PHYS.ORG

Technique enables energy-harvesting sensors to be miniaturized

February 5 2015

Self-powered sensors developed by Chakrabartty and his collaborators may be attached to or embedded inside bridges, pavements, vehicles, rotating parts and biomedical implants. They can autonomously sense, compute and store cumulative statistics of strain rates, without the aid of batteries. Credit: Shantanu Chakrabartty, Michigan State University

Imagine a world where bridges, roads, heart valves or knee replacements could monitor themselves and send a warning signal before they fail.

Imagine then, if these advanced pieces of technology could power themselves and operate for years without needing any maintenance.

Shantanu Chakrabartty, a researcher at Michigan State University (MSU), has worked for almost a decade on these safety-critical goals. Using four National Science Foundation (NSF) grants since 2006, the associate professor of electrical and computer engineering in MSU's College of Engineering has focused on the fundamental science behind self-powered sensors for health and usage monitoring.

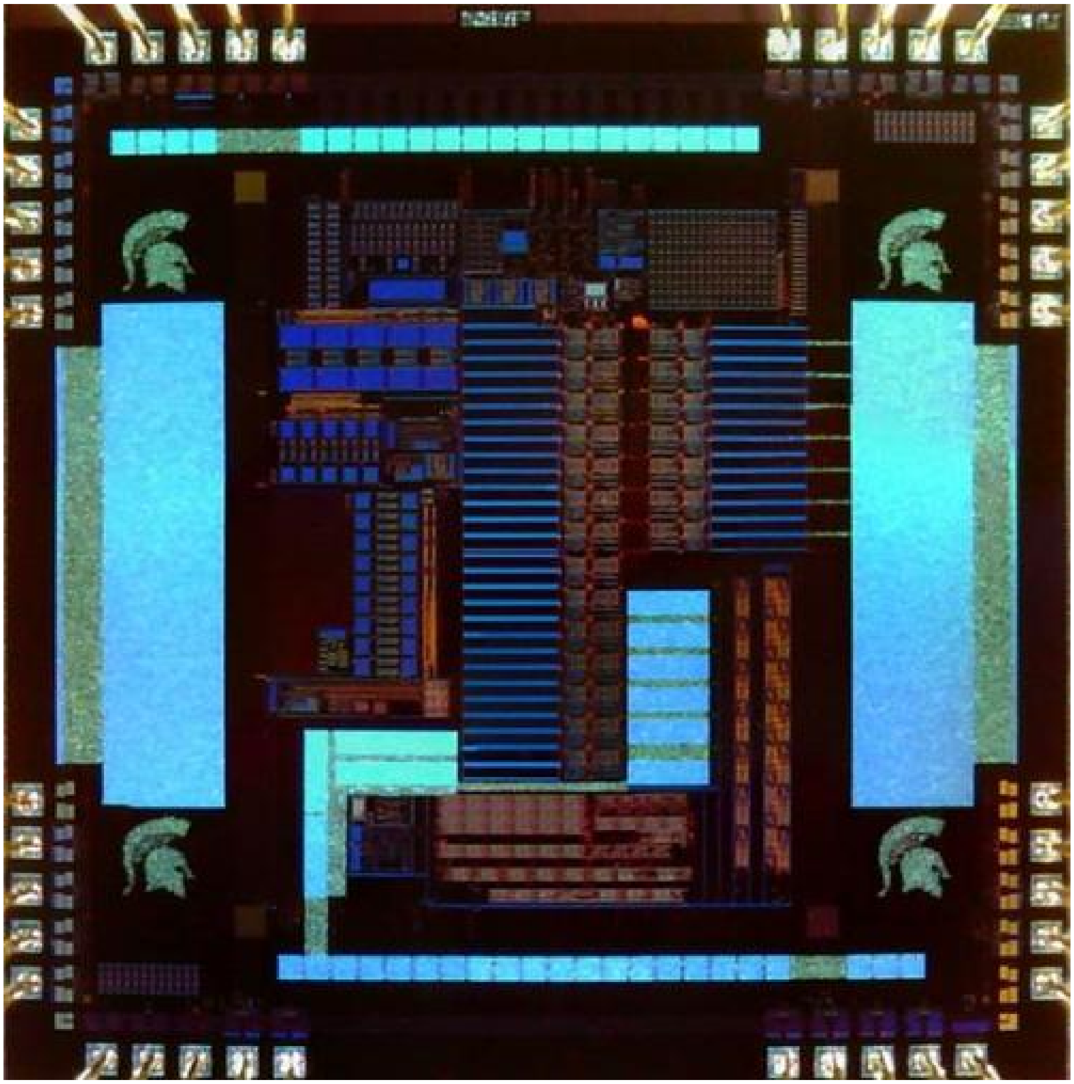
"My part is the core science that drives this technology," Chakrabartty said. "I am interested in the device's physics and in exploring new ways to sense and compute on the sensor. The technology is currently being piloted in different applications, and every new application allows me to optimize the sensor in different ways."

Self-powered sensors developed by Chakrabartty and his collaborators may be attached to or embedded inside bridges, pavements, vehicles, rotating parts and biomedical implants. They can autonomously sense, compute and store cumulative statistics of strain rates, without the aid of batteries.

Tiny sensor networks

With NSF support, Chakrabartty discovered a unique synchrony between the physics of flash memory and the physics of devices that convert mechanical stress into energy.

The innovation, called piezoelectricity-driven hot electron injection (p-IHEI), enables energy-harvesting sensors to be miniaturized.



A network of micro-sized sensors can self-diagnose any catastrophic failure, according to Chakrabartty. Once fully packaged, he hopes the sensor will become an integral part of any smart structure, whether it is civil, mechanical or biomechanical. Credit: Shantanu Chakrabartty, Michigan State University

These tiny sensors can then be embedded inside structures like wind turbines or rotor blades. They can even be placed inside the human body—for instance, in a knee implant or a heart valve.

A network of micro-sized sensors can self-diagnose any catastrophic failure, according to Chakrabartty. Once fully packaged, he hopes the sensor will become an integral part of any "smart" structure, whether it is civil, mechanical or biomechanical.

Remote access to foil failure

The sensors can be remotely retrieved with a smartphone and used to predict the onset of mechanical failure. Users may be alerted to potential problems, minimizing the risk of bodily harm and significantly reducing maintenance costs.

"Currently, we're looking at using a diagnostic ultrasound to retrieve data from the sensors implanted in the body," Chakrabartty said. "This will be highly cost-effective and will be compatible with instrumentation already used by health care professionals."

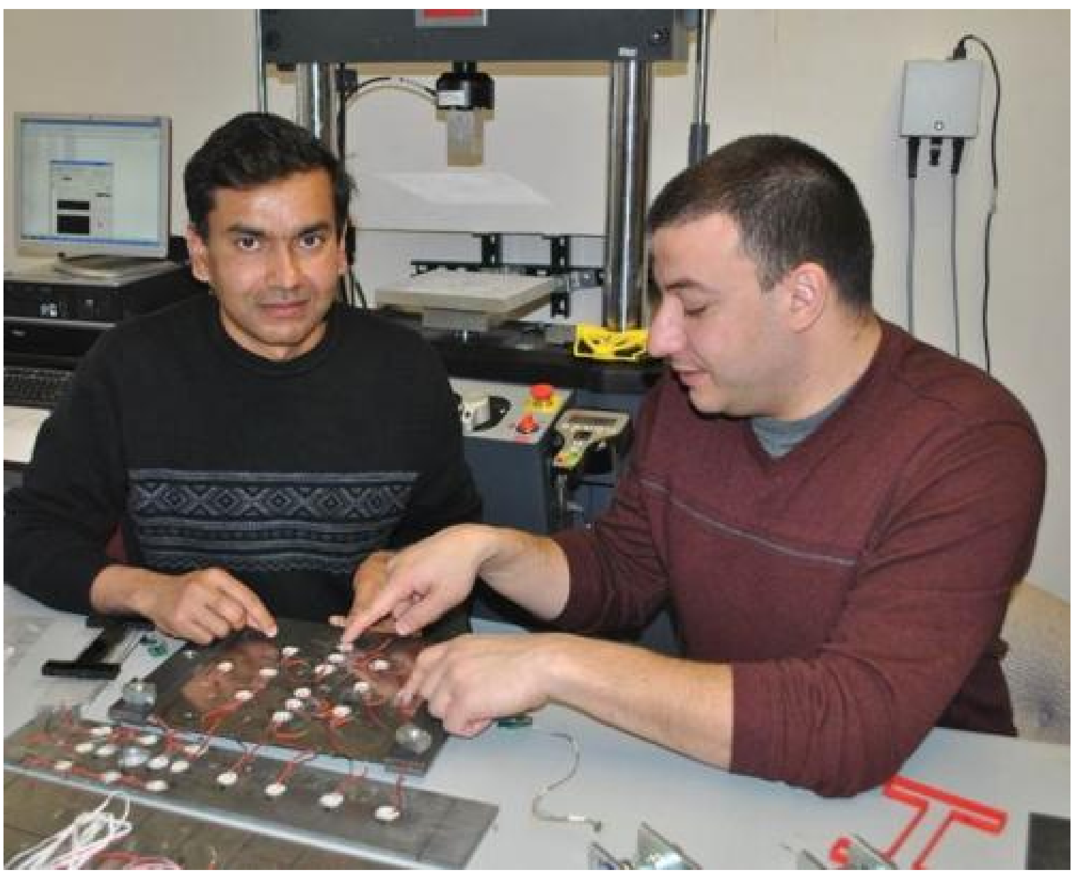
"My goal is now to explore new biomedical applications of these sensors and push its limits of performance," he said.

Data from the sensors can be remotely retrieved with a smartphone and used to predict the onset of mechanical failure. Users may be alerted to potential problems, minimizing the risk of bodily harm and significantly reducing maintenance costs. One of the new sensor applications is smart sports helmets that diagnose concussions. Credit: Shantanu Chakrabartty, Michigan State University

One of the new sensor applications is smart sports helmets that diagnose concussions.

"At a time when we all carry sensors in our pockets and on our wrists to monitor many of our daily activities, technology that enables the assessment of the health of critical infrastructure, vital organs or the occurrence of life-threatening events is long overdue and sorely needed," said Massimo Ruzzene, program director in NSF's Engineering Directorate. "Dr. Chakrabartty's innovations in the area of remote, self-powered sensing significantly contributes to this need."

Chakrabartty won an NSF CAREER Award in 2010 for his research in energy-harvesting sensors and processors. Though his Adaptive Integrated Microsystems (AIM) Laboratory at MSU, he has been working on a revolutionary sensing paradigm to help engineers and doctors monitor the health of mechanical structures.



The self-powered sensor research has spawned two U.S. and international patents with several other patents currently pending. The technology is being marketed by the MSU Technologies Office and has led to the formation of Piezonix, a startup company based in Michigan. Credit: Shantanu Chakrabartty, Michigan State University

The self-powered sensor research has spawned two U.S. and international patents with several other patents pending. The technology is being marketed by the MSU Technologies Office and has led to the formation of Piezonix, a start-up company based in Michigan.

Key outcomes:

- Chakrabartty's technology has led to two issued U.S. patent with several patents pending. The technology also won him the Michigan State University 2012 Innovation of the Year Award, and has created an array of ongoing scientific collaborations.
- Nizar Lajnef, assistant professor of civil engineering at MSU, earned his PhD through a related NSF award. His research monitors the degradation of asphalt and bridges. Read more in "Street Smarts – Monitors being created to watch for road and bridge defects."
- Formation of Piezonix, a start-up company responsible for commercialization of the self-powered sensing technology.
- Several undergraduate senior design projects led to the development of software used for collecting data from the sensors.
- Spin-off collaborations include research on smart infrastructure (roads and bridges), smart aircraft skins, smart orthopedic implants, smart heart valves and smart football helmets.

Provided by National Science Foundation