Vivek Garg
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Indian Institute of Technology Bombay, India & Monash University, Australia
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Education

Doctor of Philosophy (Ph.D.), IITB Monash Research Academy **(2015-2020)**
Mechanical Engineering, Indian Institute of Technology Bombay, India
Mechanical and Aerospace Engineering, Monash University, Australia

- **Thesis:** *Focused Ion Beam (FIB) Fabrication of Novel 2D/3D Nanoscale Structures: Process Modelling and Applications* ***(submitted)***
- **Advisor:** Prof. Jing Fu (Monash University), Prof. Rakesh G. Mote (Indian Institute of Technology Bombay)

Master of Technology (M.Tech), Indian Institute of Technology Bombay, India **(2011-2013)**

- Post-Graduation in Manufacturing Engineering (CGPA 8.8/10)
- **Thesis:** *Numerical Modelling of Excimer Laser Curved Surface Ablation*
- **Advisor:** Prof. Suhas Joshi (Indian Institute of Technology Bombay)

Bachelor of Technology (B.Tech), College of Engineering Roorkee, India **(2007-2011)**

- Graduation in Mechanical Engineering (74.4%)

Research Interests

- Functional Nanostructures with specific applications in Optics, Photovoltaics, Biology, Sensing etc.
- Focused Ion Beam (FIB): Process Development & Applications, Ion Irradiation of Nanostructures
- Microscopy and Microanalysis of Materials, Atom Probe Tomography for Novel Applications

Expertise

Experimental: Focused Ion Beam (FIB) - Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) Sample, Lamella Preparation, Lift-Out, Slice & View, Electron Beam Lithography (EBL), Nano-Imprinting Lithography, Energy Dispersive Spectroscopy (EDS), Raman Spectroscopy, UV Visible Spectroscopy, Atomic Force Microscopy (AFM), Optical Microscopy, Thin Film Deposition, Spectroscopic Ellipsometry, Laser Micromachining etc.
Theoretical & Modelling: Finite-Difference Time-Domain (FDTD) Calculations- Lumerical, Molecular Dynamics (MD) Calculations- LAMMPS, Finite Element Analysis (FEA)- ANSYS, COMSOL Multiphysics, Solidworks, MATLAB

Publications

Journal Articles (Published)

- V. Garg, R. G. Mote, T. Chou, A. Liu, A. D. Marco, B. Kamaliya, S. Qiu, and J. Fu, "Weaving Nanostructures with Site-Specific Ion Induced Bidirectional Bending," *Nanoscale Advances*, 1, 3067-3077, 2019
- V. Garg, R. G. Mote, and J. Fu, "Rapid Prototyping of Highly Ordered Subwavelength Silicon Nanostructures with Enhanced Light Trapping," *Optical Materials*, 94, 75-85, 2019
- V. Garg, R. G. Mote, and J. Fu, "Focused Ion Beam Direct Fabrication of Subwavelength Nanostructures on Silicon for Multicolor Generation," *Advanced Materials Technologies*, 3, 8, 1800100, 2018
- V. Garg, D. Marla, and S. S. Joshi "A study on Curved Surface Laser Ablation Using Beam Profile Approach," *International Journal of Additive and Subtractive Materials Manufacturing*, 1, 1, 42-56, 2017

Journal Articles (Under Review/In Preparation)

- V. Garg, B. Kamaliya, R. Singh, A. Panwar, J. Fu, R. G. Mote, "Controlled Manipulation and Multiscale Modelling of Suspended Si Nanostructures under Site-specific Ion Irradiation," *under review*
- V. Garg, B. Kamaliya, R. G. Mote, and J. Fu, "Enhanced Light Matter Interactions in Size Tunable Graphene-Gold Nanomesh," *under review*
- V. Garg et al., "Nonnegative Quadratic Programming Optimization of Focused Ion Beam Fabricated 3D Nanostructures for Structural Colors," *in preparation*

Book Chapter

- V. Garg, R. G. Mote, and J. Fu, "Focused Ion Beam Fabrication: Process Development and Optimization Strategy for Optical Applications," in *Precision Product-Process Design and Optimization*, Springer, Singapore, pp. 189–209, 2018

Conference Proceedings/Presentations

- V. Garg, S. Zhang, R. G. Mote, Y. Chen, L. Cao, and J. Fu, ""Stand-Out": A Novel Approach for Preparing Sub-100 nm Samples Through *In-Situ* Ion Induced Bending," *Microscopy and Microanalysis,* vol. 25, no. S2, pp. 898–899, 2019, Portland, Oregon, USA
- V. Garg, R. G. Mote, T. Chou, A. Liu, A. D. Marco, B. Kamaliya, S. Qiu, and J. Fu, "Ion Induced Bidirectional Bending for Controlled Manipulation at Nanoscale," *Microscopy and Microanalysis*, vol. 25, no. S2, pp. 852–853, 2019, Portland, Oregon, USA
- V. Garg, R. G. Mote, and J. Fu, "Nonnegative Quadratic Programming Optimization of Focused Ion Beam Fabricated 3D Nanostructures for Structural Colors,", *MRS Spring Meeting*, 2019, Phoenix, Arizona, USA
- V. Garg, R. G. Mote, and J. Fu, "Facile Fabrication of Freestanding Size Tunable Graphene Nanomesh for Plasmonics,", *MRS Spring Meeting*, 2019, Phoenix, Arizona, USA
- V. Garg, R. G. Mote, and J. Fu, "High Aspect Ratio Silicon Nanowires and 3D Nanostructures via Selective Focused Ion Beam Implantation and Wet Etching: Fabrication and Characterization," *19th International Microscopy Congress (IMC19),* 2018, Sydney, Australia
- V. Garg, R. G. Mote, and J. Fu, "Coloring with Focused Ion Beam Fabricated Nanostructures," *Microscopy and Microanalysis*, vol. 24, no. S1, pp. 856–857, 2018, Baltimore, Maryland, USA
- V. Garg, Y. Kim, and J. Fu, "*In-situ* Fabrication of Metallic Nano-structures for Cellular Imaging," *Imaging CoE Summit,* 2017, Melbourne, Australia
- V. Garg, R. G. Mote, and J. Fu, "FIB fabrication of highly ordered vertical Gaussian pillar nanostructures on silicon," *2017 IEEE 17th International Conference on Nanotechnology*, pp. 707–712, 2017, Pittsburgh, USA
- V. Garg, R. G. Mote, and J. Fu, "Focused Ion Beam Fabrication: Process Development and Optimization Strategy for Optical Applications," *6th International & 27th All India Manufacturing Technology, Design and Research Conference (AIMTDR),* 2016, Pune, India
- V. Garg, D. Marla, I. Saxena and S. S. Joshi "Numerical Modelling of Excimer Laser Curved Surface Ablation", *8th International Conference of Micro- Manufacturing (ICOMM)*, 2013, Victoria, Canada

Achievements/Awards

- All India Rank 7, Production & Industrial Engineering, Graduate Aptitude Test in Engineering (GATE-2011)
- Tata Consultancy Services (TCS), PhD Research Scholarship, 2015-2020
- NTC Fellowship, 17th IEEE International Conference on Nanotechnology (IEEE NANO 2017)
- Best Micrograph Award, Microscopy and Microanalysis Meeting 2018, Baltimore, Maryland, USA

- Student Scholar Award, Microscopy and Microanalysis Meeting 2018, Baltimore, Maryland, USA
- Best Conference Paper Award, Oskar 2018, IITB Monash Research Academy, Mumbai, India
- Microscopic Gardening: Tiny Blossoms of Silicon, ANFF-VIC Image of the Year 2018, Melbourne, Australia

Key Projects

PhD Project: **(Jul'15-)**

Focused Ion Beam (FIB) Fabrication of Novel 2D/3D Nanoscale Structures: Process Modelling and Applications

Investigation of ion-material interactions, process modelling, optimization of FIB nanofabrication for functional 3D structures for diverse applications like anti-reflection, color filters, sensors etc., key developments include:

Nonnegative Quadratic Programming Optimization of Focused Ion Beam Fabrication of 3D Nanostructures

- A general framework for optimization of 3D nanostructures through the formulation of a nonnegative quadratic programming problem, solved by an iterative approach based on multiplicative updates algorithm for an optimal solution of ion beam dwell time

Rapid Prototyping of Highly Ordered Subwavelength Silicon Nanostructures with Enhanced Light Trapping

- FIB rapid prototyping of Gaussian shaped Si nanostructures, supporting reflection suppression and enabling trapping of light, confirmed through calculations and experiments, leading to the realization of nanoscale light management structures for localized light trapping and antireflection applications

Focused Ion Beam Direct Fabrication of Subwavelength Nanostructures for Multicolor Generation

- A novel approach for color filtering via direct fabrication of nanostructures, enabling nanoscale structural color printing with high (~10,000 DPI) resolution, tunable selective absorption of light through developed approach has potential for nanophotonic applications such as- optical security, sensing, light harvesting, etc.

Freestanding Size Tunable Graphene Nanomesh for Plasmonics

- A facile approach for freestanding size tunable single layer graphene nanomesh, enabling graphene plasmonics through a composite graphene-gold nanomesh for optical modulation in the visible spectrum

Freeform 3D Micro/Nanostructures with Ion Beam

- Functional 3D nanostructures through anisotropic wet etching of ion implanted silicon. Si nanowires with a high aspect ratio (≈625) down to ~31 nm, various suspended and 3D nanostructures such as nanomesh, nanotrumpets etc. including freestanding Si nanostructures over pyramid array, exhibiting unique optical properties

Weaving Nanostructures with Ion Beam Induced Bidirectional Bending

- A novel route towards *in-situ* controlled weaving and strain engineering of nanostructures through site-specific ion-irradiation induced bidirectional bending for realization of advanced 3D nanostructures, such as an ultra-long vertical nanowire, folded nanomesh, live-cell imaging, and bacterial mesh trap in the current project

Multiscale Modelling (Molecular Dynamics + Finite Element Analysis) of Ion Irradiation of Nanostructures

- MD simulations combined with finite element analysis for estimating continuum bending directions pave the way towards understanding of bi-directional bending providing insight for 3D nanofabrication with an outlook on realization of novel nanostructures with anticipated functionalities for future nanoscale devices, applications

Master of Technology Thesis: **(May'12–Jun'13)**

Numerical Modelling of Excimer Laser Curved Surface Ablation

- Development of a Finite Element Model to predict temperatures and material removal associated with the laser ablation of polymers towards realization of curved surfaces. Micro-lens fabrication incorporating beam profile approach: gray-scale mask- a novel and simpler alternative to the lithography approaches, facilitating fabrication of high precision microstructures for potential applications

Experience

Engineer, Operations Department, Lafarge Readymix Qatar, Doha, Qatar **(Aug'13-Apr'14)**

- Two different roles in vehicle workshop and plant maintenance: Scheduling, planning, preparation for plant set-up, AutoCAD drawings, lifting procedures, health & safety standards, risk assessments etc.

Senior Assistant Professor, Quantum Global Campus, Roorkee, India **(Jan'15-Jun'15)**

- Teaching, Undergraduate Courses, Mechanical Engineering

Teaching Assistant

- Measurement & Metrology lab, Undergraduate Level, IIT Bombay, India
- Ultra-Precision Machining, Postgraduate Level, Mechanical Engineering, IIT Bombay, India
- Engineering Design, Undergraduate Level, Mechanical & Aerospace Engineering, Monash University, Australia

Positions of Responsibility, Extra Curricular Activities, Honours & Awards

Workshop, Conference Participation/Organization

- Two-Day Workshop on Atom Probe Tomography, 2019, IIT Madras, Chennai, India
- Advances in Single Point Diamond Turning Technology, 2016, CMTI, Bangalore, India
- Advances in Tooling for Diamond Turning, 2015, Mumbai, India
- Volunteer, 9th International Conference on Precision, Meso, Micro, and Nano Engineering, 2015, Mumbai, India

Department PG Sports Nominee, Co-ordinator, Radiance'12, IIT Bombay **(Jul'12–Jun'13)**

- Co-ordination and representation of mechanical department students for various sports activities
- Infrastructure management for annual technical festival, Mechanical Engineering, IIT Bombay

Honours & Awards

- Best Office Bearer, Department Council, Department Sports Special Mention, 2012-13, IIT Bombay
- Gold medallist: Kho- Kho, Bronze Medallist: Badminton PG Sports, 2012-13, IIT Bombay
- 1st prize, Zion- 2010, the annual cultural festival at College of Engineering Roorkee, Roorkee
- Trophy, Certificate of Appreciation for performance, Matriculation Board Examination
- Coordinator, various cultural events: Zion-2010 (College of Engineering Roorkee), Thomso-2010 (IIT Roorkee)

References

- Dr. Jing Fu, Department of Mechanical and Aerospace Engineering, Monash University, Australia (Web: https://www.monash.edu/engineering/jingfu), Email: jing.fu@monash.edu
- Dr. Rakesh G. Mote, Department of Mechanical Engineering, Indian Institute of Technology Bombay, India (Web: https://sites.google.com/site/rakeshmote/), Email: rakesh.mote@iitb.ac.in
- Dr. Suhas Joshi, Department of Mechanical Engineering, Indian Institute of Technology Bombay, India (Web https://www.me.iitb.ac.in/~ssjoshi/), Email: ssjoshi@iitb.ac.in
- Dr. Deepak Marla, Department of Mechanical Engineering, Indian Institute of Technology Bombay, India (Web https://www.me.iitb.ac.in/~dmarla/), Email: dmarla@iitb.ac.in
- Dr. Amelia Liu, Monash Centre for Electron Microscopy (MCEM), Monash University, Melbourne, Australia (Web: https://research.monash.edu/en/persons/amelia-liu), Email: amelia.liu@monash.edu
- Dr. Alex De Marco, Biochemistry & Molecular Biology, Monash University, Melbourne, Australia (Web: https://research.monash.edu/en/persons/alex-de-marco), Email: Alex.DeMarco@monash.edu
- Dr. John A. Notte, Chief Scientist for Business Development, Carl Zeiss SMT, Inc., Peabody, MA, USA, Email: john.notte@zeiss.com