semester	Credit Hours	Students Enrolled	FCE Responses	FCE Instructor Score (1-5)	FCE Course Score (1-5)
ME 310, Manufacturing Processes	Fall 2014	2	68	63	3.87	3.81
ME 310, Manufacturing Processes	Spring 2015	2	84	72	3.7	3.6
ME 414, Machine Design	Fall 2015	3	45	43	3.5	3.4
ME 474, Design for Manufacture and Modern Manufacturing Strategies	Spring 2016	3	47	18	3.9	3.9

ME 316, Mechanical Component Analysis Design	Fall 2016	3	82	52	3.9	3.9
ME 220, Materials Laboratory	Fall 2016	1	152	110	3.8	3.7
MSE 537, Fracture Mechanics	Spring 2017	3	10	-	-	-
ME 220, Materials Laboratory	Spring 2017	1	140	86	4.0	3.9

Teaching Contribution

The fundamental focus of my teaching is the use of my long experience in industry (at Intel) for the benefit of the students. I have introduced innovative hands-on projects in all the design courses I have taught at CMU to expose the students to real-world engineering problems. In one case, the students worked with Wabtec Inc., a PA-based Fortune 500 company (also the owner of GE locomotives), to invent a freight train coupler design for trains transporting goods in Australia. The student licensed the IP rights of this design to Wabtec Inc! To view some of these projects, view our CMU story on the College of Engineering's YouTube channel. Also see the CIT story on my Design-I class.

Research Contribution

- My key contribution to manufacturing science is the development of a nature-inspired aerosol jet-based AM method that can create a new class of complex three-dimensional micro/meso structures such as microlattices of metals and ceramics, without support structures. Prior to this work, jetting-based AM methods were largely confined to creating 2D planar structures via the printing of nanoparticles. Our work extended the jetting-based AM techniques to the third dimension, creating novel device structures that enable several exciting application possibilities.
- My group used this AM method to develop electrochemical sensor that rapidly detects pathogens. Here, biomolecules were attached to a 3D-printed electrode that created a hierarchical sensing platform. Using an electrochemical reaction accelerated by the 3D-structures, COVID-19 antibodies were detected in a mere 10 seconds with >99% accuracy. This is the fastest detection of this pathogen biomarker yet reported in the literature or by any company. The device was connected to a smartphone for a convenient readout, making it usable in remote or medically underserved areas. The device architecture and chemistries my group developed are generic and can be used for rapid and sensitive detection of other pathogen biomarkers as well. We published influential papers on this technology in *Nature Communications* and *Advanced Materials* (journal cover).
- We have developed a new manufacturing technique to fabricate the most advanced brain-computer interfaces (BCIs), which are fully customizable and have the highest electrode

density reported to date. *This device is a first-of-its-kind in neuroscience—it can stimulate and record electrical signals from a 3-dimensional volume of the brain*. The BCIs were successfully tested on mouse and macaque brains in collaboration with the Yttri group at CMU. A paper on this topic was accepted in the prestigious journal Science Advances.

- My group has collaboratively developed (with Fedder group in ECE) 3D-printed flexible, electronic decals (i.e., tattoos) to address a critical societal need for monitoring vitals among the aging population in the US.
- My group has also developed high-capacity 3D-printed lithium-ion batteries and physical sensors. Improving the capacity of Li-ion batteries is critical for many industries, including consumer electronics, defense, transportation, and the electric grid. One method to improve battery capacity is via geometric manipulation of the electrodes, enabling facile transport of the diffusing species. We have used 3D printing to create micro-lattice battery electrodes that increase the capacity per unit weight by 50%.

Publications

Archival Papers Critically Reviewed Before Publication (underlined authors are my students/postdocs; *corresponding author). Link to Google Scholar page.

1. Mert Arslanoglu, Bin Yuan, Rahul Panat*, O Burak Ozdoganlar*, "3D Assembly of Mxene Networks using a Ceramic Backbone with Controlled Porosity," **Advanced Materials**, 2304757 (2023).

2. Yayati Jadhav, Joseph Berthel, Chunshan Hu, Rahul Panat, Jack Beuth, Amir Barati Farimani*, "StressD: 2D Stress Estimation Using Denoising Diffusion Model," **Computer Methods in Applied Mechanics and Engineering**, 416, 116343 (2023).

3. 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).

4. J. Brenneman, M. Lovalekar, and 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).

5. 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. P. Panat*, "CMU Array: A 3D Nano-Printed, Highly Customizable High-Density Microelectrode Array Platform," **Science Advances**, 8 (40), eabj4853 (2022). CMU News

6. 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," in press, **Journal of Medical Virology** (2022).
   Impact factor = 20.6, provided as many engineers may be unfamiliar with this journal

7. 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).

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

9. 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.

10. 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.

11. M. A. Ali, C. Hu, F. Zhang, S. Jahan, B. Yuan, M. S. Saleh, S. J. Gao*, & 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).

12. M. A. Ali, C. Hu, S. Jahan, B. Yuan, M. S. Saleh, E. Ju, S.-J. Gao, & 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.

13. P. A. Borade, M. A. Ali, S. Jahan, T. Sant, K. Bogle, R. Panat*, & 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).

14. 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).

15. 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.**

16. 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).

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

18. 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).

19. 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).

20. 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).

21. 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).

22. 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).

23. 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).

24. 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).

25. 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).

26. 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.

27. 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).

28. 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.

29. 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).

30. 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).

31. 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 WSU news and video.

32. 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).

33. 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).

34. 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).

35. 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).

36. 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).

37. 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).

38. 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).

39. 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).

40. 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

41. 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.

42. 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).

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

44. 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).

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

46. 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).

47. 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****.'*

48. 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).

49. 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).

50. 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).

51. 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).

52. 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).

53. 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).

54. 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).

55. 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).

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

57. 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).

Papers in Symposium or Conference Proceedings Fully Reviewed Prior to Publication

1. 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).

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

3. 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).

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

5. 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).

6. 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).

7. 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).

8. 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).

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

Patents

Issued Patents:

1. 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**.
2. R. Panat and D. Heo, "Three-dimensional Passive Components," US Patent #9969001, **issued May 2018**.
3. R. Panat and L. Lei, "Low-Cost Fiber Optic Sensor for Large Strain," US Patent #9846276, **issued December 2017**.
4. I. Dutta and R. Panat, "Highly Stretchable Interconnect Devices and Systems," US Patent #9770759, **issued September 2017**.
5. R. Panat and B. Jaiswal, "Nanowires Coated on Traces in Electronic Devices," US Patent #9627320, **issued April 2017**.
6. 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:

7. G. K. Fedder, R. Panat, J. Brenneman, and D. Z. Tansel, "Stretchable 3D-printed circuit boards," **Patent Application #17/699,446**, filed March 2022.
8. 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," **Patent Application #PCT/US2021/040302**, filed August 2021.
9. R. Panat, E. Yttri, and M. S. Saleh, "3D Printed Microelectrode Array," **Patent Application #PCT/US2019/016050**, filed February 2019.

10. R. Panat, J. Park, M. S. Saleh, and J. Lie, “Three-dimensional lattice batteries via additive manufacturing,” **Patent Application #16/593,622**, filed October 2019.
11. 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,” **Patent Application #PCT/US18 /28013**, filed April 2018.
12. 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,” **Patent Application # PCT/US2022/022916,** filed March 2022.
13. R. Panat and A. Ali, “Laser-based Fast Micromanufacturing of Test Device for Rapid Detection of Pathogens,” **Patent Application # PCT/US22/22762**, filed March 2022.
14. 4. R. Panat, B. Yuan, and C. Hu, "3D-Printed Micro-Supercapacitors and Methods for Fabricating the Same," **Patent Application #PCT/US22/79851**, filed November 2022
15. 5. R. Panat, and B. Yuan, “A simple method for scalable dispersion of Ti3C2Tx MXene in nonpolar organic solvents,” **US Patent Application**, filed October 2022.

Grants and Contracts Awarded to Date

5.A Principal Investigator

Funding obtained since joining CMU in fall 2017 (until July 2023):

	External	Internal
As PI	$4.504 million	$ 0.575 million
As co-PI	$0.180 million	-
Total	**$ 5.26 million**	

External Grants ($4.504 million as PI)

1. **Clarkson Aerospace/AFOSR Grant**, “Three-dimensional Device Architectures of 2D Materials via Aerosol Jet 3D Printing,” **PI: Rahul Panat (ME),** $456,583, Nov 2021 – Oct 2023.

2. **Army Research Laboratory**, “Deep Learning Enabled Additive Manufacturing of Ultra-stiff & Ultra-light Plate-lattice Materials,” **PI: Rahul Panat (ME)** and co-PIs: Amir Farimani and Jack Beuth (ME), $275,000, Jul 2020 – Jun 2022.

3. **Pennsylvania Manufacturing Innovation Program**, "Fabrication of Alumina Devices via Freeze-Casting for use in the Manufacture of Advanced Steels," **PI: Rahul Panat (ME)**, co-PI: Burak Ozdoganlar (ME), $70,000, May 2022 – Jun 2023.

4. **Pennsylvania Infrastructure Transportation Authority (PITA),** Industry Partner: UPMC, "A Rapid COVID-19 Test," **PI: Rahul Panat (ME),** $74,000, Jan 2021 – May 2022.

5. **US Department of Energy**, "A Novel Access Control Blockchain Paradigm for Cybersecure Sensor Infrastructure in Fossil Power Generation Systems," **PI: Rahul Panat (ME)** and co-PI: Vipul Goyal (CS), $400,000, Sep 2019 – Aug 2022. See CMU News.

6. **National Institutes of Health** R01 Grant, "Customizable, Ultra-High-Density Optic Fiber-paired Multielectrode Array by 3D Nanoparticle Printing," **PI: Rahul Panat (ME)** and co-investigator: Eric Yttri (MCS), $1,946,748, Sep 2019 – Aug 2022 (NCE planned through Aug 2023). See CMU News.

7. **David Scaife Foundation**, "A 10-second Rapid COVID-19 Test via 3D Printed Biosensors," **PI: Rahul Panat (ME)**, $70,000, Jun 2020 – May 2021.
8. **PITA**, Industry Partner: Highmark Health, "Remote Health Monitoring via 3D Printed Wearable Electronic Decals," **PI: Rahul Panat (ME)** and co-PI: Gary Fedder (ECE), $51,500, Jan 2020 – May 2021.

9. **Pennsylvania Manufacturing Innovation Program**, "3D Printed Conformal Sensors for In-situ Monitoring of Cracks in Critical Freight Car Components," **PI: Rahul Panat (ME)**, $64,060, Jul 2019 – Jun 2020.

10. **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 (ME),** $414,204.00, Jun 2018 – May 2021.

11. **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 (ME)**, $133,949, Sep 2017 – Apr 2020.

12. **National Science Foundation**, "A Breakthrough Additive Manufacturing Method for High-Strength Lightweight 3D Micro-architectured Materials," **PI: Rahul Panat (ME)** and co-PI: Hussein Zbib (WSU), $309,943, Aug 2017 – Jul 2021.

13. **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 (ME)** and co-PI: Prof. C. V. Ramana (University of Texas), $203,788, Feb 2018 – Sep 2019.

14. **Gift grant from Drew Perkins**, CEO of Mojo Vision, Saratoga CA, **PI: Rahul Panat (ME)**, $10,000, Feb 2019 – present.

15. **Gift grant from AllPointe**, "Solutions for class projects in Advanced Mechanical Design class," **PI: Rahul Panat (ME)**, $10,000, 2018 – present.

16. **Gift grant from Wabtec** (formerly Westinghouse Air Brake Corporation) for a class project in Design of Machine Elements class, **PI: Rahul Panat (ME)**, $15,000, 2019 – present.

Internal Grants ($0.575 million as PI)

17. Manufacturing Futures Institute, "Acquisition of electronics 3D Printing Testbed at Mill-19," **PI: Rahul Panat (ME)**, multiple co-PIs. $419,060 (this includes cash contribution of $188,400 from Optomec Inc.), May 2022 – Apr 2023.
    Under Negotiations with MFI.

18. Moonshot, "Development of soft robotic e-skin," **PI: Rahul Panat (ME)** and co-PI: Gary Fedder, $80,988, 2020 – 2021.

19. Commercialization fund, CTTEC, CMU "3D Printed Batteries," **PI: Rahul Panat (ME),** $25,000, Feb 2019 – present.

20. CIT equipment grant, "Multi-material printing upgrade to the Aerosol Jet machine," **PI: Rahul Panat (ME),** $50,000, Apr 2018 – Dec 2018.

Co-Principal Investigator

External Grants ($180,000 as co-PI since 2017)

1. 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.

2. 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.

3. 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).

Professional Activities

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

1. R. Panat, "Printed Electronics: From Next Generation Devices to Manufacturing Digital Twins s," invited seminar in the EE Department, **Pennsylvania State University, State College, PA**.
2. 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**.
3. R. Panat, "Aerosol Jet 3D printing of electronic devices," invited seminar in the ME Department at **Nanyang Technological University**, **Singapore**, July 2023.
4. 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.
5. 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.
6. R. Panat, "Next generation electronic devices via nanoparticle 3D printing" seminar at **ME Department at CMU**, Jan 2022.
7. R. Panat, "Next generation bioelectronic and biosensing devices via nanoparticle 3D printing," invited seminar at **Materials Research Society** fall meeting, Boston MA, Dec 2021.
8. R. Panat, "Three-dimensional device architectures of 2D materials via aerosol jet 3D printing," invited seminar at **Clarkson Aerospace,** Houston TX, Jul 2021.
9. 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.
10. 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.

11. R. Panat, “Next generation bioelectronic and biosensing devices via nanoparticle 3D printing,” invited seminar at the **University of Minnesota**, Minneapolis MN, Oct 2020.
12. R. Panat, “Next generation bioelectronic and biosensing devices via 3D printing,” invited seminar at the **West Virginia University**, Morgantown, WV, Sep 2020.
13. 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.
14. 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.
15. R. Panat, “Low-cost 3D printed sensors for high temperature applications,” invited seminar at the **Department of Energy, NETL**, Morgantown WV, Jan 2020.
16. 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.
17. R. Panat, “Micro and nanoscale additive manufacturing of biomedical devices,” invited seminar in the BME Department at **University of Pittsburgh**, Pittsburgh PA, Sep 2019.
18. R. Panat, “3D nanoparticle printing,” **invited distinguished seminar** at the Mechanical Engineering Department, **West Virginia University**, Morgantown WV, Sep 2019.
19. R. Panat, “3D nanoparticle printing,” invited seminar in the Mechanical Engineering Department at **University of Massachusetts**, Amherst MA, Sep 2019.
20. R. Panat, “3D printing at microscale: process and devices,” invited seminar in the Physics Department, **Pune University, India**, Jun 2019.
21. 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.
22. R. Panat, “Micro-architected macrostructures: Bridging the length scale gap via nanoparticle 3D printing,” invited seminar in the **CEE department at CMU**, Apr 2019.
23. R. Panat, “Low-cost efficient sensor by nanoparticle 3D Printing,” invited seminar at the **Department of Energy**, **NETL annual meeting**, Pittsburgh PA, Apr 2019.
24. 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.
25. R. Panat, Md. Taibur Rahman, C. Ramana, “3D printed metal films,” invited seminar at **annual TMS conference**, San Antonio TX, Mar 2019.
26. R. Panat, “3D nanoparticle printing for sensors and energy storage devices,” invited seminar at **National Energy Technology Laboratory, DOE**, Pittsburgh PA, Jan 2019.
27. R. Panat, “3D printed high temperature sensors,” invited seminar at the **Department of Energy, NETL annual meeting**, Pittsburgh PA, Apr 2018.
28. R. Panat, “3D micro-devices using nanoparticle printing,” invited **ECE departmental seminar at CMU**, Apr 2018.

29. R. Panat, “Micro and nanoscale additive printing of electronic devices,” invited seminar at **Intel Corporation**, Chandler AZ, Mar 2018.
30. 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.
31. R. Panat, “Micro and nanoscale additive printing,” invited seminar at the Mechanical Engineering Department, **Rutgers University**, New Brunsvick NJ, Feb 2018.
32. R. Panat, “Micro and mesoscale additive manufacturing,” invited seminar at **DSN-I, ECE Department at CMU**, Jan 2018.
33. R. Panat, “Micro and mesoscale additive manufacturing,” invited seminar at the **NextManufacturing Center at CMU**, Oct 2017.
34. R. Panat “Microscale 3D printing,” invited seminar at the **NEET conference in University of Texas**, El Paso TX, May 2017.
35. Md. Taibur Rahman and R. Panat, “3D printed high temperature sensors,” invited seminar at the **Department of Energy**, **NETL**, Pittsburgh PA, Apr 2017.
36. 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.
37. R. Panat, “3D printed microelectronics,” invited seminar at the Mechanical, Industrial, and Manufacturing Engineering Department, **Oregon State University**, Corvallis OR, Nov 2016.
38. R. Panat, “3D printing at microscales,” invited seminar at the **Air Force Research Laboratory**, Dayton OH, Jun 2016.
39. R. Panat, “Printed and flexible microelectronics manufacturing for smart devices and systems,” invited seminar at the **NextManufacturing center at CMU**, Apr 2016.
40. R. Panat, “Some problems in flexible and printed electronics and flexible Li-ion batteries,” invited seminar at the **Sharp Labs**, Camas WA, Jun 2015.
41. 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.
42. 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.
43. 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.
44. R. Panat, “Mechanics of microelectronic packaging,” invited seminar at the Mechanical and Aerospace Seminar Series, **Arizona State University**, Tempe AZ, Aug 2010.

45. R. Panat, “Bond coat surface rumpling in thermal barrier coatings,” invited seminar in the Physics department, **Pune University, India**, Jun 2005.
46. 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. **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.
3. **Reviewer**: *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*, and *Elsevier Tribology*.

Awards, Prizes, Honors

1. Russell V Trader (Endowed) Professorship, CMU, Jan 2021
2. Senior Member, IEEE, 2022
3. Struminger Teaching Fellowship to develop an industry-oriented design course(s) at CMU, Dec 2019
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 world's 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

Service at CMU

1. Associate Director of Research, Manufacturing Futures Institute (MFI), Sep 2021 – present.
2. Faculty Search Committee, MSE Department, Sep 2021 – present.
3. Chair of ME PhD Qualifiers, Dec 2019 – present,
4. Carnegie Mellon Faculty Senate Member, Feb 2019 – Aug 2020
   Graduate Education Committee (GEC) Member, ME Department, Dec 2018 – present.
5. Undergraduate Education Committee (UEC), ME Department, Jul 2017 – Aug 2018:
6. Faculty Search Committee, ME Department, 2018 – present.

7. Other

i. Consulted with several companies on mechanical design regularly since joining CMU.

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

iii. Conference talks and posters (excluding invited talks):

a. R. Panat, "3D Printed Customizable Neural Probes," **Microelectrode Array Conference, Tubingen, Germany**, July 2022.

b. S. Ritchie, S. Kovacevic, P. Deshmukh, S. Mesarovic, R. Panat, "Deciphering the Fundamental Cause of Shape Distortion in Sintering-based Additive and Non-additive Manufacturing Processes," talk poster at the **TMS Annual Meeting & Exhibition**, Los Angeles CA, Feb 2022.

c. J. Brenneman, D. Z. Tansel, G. K. Fedder, R. Panat, "J-39: Crack-free Three-dimensional Electrical Interconnects 3D Printed on Soft PDMS Substrates," poster at the **TMS Annual Meeting & Exhibition**, Los Angeles CA, Feb 2022.

d. D. Z. Tansel, J. Brenneman, R. Panat, G. K. Fedder, "Aerosol-Jet-Printed Stretchable Electronic Decal Technology," poster at the **35th international conference on Micro Electro Mechanical Systems IEEE MEMS 2022**, Tokyo, Japan, and virtually, Jan 2022.

e. J. Brenneman, D. Z. Tansel, G. K. Fedder, R. Panat, "Fabrication of Stretchable Electronic Interconnect by Aerosol Printing," poster at the **47th annual Northeast Bioengineering Conference NEBEC**, Pittsburgh PA and virtually, Mar 2021.

f. J. Brenneman, D. Z. Tansel, G. K. Fedder, R. Panat, "Skin-wearable PDMS-based Electronic Decals by Aerosol Jet 3D Printing semi-empirical model has been proposed in this paper that can predict the stress-strain response of the cellular structures," presentation at the **annual MS&T conference**, Columbus OH, Oct 2021.

g. D. Z. Tansel, J. Brenneman, R. Panat, G. K. Fedder, "Fabrication of Stretchable Electronic Decals by Aerosol Printing," poster at the **19th annual FLEX 2020 Conference and Exhibition**, San Jose CA, Feb 2020.

h. M. Sadeq Saleh, R. Panat, "Beyond the Powder-bed: Fabricating Microscale Three-dimensional Metallic Structures Without Support Using Nanoparticle 3D Printing," talk at the **TMS Annual Meeting & Exhibition**, San Diego CA, Feb 2020.

i. J. Brenneman, D. Tansel, M. Forssell, S. Saleh, G. K. Fedder, R. Panat, "3D Printed Electrical Interconnects for Stretchable Health Monitoring Devices," poster at **Next Manufacturing Winter Meeting**, Pittsburgh PA, Jan 2020.

j. Md. T. Rahman, C. V. Ramana, A. Rahimi, S. Gupta, D. Heo, C. Ramana, R. Panat, "High Performance Sensors and Antennas by 2D and 3D Printing of Nanoparticles," talk at the **TMS Annual Meeting & Exhibition**, Phoenix AZ, Mar 2018.

k. Md. T. Rahman, A. W., C. V. Ramana, and R. Panat, "High Temperature Mechanical and Electrical Properties of Additively Manufactured Metal Nanoparticle Films," talk at the **TMS Annual Meeting & Exhibition**, Nashville TN, Mar 2016.

l. Md. T. Rahman, C. V. Ramana, R. Panat, "Electrical Characterization of Additively Manufactured Metal Films for High Temperature Sensor Applications," seminar at the **43rd ICMCTF**, San Diego CA, Apr 2016.

m. R. Panat, "Printed and Flexible Microelectronics Manufacturing for Smart Devices and Systems" seminar at the **WSU School of Mechanical and Materials Engineering**, Pullman WA, Nov 2015.

n. R. Panat, "Bond coat surface rumpling in thermal barrier coatings," Materials Interest Group seminar given at the **ME Department, UIUC**, Urbana IL, Oct 2003.

o. R. Panat, "Bond coat surface rumpling in thermal barrier coatings," **MRS Annual Winter Meeting**, Boston MA, Dec 2002, **MRS gold medal** awarded for this presentation.