Saurabh S. Sawant

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Research Interests

- Scientific software development and high-performance computing
- Adaptive mesh refinement algorithms for particle based methods and structured grids
- Quantum and classical charge transport in the next-generation nanoelectronics
- Kinetic transport in gas dynamics
- Data-driven methods and stability theory for modal analysis in fluid dynamics

Education

Ph.D. *May 2022*
Department of Aerospace Engineering, University of Illinois Urbana-Champaign
Thesis: **The development of kinetic models and simulation methods to study molecular fluctuations, modal response, and shock-laminar separation bubble instabilities**
Advisor: Professor Deborah A. Levin
Cumulative GPA: 3.76 on a scale of 4

M.S. *Dec. 2015*
Department of Aerospace Engineering, University of Illinois Urbana-Champaign
Thesis: **Development of AMR octree Direct Simulation Monte Carlo (DSMC) approach for shock dominated flows.**
Advisor: Professor Deborah A. Levin
GPA: 3.87 on a scale of 4

B.E. *Aug. 2011*
Department of Mechanical Engineering, Vidyavardhini's College of Engineering & Tech., Mumbai University, India.
Thesis: **Efficiency analysis of an aerospike nozzle.**
Guide: Professor Dipak Choudhary
Class: First Class

Achievements

AE Outstanding Graduate Student Fellowship *2020*
University of Illinois Urbana-Champaign.
MAVIS Future Faculty Fellows (MF3) Program *Fall 2019–2020*
University of Illinois Urbana-Champaign.
Best Undergraduate Project *2011*
Vidyavardhini's College of Engineering, Mumbai University, India.

Research Experience

Postdoctoral Scholar
Microelectronics Group
Center for Computational Sciences and Engineering (CCSE)
Applied Mathematics and Computational Research Division (AMCR)
Lawrence Berkeley National Laboratory *Jan. 2022- Present*
Group Lead: Dr. Andrew Nonaka

I contribute to a DOE-funded project entitled, "Codesign and Integration of Nanosensors on CMOS", which aims to build a CMOS chip that will serve as a nanoscale photon sensor using carbon nanotubes functionalized with quantum dots for sensing photons. On the computational side, my contribution is two-fold: at nanoscales, modeling of a large array carbon nanotube field effect transistors functionalized with quantum dots, and at microscales, modeling of transmission lines carrying pulses from carbon nanotubes to inputs of integrated circuits. My specific accomplishments for these two works are summarize below:

- **(Ongoing) Multi-physics modeling of Carbon Nanotube Field Effect Transistors (CNTFETs) used as nanosensors on a photodetector chip.**
  - Developed the 3D **ex**ascale electro**static** (eXstatic) solver using the AMReX library for solving Poisson's equation with embedded boundaries
    🔗 https://github.com/AMReX-Microelectronics/eXstatic
  - Performed weak-scaling of eXstatic up to 2048 NVIDIA A100 GPUs on NERSC's Perlmutter supercomputer
  - Presently, developing a self-consistently coupled quantum transport module in eXstatic using the Nonequilibrium Green's function method in collaboration with Dr. François Léonard from the photonics group in Sandia National Laboratories at Livermore, CA.
  - The solver will be applied to simulate an array of CNTFETs functionalized with quantum dots and compute the current-voltage characteristics

- **Characterization of microscale transmission lines using the ARTEMIS Maxwell solver.**
  - Developed a workflow to compute scattering ($\boldsymbol{S}$-) parameter that signify the amount of power transmitted, reflected, and lost when electromagnetic waves traverse through microscale transmission lines
    🔗 https://github.com/AMReX-Microelectronics/artemis
  - Demonstrated the workflow to compute $\boldsymbol{S}$-parameter of a part of newly proposed transmission line to carry signals from carbon nanotubes to IC inputs
  - Performed weak-scaling of ARTEMIS up to 2048 NVIDIA A100 GPUs on NERSC's Perlmutter supercomputer
  - Implemented diagnostics in the ARTEMIS Maxwell solver to compute voltage and current from the electric and magnetic fields as a function of time

Graduate Research Assistant
Department of Aerospace Engineering
University of Illinois Urbana-Champaign *Aug. 2014- Dec. 2021*
Advisor: Professor Deborah Levin

- **Development of scalable Direct Simulation Monte Carlo (DSMC) solver known as SUGAR (Scalable Unstructured Gas-dynamic Adaptive mesh-Refinement) to simulate hypersonic shock-boundary layer interactions.**
  - Implementation of Adaptive Mesh Refinement (AMR) in octree-based collision grids in DSMC and performance improvement strategies tailored for simulations of hypersonic flows.
  - Implementation of thermal non-equilibrium models for rotational and vibrational relaxation.
  - Use of Morton-based space-filling curve and run-time memory optimization technique for adaptively refined grids.
  - Ideal strong scaling speed-up for up to 4096 processors.
  - Weak scaling efficiency of 87% for 8192 processors.
  - Application to 3-D simulation of shock-wave boundary layer interactions over a double wedge using 20,000 processors.

- **Modeling of multi-scale thermal response of an AVCOAT-like thermal protection system.**
  - DSMC study of the effect of microstructure of an AVCOAT-like ablative heatshield on internal gas transport.
  - Permeability and tortuosity computation for AVCOAT and comparison with fibrous TPS.
  - Development of a random walk model for coupled convection, conduction, and radiation through the microstructure.
  - Study of AVCOAT with spatially varying thermophysical properties at high temperatures.
  - Comparison of thermal response predicted by stochastic versus finite-volume approaches.
- **A kinetic approach to studying low-frequency fluctuations in a one-dimensional shock.**
  - First observation of two orders of mangitude lower frequency and larger amplitude fluctuations of macroscopic flow parameters in the internal shock structure of argon than the freestream.
  - Bimodality of energy density function is responsible for lower frequencies in shocks.
  - Construction of Lotka-Volterra type two-energy-bin dynamical model to predict differences in frequencies observed from DSMC.
  - Established range of Strouhal number in Mach 2 to 10 argon shocks, $St = 0.002 - 0.02$.
  - Analytical derivation of non-central chi-squared (NCCS) bimodal energy distribution functions.
  - Established correlation of NCCS functions with DSMC-computed frequencies.
- **DSMC investigation of linear instability mechanism in a laminar hypersonic seperated flow.**
  - Spanwise periodic simulation of Mach 7 flow of nitrogen over a 30°-55° double wedge at $Re_1 = 5.22 \times 10^5$ m^{-1} (above 60 km alitude).
  - Modeling of surface rarefaction effects and the translational, rotational, vibrational nonequilibrium.
  - First observation of coupling of linear instability of 3-D laminar separation bubble with separation and detached shocks.
  - Linear instability leads to spanwise corrugation of separation and detached (bow) shocks and the presence of low-frequency unsteadiness of the triple point at a Strouhal number, $St \sim 0.02$.
- **Framework for stability analysis of internal shock structure.**
  - Formulation revisits and corrects the assumptions made in the Navier-Stokes-Fourier constitutive relations using kinetic theory concepts.
  - Formulation accounts for anisotropy in heat flux and stresses, and the nonlinear dependence of stress on strain in the translational nonequilibrium zone of shocks.
  - No assumption of zero bulk viscosity, as opposed to the Navier-Stokes formulation.
  - Eigenvalue problem is constructed to predict stability of DSMC-computed 1-D shock structure against small-amplitude perturbations in shock-parallel direction.

- **Implementation of dust particles in an open-source flow solver, FLASH, for the study of particle lifting mechanism in electrostatic discharge.**
  - Implementation and verification of dust particles in the open-source FLASH solver.
  - Investigation of dust-lifting mechanism due to particle-fluid interaction shows Saffman lifting force is the major lifting mechanism.
  - Qualitative agreement between simulations and experiments for particle lifting heights and velocities.
  - Charge deposition on dust particles will be modeled by a colleague in the future.

For brief description of my Ph.D. work, please visit: www.saurabhsawant.net/phd-projects

Research Associate at the Department of Mechanical Engineering,
Indian Institute of Technology, Bombay. *Dec. 2012–July 2013*

- **Create open-source tutorials and conduct workshops on OpenFOAM & Salome software.**
  Advisor: Dr. Shivasubramanian Gopalakrishnan Project: FOSSEE, National Mission on Education through Information and Communication Technology, Sponsored by MHRD, Government of India.
  Link: http://www.spoken-tutorial.org/list_videos?view=1 &foss=OpenFOAM&language=English

Teaching Experience

Teaching Assistant (TA) at the Department of Aerospace Engineering,
University of Illinois Urbana-Champaign.

- **Incompressible Flows (AE 311)** *Spring 2020*
  Instructor: Professor Laura Villafane Roca
- **Aerospace Flight Mechanics (AE 202)** *Fall 2019*
  Instructor: Professor Huy Tran
- **Incompressible Flows (AE 311)** *Spring 2019*
  Instructor: Professor Theresa Saxton-Fox
- **Rocket Propulsion (AE 434)** *Spring 2018*
  Instructor: Professor Deborah Levin
  Duties for last four TAs: To prepare homework and exam solutions, hold office hours, conduct python workshops, and lectures when instructor is traveling.

- **Aerospace Propulsion (AE 433)** *Fall 2018*
  Instructor: Professor Joshua Rovey
  Duties: To make sure that the lectures are recorded for online students.

Lecturer at the Atharva College of Engineering,
Mumbai University, India. *Jan.–July. 2012*

- **Engineering Drawing and CAD software packages**
  Duties: To teach engineering drawing to first-year students of engineering, conduct workshops for AUTOCAD, SolidWorks, and CATIA software, hold office hours, prepare homework and exams.

Professional Service

Reviewed a conference article for the *31st International Symposium on Rarefied Gas Dynamics* *Spring 2019*
Reviewed a journal article for *Acta Astronautica* *2022*

Reviewed two journal articles for the *Theor. and Comput. Fluid Dyn.* *2021-2022*

Journal Publications

Sawant, S. S., Yao, J., Jambunathan, R., & Nonaka, A. (2023) **Characterization of Transmission Lines in Microelectronic Circuits Using the ARTEMIS Solver.** ***IEEE Journal on Multiscale and Multiphysics Computational Techniques***, vol. 8, pp. 31-39.
doi:10.1109/JMMCT.2022.3228281

Sawant, S. S., Theofilis, V., & Levin, D. A. (2022) **On the synchronisation of three-dimensional shock layer and laminar separation bubble instabilities in hypersonic flow over a double wedge.** ***Journal of Fluid Mechanics***, 941, A7.
doi:10.1017/jfm.2022.276 Video presentation

Sawant, S. S., Levin, D. A., & Theofilis, V. (2022) **Analytical prediction of low-frequency fluctuations inside a one-dimensional shock.** ***Theoretical and Computational Fluid Dynamics.***, 36, 25-40.
doi:10.1007/s00162-021-00589-5

Klothakis, A., Quintanilha, H., & Sawant S. S., Protopapadakis, E., Theofilis V., & Levin D. A. (2022) **Linear stability analysis of hypersonic boundary layers computed by a kinetic approach: a semi-infinite flat plate at $4.5 \leq M_\infty \leq 9$.** ***Theoretical and Computational Fluid Dynamics.***, 36, 117-139.
doi:10.1007/s00162-021-00601-y

Sawant, S. S., Levin, D. A., & Theofilis, V. (2021) **A kinetic approach to studying low-frequency molecular fluctuations in a one-dimensional shock.** ***Physics of Fluids***, 33 (10), 104106.
doi:10.1063/5.0065971 Video presentation

Marayikkottu, V. A., Sawant, S. S., & Levin, D. A. (2021) **Study of particle lifting mechanisms in an electrostatic discharge plasma.** ***International Journal of Multiphase Flows***, 137, 103564.
doi:10.1016/j.ijmultiphaseflow.2021.103564

Sawant, S. S., Rao, P., Harpale, A., Chew, H. B., & Levin, D. A. (2019) **Multi-scale thermal response modeling of an AVCOAT-like thermal protection material.** ***International Journal of Heat and Mass Transfer***, 133, 1176-1195.
doi:10.1016/j.ijheatmasstransfer.2018.12.182

Harpale, A., Sawant, S. S., Kumar, R., Levin, D. A., & Chew, H. B. (2018) **Ablative thermal protection systems: Pyrolysis modeling by scale-bridging molecular dynamics.** ***Carbon***, 130, 315-324.
doi:10.1016/j.carbon.2017.12.099

Sawant, S. S., Tumuklu, O., Jambunathan, R., & Levin, D. A. (2018) **Application of adaptively refined unstructured grids in DSMC to shock wave simulations.** ***Computers & Fluids***, 170, 197-212.
doi:10.1016/j.compfluid.2018.04.026

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Refereed Conference Proceedings

Sawant, S. S., Tumuklu, O., Theofilis, V., & Levin, D. A. (2022). **Linear Instability of Shock-Dominated Laminar Hypersonic Separated Flows. In: Sherwin, S., Schmid, P., Wu, X. (eds) *IUTAM Laminar-Turbulent Transition.*** IUTAM Bookseries, vol 38. Springer, Cham.

doi:10.1007/978-3-030-67902-6_57

Conference Publications

Klothakis, A., Sawant S. S., Quintanilha, H., Theofilis V., & Levin, D. A. (2021). **Slip Effects on the Stability of Supersonic Laminar Flat Plate Boundary Layer.** ***AIAA Scitech 2021 Forum*** (Paper No. 1659).

Sawant, S. S., Tumuklu, O., Theofilis, V., & Levin, D. A. (2020). **Analysis of Spanwise Perturbations in Laminar Hypersonic Shock-Boundary Layer Interactions.** ***AIAA Scitech 2020 Forum*** (Paper No. 0108).

Marayikkottu, V. A., Sawant, S. S., Levin, D. A., Huang, C., Schoenitz, M., & Dreizin, E. (2020). **Comparison of numerical simulations of inert particle transport in an electrostatic discharge with experimental results.** ***AIAA Scitech 2020 Forum*** (Paper No. 1798).

Marayikkottu, V. A., Sawant, S. S., Rao, P., & Levin, D. A. (2019). **Study of inert simulated particle transportation in a moving shock/pressure wave generated by electrostatic discharges.** ***AIAA Scitech 2019 Forum*** (Paper No. 0631).

Sawant, S. S., Rao, P., Harpale, A., Chew, H. B., & Levin, D. A. (2018). **Micro-scale thermal response modeling of Avcoat-like TPS.** ***2018 AIAA Aerospace Sciences Meeting*** (Paper No. 0495).

Sawant, S. S., Harpale, A., Jambunathan, R., Beng Chew, H., & Levin, D. A. (2017). **High fidelity and multi-scale thermal response modeling of an Avcoat-like TPS.** ***55^{th} AIAA Aerospace Sciences Meeting*** (Paper No. 0438).

Sawant, S. S., Tumuklu, O., Jambunathan, R., & Levin, D. A. (2017). **Novel use of AMR Unstructured Grids in DSMC Compressible Flow Simulations.** ***47^{th} AIAA Thermophysics Conference*** (Paper No. 4028).

Sawant, S. S., Jambunathan, R., Tumuklu, O., Korkut, B., & Levin, D. A. (2016). **Study of shock-shock interactions using an unstructured AMR octree DSMC code.** ***54^{th} AIAA Aerospace Sciences Meeting*** (Paper No. 0501).

Sawant, S. S., Korkut, B., Tumuklu, O., & Levin, D. A. (2015). **Development of an amr octree dsmc approach for shock dominated flows.** ***53^{rd} AIAA Aerospace Sciences Meeting*** (Paper No. 0070).

Poster Presentations and Talks

Sawant, S. S., Yao, J., Jambunathan, R., Léonard F., & Nonaka, A. (2019). **A Highly Scalable NEGF Solver for Modeling Time-Dependent Quantum Transport in Nanomaterials.** ***The APS March Meeting 2023, Las Vegas, Nevada, USA***.

Sawant, S. S., Tumuklu, O., Theofilis, V., & Levin, D. A. (2019). **Linear instability of shock-dominated laminar hypersonic separated flows.**, ***IUTAM Symposium on Laminar-Turbulent Transition 2019, London, UK***.

Sawant, S. S., Rao, P., Harpale, A., Chew, H. B., & Levin, D. A. (2019). **Multi-scale thermal response modeling of an AVCOAT-like thermal protection material.**, ***11th Ablation Workshop, University of Minnesota, Minneapolis, MN***.

Rao, P., Sawant, S. S., Harpale, A., Chew, H. B., & Levin, D. A. (2017). **Hybrid Walker Approach to Conduction-Radiation Coupling in Micro-Scale Ablation Modeling**, ***9th Ablation Workshop, Montana State University, Bozeman, MT***.

Sawant, S. S., Jambunathan R., and & Levin, D. A. (2018). **Multi-scale Gas Dynamic and Thermal Response Modeling of Ablative Thermal Protection Systems**, ***31st Rarefied Gas Dynamics Conference, Glasgow, Scotland***.