



Berkeley Sensor & Actuator Center

A National Science Foundation/Industry/University Cooperative Research Center
University of California, Berkeley and University of California, Davis Main
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BSAC operates under the framework and rules of the NSF I/UCRC program, with primary objectives:

1. **Technology transfer** to Industrial Companies best able to commercialize longer term BSAC research.
2. **Early stage exploratory research** which may subsequently evolve into commercially relevant fully funded projects.
3. **Education and research experience for graduate students** and postdoctoral researchers.

Benefits to Member Companies (Regular Members and Collaboration Members)

Although BSAC membership does not (by itself) sponsor individual member-directed projects, a number of valuable and far-reaching tangible and intangible benefits are provided, including:

- **(Syndicated Research Leverage)** Member fees are pooled among 30-40 Industry members and further leveraged with external awards (federal & state) to fund more than 150 times as many early stage projects as any one member could fund internally with their membership fees alone. Membership fees also provide operating funds for center membership services, research reviews, and personnel.
- **(Influence over Research Directions)** Industrial Membership fees are, after common expenses are paid, distributed to individual core research funds of each faculty co-Director. This distribution to faculty is in part *uniform* and in part according to the wishes of each industrial member from their (confidential) annual membership fee distribution election.
- **(Sponsored Research)** Individually funded BSAC directed research projects may be contracted with BSAC faculty. Such sponsored research is generally undertaken only with Industrial Members, under separate agreements.
- **(Joint Research)** Members may partner with BSAC faculty on joint proposals for federal, state or foundation funding (where member may be a user of funds). Faculty will partner only with BSAC member companies on such proposals.
- **(Research Reviews/IAB)** An intensive 3-day semiannual research review conducted on campus, including member-only sessions and private publication of a comprehensive 600+ page research report covering all BSAC projects. Members also meet in executive session (Industrial Advisory Board) to assess the operations and research directions of the center.
- **(Secure Website)** BSAC website with both public and extensive member-only privileges, pre-publication review of BSAC research, access to BSAC invention disclosures, and portals for connection to projects and researchers. **(Gatekeeper Option):** Members may however, restrict distribution of all nonpublic BSAC information, and route all such information only through their selected "gatekeeper(s)". All BSAC information becomes public 12 months after first internal disclosure.
- **(IP Access)** Industrial Members are offered time-advantaged access to inventions which derive from BSAC research.
- **(Visiting Industrial Fellow program)** Ability to embed, under separate agreement and with additional funding, industrial researchers into the research groups of BSAC faculty for extended periods (one-to-three years).
- **(NanoLab Affiliate Program)** BSAC companies have guaranteed eligibility for and discounted membership in the UC Berkeley NanoLab Affiliate program wherein employees of the member may, on an hourly recharge basis, avail themselves of the facilities of the microfabrication facility for research fabrication and process development.
- **(Campus and Center Access)** Members can request by-arrangement meetings with BSAC faculty or members of their research groups.
- **(Access to BSAC Graduates)** Our graduates, the large majority of whom receive the degree of PhD from the departments of electrical, mechanical or bio- engineering, are among the most highly recruited technologists from the US educational system. Most go on to industry and academic leadership positions, Member companies have many opportunities to network with, assess, and form continuing relationships with our graduate students. Many of our graduates take positions with member companies.

Additionally Available to Collaboration Members

- **(Collaboration Research Projects*)** Optional *Collaboration Membership* entitles Collaboration Member to work with BSAC faculty who defines & manages a project of high interest to the member, staffed by a Graduate Student Researcher.



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Co-Directors from Electrical, Mechanical, and BioEngineering at UC Berkeley and UC Davis*

Prof. Bernhard E. Boser, Prof. David A. Horsley, Prof. Ali Javey, Prof. Luke P. Lee, Prof. Dorian Liepmann, Prof. Liwei W. Lin,

Prof. Roya Maboudian, Prof. Michel M. Maharbiz, Prof. Clark T-C Nguyen, Prof. Kristofer S.J. Pister, Prof. Ming C. Wu

Founding Directors: Prof. Richard S. Muller, Prof. Richard M. White

Executive Directors: John M. Huggins, Michael D. Cable

This Industry/University Cooperative Research Center, founded in 1986 as the National Science Foundation Center for Microsensors and Microactuators, and "Graduated" as a self-sufficient I/UCRC in 2008, is devoted to interdisciplinary engineering research on micro- and nano-scale sensors, moving mechanical elements, microfluidics, materials, and processes that take advantage of progress made in integrated-circuit, bio, and polymer technologies. BSAC is perennially the top University-based MEMS/Microtechnology research center in peer rankings (Small Times Magazine).

Goals of BSAC:

1. Create a leadership microsystems research environment. Combine the best researchers, faculty, and industrial partners. Bind them through the collective appeal of *top rank University resources, an environment of collaboration, and access to a diverse group of Industrial members* who are usually current or future market leaders in their segments.
2. Enhance the educational experience of our graduate students.
3. Reduce the time to commercialization of BSAC research by Industrial Members and entrepreneurial researchers by establishing systematic progress in *multiple phases* of new technology formation: *a) materials/process/packaging; b) devices and structures; and c) system integration*. This strategy requires a broader range of projects and a larger research organization than most research consortia would be able to maintain.
4. Maintain collaboration with Industrial Members to insure commercial relevancy of the research.

Research Scope: Topics, which will vary as the field develops, include: (1) phenomena useful for sensing various measurands (mechanical, electromagnetic, optical, fluidic, thermal, chemical and biological variables); (2) physical and electrical methods for interfacing arrays of sensors, actuators, and other MEMS and NEMS structures to electronic devices for detection, control, analysis, communications, and display purposes; (3) fabrication techniques for making economical integrated MEMS/NEMS in large quantities; and (4) materials, processes, and packaging to enable new applications and new levels of performance. Individual research projects are expected to last from two to four years.

Personnel: The research involves more than 120 graduate students and post-doctoral researchers, and more than 30 faculty from Electrical Engineering; Computer Science; Chemical Engineering; Mechanical Engineering; Materials Science; Bio-Engineering; and the University of California at Davis, and the University of California San Francisco; and more than 100 research projects. Collaboration with other on-campus research groups expands the research impact of BSAC. Several Industrial Members have researchers in residence; others visit campus frequently to use laboratory facilities.

Benefits to Industrial Partners: Participation in the Center provides Industrial Members (partners) with access to wide-ranging research from the best and brightest researchers in a University with worldwide recognition. Members see Center research at an early stage for a timely view of new developments before publication. Extensive formal research reviews are conducted on-campus twice per year, in March and September and once per year in Japan and Europe, specifically for Industrial Members. Members, through the Industrial Advisory Board, influence the directions taken in the research and policies of the consortium. Members can obtain exclusive or non-exclusive, royalty-bearing rights to inventions made in the Center prior to any non-member disclosures or licensing. Member organizations can nominate researchers to be seminar speakers and medium-term Center visitors. Industrial funding for the Center has been granted full DoD IR&D status. Industrial Members are invited to special presentations of research at the Center. Relationships formed among Industrial Members, faculty, and researchers tend to persist throughout developers' and researchers' careers, creating subtle but lasting organizational value to members and graduates. Contact with graduate students in training can lead to hiring for summer and long-term positions. Nearly 50% of BSAC PhD graduates take, at graduation or thereafter, positions with BSAC Industrial Member companies or Laboratories. No single Industrial Member is likely to establish the high risk, high reward multi-project environment available through the research consortium. BSAC research has spawned new businesses or divisions for its members and new start-ups from among its researchers.

Administrative Structure: The Center is directed administratively by Executive Director John Huggins and the faculty co-Directors, with administrative support from the campus and college and by the Engineering Research Support Organization. The Industrial Advisory Board mentioned above includes up to two voting representatives from each member organization.

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Facilities: BSAC researchers are the largest users of the new extensive Marvell Nanofabrication Lab (integrated circuits) in Sutardja Dai Hall and the major Bionanotechnology Laboratory in Stanley Hall which was planned and co-directed by BSAC co-director, Luke P. Lee. We have access to other specialized facilities, such as those for polymer and plasma-deposition research in Lewis Hall (Chemical Engineering), photonics laboratory at UC Davis, and surface characterization and advanced tools at the Molecular Foundry at Lawrence Berkeley Laboratory.

Funding: Federal and State research funds, together with **annual \$50,000 per-Member (Regular Membership) or \$135,000 (Collaboration Membership)** contributions, support the Center. The funds from BSAC Industry Membership fees comprise only about 15%-20% of BSAC research funds, the bulk of which are from competitive federal grants. But 100% of the research results are made available to Industrial Members, as they happen, before external disclosure or publication, and with favored IP access by members. This funding gain represents a large advantage in the research investment for Industrial Members.

Some Current Major BSAC Multi-Project Programs

- Open Wireless Sensor Network (WSN) systems
- Wireless networks of energy-scavenging communicating Microsensors
- RF “Resonets”: networks of coupled MEMS resonators for low power high Q multi-band radio front-ends
- Biosensors and biomanipulators
- e-Skin: Active electronic sensors fabricated on large scale conformal materials.
- Plasmonics for cellular, intracellular and surface imaging
- Fluidic microvalves, mixers and micropumps
- LIDAR system (Light Detection and Ranging)
- Airborne particulate measurement and monitoring system
- Advancing the “E” in MEMS (benchmark electronic mixed-signal IC interface electronics)
- MEMS + CMOS process (SiGe, Metal, and Piezo)
- Silicon Carbide harsh environment and rigid structure MEMS processing
- Polymer micromachining process
- Integrated Photonics & optical couplers / drop/insert devices; injection locked VCSEL

Achievements - among the pioneering milestones, firsts, or significant benchmarks of BSAC are:

- First Surface Micromachining of Polysilicon
- Gyro Inertial Sensors and Accelerometers
- Thin-Film MEMS Poly-Si, Silicon Nitride, Silicon Carbide
- Lamb Wave Acoustic Sensors
- Acoustic Wave and Fluidic Micropumps and Mixers
- Comb-Driven MEMS Actuators
- MEMS Micropositioning Components & System for Hard Disk Drive
- Surface-Micromachined Gears, Cranks, Springs, and out-of-plane Structures
- Anti-Stiction Elements, Dimpled Structures, and Surface Treatments
- MEMS Micro-Vibromotors
- X-and Y-Rastered Real-Time Projected Display System
- MEMS Based Free-Space Collimated Beam Communications/ Optics
- Piezoelectric MEMS Silicon-Diaphragm Microphone
- Microfluidic Host-Fueled Glucose Microbial Power Cell
- Room temperature, directed growth & self assembly of Multiwalled carbon nanotubes and Silicon nanowires
- Localized thermal bonding for micropackaging and fluidic / biosample encapsulation
- Precision controllable arrays of polymer lenses and mirrors for adaptive optics and imaging applications

For a complete searchable HTML list of 100+ current BSAC projects, titles, and abstracts please visit: <http://www-bsac.eecs.berkeley.edu/publicAbstracts>

BSAC welcomes inquiries from technology-based companies interested in participating in our research consortium as industrial members, and from top students seeking advanced degrees in our specialties.

For a current roster of BSAC members, go to http://bsac.berkeley.edu/affiliates/list_member_companies.php