

Robert A. Buhrman

John Edson Sweet Professor of Engineering
School of Applied and Engineering Physics
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Professional Preparation:

B.E.S., Engineering Physics, 1967, Johns Hopkins University

M.S., Applied Physics, 1969, Cornell University

Ph.D., Applied Physics, 1973, Cornell University

Professional Experience:

- 1973-78 Assistant Professor, School of Applied and Engineering Physics
- 1978-83 Associate Professor, School of Applied and Engineering Physics
- 1983-93 Professor, School of Applied and Engineering Physics
- 1993- John Edson Sweet Professor of Engineering, School of Applied and Engineering Physics, College of Engineering

Other Appointments:

- 1980-83 Associate Director, National Research and Resource Facility for Submicron Structures, Cornell University
- 1988-98 Director, School of Applied and Engineering Physics
- 2000 Acting Director, School of Applied and Engineering Physics
(3/1/00 – 8/31/00)
- 2001-07 Founding Director, Cornell Center for Nanoscale Systems in Information Technologies (CNS)
- 2007-17 Senior Vice Provost for Research, Cornell University

Areas of Research Interest:

Applied condensed matter physics with current emphasis on nanoscale magnetism and spintronics. Research interests and activities include: Electron and spin transport in thin film electronic structures, Spin torque and spin transfer effects in magnetic nanostructures, Superconducting thin film and Josephson tunnel junctions, Noise and quantum transport studies in nanoscale systems and devices, Ballistic electron emission microscopy and scanned probe spectroscopy, Surface analytical spectroscopy of thin films, Thin film materials growth and processing, optical and electronic properties of thin film systems and solar energy photothermal collectors.

Honors and Professional Recognition:

- Undergraduate: Tau Beta Pi; Pi Tau Sigma; B.E.S. with departmental and general honors
- Graduate: NSF Graduate Fellowship (1969-1972)
- Professional: Fellow, American Physical Society
College of Engineering Dorothy and Fred Chau Distinguished Teaching Award (2000)
Fellow, American Academy of Arts and Sciences (elected – 2006)

Brief Summary of Major Research Contributions

Throughout his professional career Buhrman's research focus has been in the area of applied condensed matter physics, with an emphasis on what is now known as nanoscale science and engineering. He has contributed regularly to the scientific literature in these fields with currently more than 220 publications that have received more than 22,000 citations (WoS – h-index 58). Among the more noted research contributions of Buhrman and his collaborators are a seminal study of metallic nanoparticles, pioneering work in the understanding and optimization of metal/dielectric composite selective solar absorbers, the first demonstration of the in-situ formation of superconducting rare-earth cuprate thin films, the first definitive demonstration of spin transfer torque switching in magnetic nanostructures, and the pioneering demonstration of spin transfer torque switching and excitation effects in magnetic tunnel junctions. Most recently Buhrman and his collaborators have discovered a giant spin Hall effect in Pt, Ta, and W thin films and successfully applied it in a novel 3-terminal spin torque device that has potential for high performance magnetic memory and other spintronics applications.

Areas of Current Research Interest:

Nanoscale science and nanotechnology, with particular focus on nanoscale magnetism and spintronics. Spin torque and spin transfer effects. Study and application of spin currents generated by the giant spin Hall effect. Spin-dependent electron and pure spin transport in thin film electronic structures and magnetic tunnel junctions. Ultra-fast magnetic dynamics, and spin-torque-driven microwave oscillators. Thin film materials growth, processing and nanofabrication for advanced device research and applications.

Professional Service:

Member, Panel on Scientific Interfaces and Technological Applications, Physics Survey Committee, National Research Council, 1985-86.
Member, Board of Directors, Applied Superconductivity Conference, Inc., 1986-1992.
Member, Organizing Committee, Workshop on Superconducting Electronics, 1985-1991, Chair, Program Committee, 1987.
Member, Technical Advisory Committee, New York State Institute on Superconductivity, 1988-1992.
Appointment Advisory Board, Physics Department, Chalmers Institute of Technology, Goteborg, Sweden, October 1994.
Chair, Ballistic Electron Emission Microscopy Workshop, Death Valley, CA, 1992.
Member, Science Advisory Board, Illinois Science and Technology Center for Superconductivity, 1989-1998.
Member, Panel on New Research Opportunities in Superconductivity, 1997.
Member, National Research Council Board on Assessment of NIST Programs, 1998-2000.
Member, External Review Committee, Stanford University Physics and Applied Physics Departments, 1999.
Associate Editor, *Physica C*, 2000 – 2004.
Member, External Review Committee, University of Georgia Physics Department, 2000.
Member, NSF/DARPA Panel for Assessment of International Research Activities in Spin Electronics, 2000 - 2001.

Program Committee, Magnetic Materials and Magnetism Conference, 2004.
Program Organizer, Focus Session on Spin Transport, APS Meeting, March 2005
Chair, Scientific Advisory Committee, Argonne Center for Nanoscale Materials, 2003-2009
External Advisory Committee, Center for Nanoscale Materials, University of Puerto Rico,
Rio Piedras, 2003-2005,
Member, Scientific Advisory Committee, Stanford University Center for Probing the
Nanoscale (2006, 2009)
Member, Scientific Advisory Committee, Harvard University Nanoscale Science and
Engineering Center (2006)

Reviewer: NSF and DOE proposals, Swiss National Science Foundation, Netherlands
Science Foundation; Singapore Government, Chilean Science Foundation

Physical Review Letters, Physical Review B, Physica C, Applied Physics Letters, Journal
of Applied Physics, Journal of Electrochemical Society, Journal of Materials Research,
Electron Device Letters, Nature Materials, Nature Physics, other Nature journals, Journal
of Magnetic Materials and Magnetism, Science

Professional Societies: American Physical Society (Fellow), Materials Research Society

Consulting: Foreign Applied Sciences Assessment Center, 1986 – 1989; Sanders Associates,
1987 – 1989; Member, Technical Advisory Board, Superconductor Technologies Inc., Santa
Barbara CA, 1988-1996; Foster-Miller, Inc. 1989 – 1991.

Publications: 258+ publications, 24,000+ citations, h-index: 61

Invited Presentations: 67 (2000-2017)

Selected publications

- “Spin torque switching with the giant spin Hall effect of tantalum.” L. Q. Liu, C.-F. Pai, Y. Li, H. W. Tseng, D. C. Ralph, and R. A. Buhrman. *Science* 336, 555 (2012). *93 citations*
- “Magnetic vortex oscillator driven by d.c. spin-polarized current,” V. S. Pribiag, I. N. Krivorotov, G. D. Fuchs, P. M. Braganca, O. Ozatay, J. C. Sankey, D. C. Ralph, and R. A. Buhrman, *Nat Phys* 3 (7), 498-503 (2007). *181 citations*
- “Time-domain measurements of nanomagnet dynamics driven by spin-transfer torque,” I.N. Krivorotov, N.C. Emley, J.C. Sankey, S.I. Kiselev, D.C. Ralph, and R.A. Buhrman, *Science* 307(5707): p. 228, 2005. *297 citations*
- “Spin-transfer effects in nanoscale magnetic tunnel junctions,” G.D. Fuchs, N.C. Emley, I.N. Krivorotov, P.M. Braganca, E.M. Ryan, S.I. Kiselev, J.C. Sankey, D.C. Ralph, R.A. Buhrman, and J.A. Katine, *Appl. Phys. Lett.* 85(7): p. 1205, 2004. *180 citations*
- “Microwave oscillations of a nanomagnet driven by a spin-polarized current,” S.I. Kiselev, J.C. Sankey, I.N. Krivorotov, N.C. Emley, R.J. Schoelkopf, R.A. Buhrman, and D.C. Ralph, *Nature*. 425(6956): p. 380, 2003. *894 citations*
- “Spintronics: A spin-based electronics vision for the future,” S.A. Wolf, D.D. Awschalom, R.A. Buhrman, J.M. Daughton, S. von Molnar, M.L. Roukes, A.Y. Chtchelkanova, and D.M. Treger, *Science*. 294(5546): p. 1488, 2001. *5315 citations*
- “Current-driven magnetization reversal and spin-wave excitations in Co/Cu/Co pillars,” J. A. Katine, F. J. Albert, R. A. Buhrman, E. B. Myers, and D. C. Ralph, *Phys. Rev. Lett.* 84, 3149-3152 (2000). *1066 citations*

- “Probing Ferromagnets with Andreev Reflection,” S. K. Upadhyay, A. Palanisami, R. N. Louie, and R. A. Buhrman, *Phys. Rev. Lett.* **81**, 3247 (1998). *322 citations*
- “Role of Interfacial Nitrogen in Improving Thin Silicon-Oxides Grown in N₂O,” E.C. Carr and R.A. Buhrman, *Appl. Phys. Lett.* **63**(1): p. 54, 1993. *155 citations*
- “Electromigration Study of Oxygen Disorder and Grain-Boundary Effects in YBa₂Cu₃O_{7-x} Thin Films,” B.H. Moeckly, D.K. Lathrop, and R.A. Buhrman, *Phys. Rev. B* **47**, 400-417 (1993). *190 citations*
- “Production of YBa₂Cu₃O_{7-x} Superconducting Thin-Films *in-situ* by High-Pressure Reactive Evaporation and Rapid Thermal Annealing,” D. K. Lathrop, S. E. Russek, and R. A. Buhrman, *Appl. Phys. Lett.* **51**, 1554-1556 (1987). *147 citations*
- “Composition of 1/f Noise in Metal-Insulator-Metal Tunnel-Junctions” C.T. Rogers and R.A. Buhrman, *Phys. Rev. Lett.* **53**(13): p. 1272, 1984. *202 citations*
- “Metal-Insulator Composite Selective Absorbers,” H.G. Craighead, R. Bartynski, R.A. Buhrman, L. Wojcik, and A.J. Sievers, *Sol. Energy Mater.* **1**(1-2): p. 105, 1979. *84 citations*
- “Ultrafine Metal Particles,” C. G. Granqvist and R. A. Buhrman, *J. Appl. Phys.* **47**, 2200-2219 (1976). *1141 citations*
- “Fluctuation Diamagnetism in a Zero-Dimensional Superconductor,” R. A. Buhrman and W. P. Halperin, *Phys Rev Lett* **30** (15), 692-695 (1973). *50 citations*

Research Mentoring and Synergistic Activities:

- 15 postdocs (2 F), 44 Ph.D. Graduates (7 F, 1 URM), 10UGs (last 10 yrs) (4 F, 2 M)
 - F = Female, M = Under-represented Minority
- Organized CNS Institute for Physics Teachers to support and inform high school physics teachers about current topics in science and nanotechnology. Over 560 different teachers nationwide participated in CIPT workshops or summer institute events during the period of time that CIPT was active – 2002-2011.
- Lecturer on nanoscale science and nanotechnology at teacher workshops and public forums.
- PI and co-coordinator for CNS Research Experience for Undergraduates Site Program – 2002-2007

Ph.D. Theses: [53]

John Warlaumont (1980); C. Marc. Bastuscheck (1980); Harold Craighead (1980); Alan.Kleinsasser (1981); James Brown (1983); Ursula Gibson (1983); Brian Hunt (1985); Glen Nyberg (1985); Charles Rogers (1987); Scott Nelson (1988); Kristin Ralls (1990); Raphael Robertazzi (1990); Kenneth Farmer, II (1990); Steven Russek (1990); Hans Hallen (1991); Daniel Lathrop (1991); Hye-Rim Kim (1991); Leon Pesenson (1992); Elizabeth Carr (1994); Brian Moeckly (1994); Daniel Ralph (1994); Richard Louie (1997); Martin Weilmeier (1998); Kenneth Ellis (1998); Shashi Upadhyay (1999); Jason Sydow (1999); William Rippard (2000); Monica Plisch (2001); Frank Albert (2003); Michael Berninger (2004); Andrew Perrella (2004); Ei-leen Tan (2005); Preeti Chalsani (2006); Nathan Emley (2006); Philip Mather (2006); Ozhan Ozatay (2007); Gregory Fuchs (2007); Patrick Braganca (2008); John Read (2009); Vlad Pribiag (2010) Luqiao Liu (2012); OukJae Lee (2012); Hsin-

wei Tseng (2012); Eric Ryan (2012); Yun Li(2014); Chi-Feng Pai (2014), Praveen Gowtham (2015), Junbo Park (2015), Minh-Hai Nguyen (2017)

Postdoctoral Scholars: [17]

Claes-Goran Granquist, Alessandro Callegari, James Yeh, Gosta Ehnholm, Ilona Blattner-Merkle, Ken-Ichi Tanabe, Roberto Saletti, Hye-Rim Kim, Yizi Xu, Jordan Katine, Ilya Krivorotov, Zhi-Pan Li, Takahiro Moriyama, Luis Leao, Graham Rowlands, Sriharsha Aradhya, Lijun Zhu.