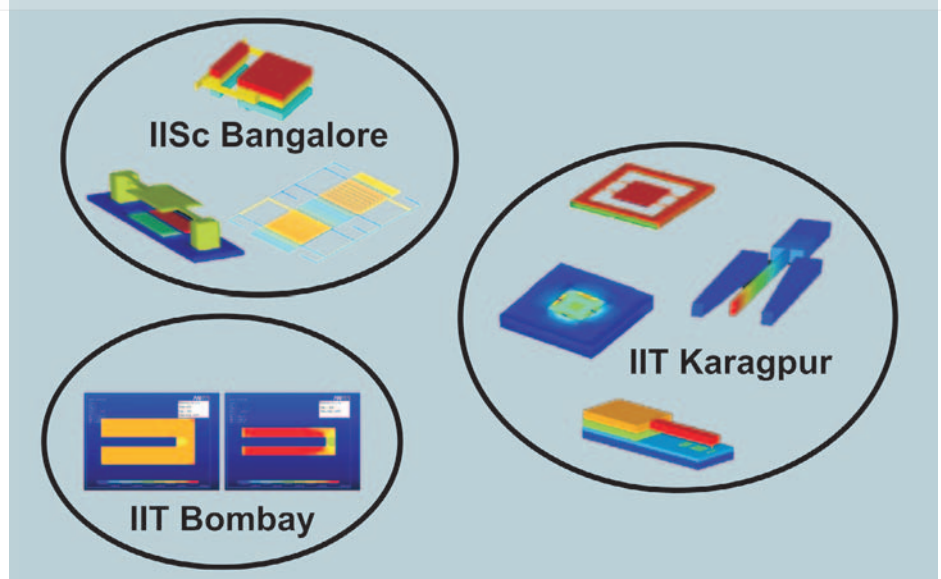


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Growing microsystem capability

Another area where India has been developing capabilities, both design and fabrication, has been in micro electro mechanical systems. The following is largely based on work by the French market analyst company Yole Développement.

Semiconductor technologies such as etch, deposition and lithography have been applied increasingly outside of pure electronics to produce microsensors (e.g. accelerometers for car airbag deployment, gas and pressure), micropumps (e.g. inkjet cartridges), microactuators, hard disk drive magnetic heads, and so on. India has already launched many projects to develop these micro electro mechanical system (MEMS) capabilities.

In 2002, the government launched a five year National Program on Smart Materials (NPSM) with expected funding of \$15 million over the whole project. This venture has involved 10 research centres with a key focus on MEMS. A little mental calculation suggests that this project should be winding up this year, but the official website (<http://www.ada.gov.in/npsm/>) does not seem to have been updated with material beyond July 2005.

In 2005, the Department of Science and Technology launched a national Microelectronics and Nanotech Development Program (\$10 million over three years). Aims of this project

include MEMS and DNA chip technologies and also nano related R&D: nanoelectronics (quantum computing, optoelectronics), nanomaterials (carbon nanotubes, nanocomposites).

One of the most important goals of these initiatives is to strengthen the current lack of co-operation between private commercial companies and public sector universities and research institutes in India.

The CraneSci MEMS Lab (<http://www.mecheng.iisc.ernet.in/~mems/index.html>) was the first MEMS research laboratory to receive private funding. The joint venture between the public Indian Institute of Science (IISc) and Cranes Software International Ltd (CSIL, a Bombay stock exchange listed company with market capital of \$ 20 million based in Bangalore) was established in 2003 to create such co-operation and cross fertilization between public and private sectors. The lab focuses its activity on intellectual property (IP) generation for MEMS, while the actual fabrication is outsourced.

Current developments include MEMS

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microphones, MEMS ultrasound medical imaging systems, pressure sensors and inertial MEMS. On the fabrication side, there are two established MEMS foundries and small foundry activities have also been set up in a number of R&D labs. The MEMS National Foundry has been set up at Semiconductor Complex Limited (SCL), a CMOS fab at Chandigarth that has a small production capacity of 150mm (6") wafers up to 100,000 wafers/year (<http://www.sclindia.com/>). MEMS capability has been developed from 2003. Manufacturing processes include bulk and surface micromachining and wafer bonding. The plant also contains capabilities for MEMS packaging, a key requirement for developing commercial, robust parts that have the correct, useful interfaces with the outside world while protecting delicate components. Among the foundry's current standard MEMS products is a pressure sensor.

The second MEMS foundry is at Bharat Electronics (<http://www.bel-india.com/BelWebsite/index.aspx>) in Bangalore, employing 210 people in producing bipolar and CMOS devices on 100mm (4") wafers. The main focus of the company is defence electronics. Capabilities include micro opto electro mechanical systems (MOEMS), radio frequency devices (RF MEMS) and MEMS packaging with applications in aerospace, civil and biomedical technologies. IIT Bombay (Mumbai) is an example of an R&D lab with small foundry activities producing cantilever-based biosensors. There is a fab currently under construction at the Centre for Materials Research (Pune) in support of design activity. As with microelectronics, India has strong know how in MEMS design with a number of national MEMS design centres. (<http://mems.ece.iisc.ernet.in/pages/home.php>)

designs gyroscopes, MEMS varactors and micro-mirrors; the Indian Institute of Technology (IIT) Kharagpur has piezo accelerometer, pressure sensor, microthruster, rotation sensor capabilities; IIT Bombay designs the cantilever-based biosensors that it produces. Another design centre (<http://www.ee.iitm.ac.in/divisions/divisions-micro-research-mems.html>) is due soon at IIT Madras (Chennai). Among the aims at Madras have been biomedical devices such as pressure sensors for the detection of glaucoma, and blood and bladder pressures along with chemical sensors (triglycerides, urea). Micropumps, microvalves and microneedles for drug delivery and dosage control have also been developed. IIT Madras has facilities for design, modelling, fabrication and testing of MEMS and some technology (accelerometers and pressure sensors) have been transferred to industry.

Players	Activity	MEMS Products
Cranes Software International Limited	R&D	Pressure Sensors, acoustic pressure sensors, inertial sensors
SCL	Fab	Pressure sensor
Bharat Electronics Limited	Fab	Optical sensors, MEMS packaging, gas sensor, RF devices, accelerometer and gyroscopes
CSIR Initiative on Microsensors/CEERI	R&D	Pressure sensors, acoustic sensors, polysilicon load sensors, RF switches, infrared detectors
SSPL/IIT - Delhi	R&D/Design	Pressure sensors
IISc - Bangalore	R&D/Design	Gyroscope, varactor, micro-mirror
IIT - Kharagpur	R&D/Design	Silicon piezoresistive accelerometer, silicon piezoresistive pressure sensor, tunneling accelerometer, MEMS micro-thruster, micro-mirror
IIT - Bombay	R&D/Design	Biosensors
IIT - Madras	R&D	Biosensors
IIT - Gowhati	R&D	Silicon sensors
IIT - Kanpur	R&D	Pressure Sensors
Tata Institute of Fundamental Research	R&D	Pressure Sensors