Center for Advanced Manufacturing and Packaging of Microwave, Optical and Digital Electronics (CAMPmode)

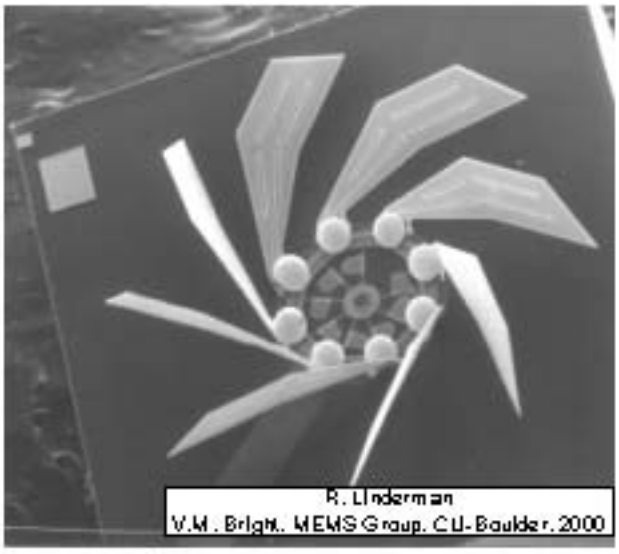
University of Colorado at Boulder

Enabling technologies and solutions for packaging of microsystems, including microelectronics

A National Science Foundation Industry/University Cooperative Research Center since 1994

Center Mission and Rationale

The establishment of the Center for Advanced Manufacturing and Packaging of Microwave, Optical and Digital Electronics (CAMPmode) evolved from the growing recognition that, for U.S.-based companies to compete successfully in the rapidly growing electronics market, pathfinding research must be undertaken at the universities to provide a knowledge base for the manufacturing and packaging of very high-speed microwave, optical, and digital electronics to enhance the manufacturability and functionality of future systems. The formal process of identifying the research needs of the electronics industry was initiated in the summer of 1991 at the University of Colorado, Boulder. Subsequently, a series of meetings and discussions were held, with participation by several major electronics companies from across the nation, the State of Colorado, and Federal Laboratory representatives. The result of these collective inputs was the formation of CAMPmode in early 1992. In 1994, the MIMICAD Center (the Center for Microwave/Millimeter-Wave Computer-Aided Design), an NSF I/UCRC, merged with CAMPmode, thereby significantly enhancing the Center's capabilities and strengths.



MEMS rotary fan

More recently, the Center has shifted its focus to packaging of microsystems. Started in 1997 as a TIE Project, in collaboration with the Berkeley Sensors and Actuators Center (BSAC), to explore MEMS (MicroElectroMechanical Systems) as tuning elements, the MEMS research has blossomed and is now perhaps the strongest research area of the Center. In line with these developments, the Center's mission statement now reads, "…to perform interdisciplinary research at the forefront of developing computer-aided designs, packaging, and manufacturing technologies for microsystems including MEMS and microelectronics." Our current focus is on RF MEMS, high-speed digital, and microwave/millimeter-wave electronic systems.

The objectives of CAMPmode are to:

- Establish a knowledge base for CAD methodologies and tools, packaging, and manufacturing technologies for the integration of microwave/millimeter-wave, high-speed digital, optical electronics, and MEMS
- Increase the number of engineers in the United States who are equipped to design and manufacture electronic systems
- Foster strong collaboration between industry, university, and government R&D organizations in the Center's focus areas of research.

Research Program

The Center's research program focuses on:

- ***Area Array Packaging:*** In this area, our focus is on concurrent electrical, thermal and mechanical modeling of flip-chip, ball grid array (BGA) and chip scale packaging technologies. Typical projects include (i) experimental and computational analysis of area array packages; (ii) solder self-alignment for packaging; (iii) thermosonic flip-chip bonding; (iv) novel metal-foam heat sinks for thermal management of electronic systems up to 100 W/cm2; and (v) characterization of laminate substrates for flip-chip and surface mount technologies.
- ***RF Modeling and Design:*** Three major aspects of design activity based on CAD methodology are modeling, analysis, and optimization. Typical projects include: (i) CAD-oriented EM-ANN modeling of microwave/millimeter-wave circuit components; (ii) electromagnetic modeling of MCMs; (iii) development of multilayer microwave circuits; (iv) RF modeling of flip-chip interconnects for microwave and millimeter-wave applications; and (v) effect of metallic packages on the performance of microstrip and CPW circuits housed in these packages.

- ***MEMS:*** As mentioned earlier, MEMS is a new but very strong thrust for the Center. Various novel MEMS components have been designed, fabricated, assembled and tested using flip-chip assembly with silicon removal technology. Typical projects include: (i) a high Q-variable oscillator and preselector using RF MEMS; (ii) optical MEMS; (iii) RF MEMS switches for cryogenic applications; (iv) programmable aperture MEMS-interconnected antenna array (v) MEMS and solder self-assembly for 3-D MEMS and MEMS arrays; (vi) bulk etched surface micromachined micromirror arrays for adaptive optics; and (vii) injectable ceramic microcast SiCN MEMS for extreme temperature environments.
- ***Manufacturing:*** In manufacturing, the focus is on low-cost, high-yield manufacture of electronic systems. Typical projects include: (i) artificial neural networks (ANNs) for process modeling, optimization and control, and (ii) development of new cure techniques for chip-on-board assemblies.

CAMPmode's milestone achievements include:

- Development of PMESH, a full-wave integral-equation/moment-method based electromagnetic simulation software for microstrip, slotline, coplanar waveguide, and coplanar stripline microwave circuits
- Modeling of spurious coupling among, and radiation from, microstrip circuits
- Complete quasi-static, experimentally verifiable software for analysis of coplanar MMIC circuits
- Demonstration of the first calibrated-area optical sampling system for *in situ* sampling of MMIC circuits
- Development of hybrid FDTD and edge element algorithms for time-domain analysis of high-frequency interconnects
- Algorithms for optimal mechanical design of land-grid array connectors and other systems with significant analysis complexity
- Demonstration of significant power efficiency improvement and reduction of noise in dc power distribution for battery-operated systems
- Demonstration of feasibility of integrated local power processors and low-voltage, low-noise power distribution for mixed-signal electronic systems
- Development of a novel approach to build faster and more accurate artificial neural network (ANN) models for process modeling, optimization, and control
- EM performance estimation of high-speed ceramic packages
- Development of solder profile-modeling software for precision alignment and/or reliable connections
- Patented finned metal-foam heat sinks for superior thermal management
- Power cycling to thermal cycling correlations
- Development of an actuatable microconnector for use in high-density electronic packaging
- High-Q RF MEMS tunable capacitors and switches for microwave and millimeter-wave applications
- The first SiCN actuator
- Variable MEMS capacitors.

Special Center Activities

In addition to the traditional support of M.S. and Ph.D. programs in the Mechanical Engineering and Electrical and Computer Engineering Departments, the Center publishes a bi-annual newsletter to inform the public of CAMPmode activities, hosts postdoctoral students and visiting scientists in the Center's programs, and participates in cooperative and internship programs at sponsor locations.

Facilities and Laboratories:

The facilities and laboratories available to faculty, staff, students, and sponsors include: clean room for optical and microwave circuit fabrication and antenna construction; mask-making facility; network of HP-300 and HP-700 series color graphic computers; HP-8510 network analyzer; RF probing station; optical and scanning electron microscopy; microtensile tester; instrumented micro-indentor; and interferometric microscope with temperature channeler. In addition, the Center houses a Packaging Laboratory that includes a thermosonic flip-chip bonder, flip-chip soldering, MCM prototyping, fluxless reflow facilities, and an Electronic Manufacturing Laboratory including reflow soldering equipment, thermal diagnostic equipment, CVD prototypes, and wind tunnel.

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