

IIT Bombay makes low cost vibration sensors

These can monitor industrial machine health and help prevent incipient failure

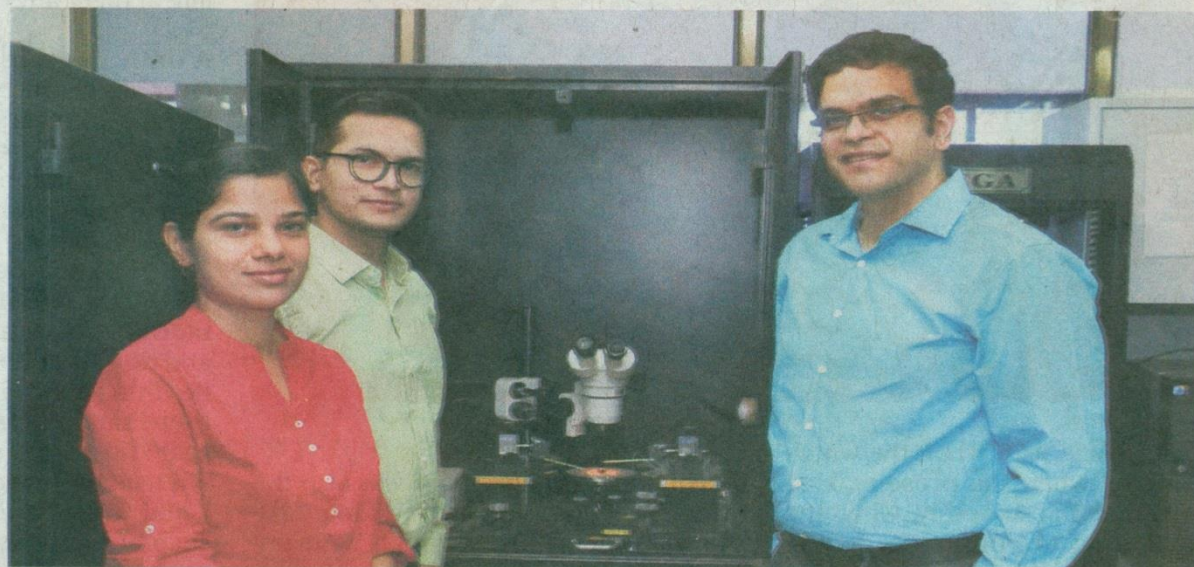
R. PRASAD

Researchers at the Indian Institute of Technology (IIT) Bombay have successfully made low-cost piezo-resistive vibration sensors using polyurethane foam coated with carbon nanomaterial-based ink. These sensors can be used for monitoring the health of industrial machines and equipment and help identify incipient failures thereby enabling efficient maintenance schedule planning.

The ink is made of functionalised multi-walled nanotubes that are dispersed in a reduced graphene oxide matrix. It is conductive due to the presence of large number of multi-walled nanotubes. The ink, which uniformly coats the pores of the foam when dipped-coated, imparts piezo-resistive properties. Conductive sheets were pasted on the top and bottom sides of the foam and electrical wires connected to the sheets for measurements. The ink and sensor were developed at the Plastic Electronics and Energy Laboratory (PEEL), Department of Metallurgical Engineering and Material Science, IIT Bombay.

"When the PU foam coated with the ink is perturbed, in this case compressed, the air gaps are removed and the foam gets thinner. This provides a conduction path for electrical charges. The resistance drops as the foam is compressed and it becomes more conductive," says Amit Tewari at IITB-Monash Research Academy, IIT Bombay, and one of the authors of the paper published in the journal *IEEE Sensors Letters*. "The sensor is so sensitive that it can measure blood pulse."

"The total cost of materials



Collaboration: "We are working on developing more such novel, improved sensors and exploring more application spaces as well as deployment," say Siddharth Tallur (right) and Dipti Gupta.

required for making the sensors works out to less than Rs.200 per sensor, and can be reduced further if mass produced. The ink costs only about Rs.7 per sensor. No sophisticated equipment is required for fabricating the sensor," says Prof. Dipti Gupta from PEEL, IIT Bombay and one of the authors of the paper. In comparison, commercially available vibration sensors for such applications cost more than \$50 per sensor, which makes it prohibitively expensive.

Characterisation

The team validated the suitability of the foam-based material as vibration sensors. The team was able to classify different machine operating conditions (good versus bad bearing, and good versus bad gearbox) based on vibration signals.

In the absence of a shaker table to characterise the vibration sensor, the researchers used a portable Phillips Bluetooth speaker. The foam sensor was rigidly mounted to the

speaker and audio recordings were used to generate vibrations that were to be studied. Acoustic recordings for different machine operating conditions were played on the speaker and the sensor was validated.

Unlike a shaker table, speakers will not produce high amplitudes, so the team focussed on the frequency of the tones to validate the sensors. "Our interest was to locate the frequency of the excitation vibration signal," says Siddharth Tallur, Department of Electrical Engineering, IIT Bombay, who is corresponding author of the paper. "We were looking for these tones in the sensor output."

Danger signs

To be able to identify the danger signs of a machine, the output of the vibration sensor has to be captured and the Fast Fourier Transform (FFT) has to be computed. One should then look where the peaks are located in the FFT.

Since the vibration signal would vary from one gearbox

to another, the vibration signal prior to failure can be identified only when data for each gearbox in its good state is available. It will then be possible to look for shifts in the frequency as the machine ages. One way to make the measurements independent of the variation in machines is by increasing the bandwidth studied. Another will be to look for variation in particular frequency bands than specific frequencies.

"In the real-world scenario, we will be using the sensors directly on the machines," Prof. Tallur says. "It is not clear how many sensors are needed per machine and the location of placement on the machines. If sensors are cheap we can deploy more sensors per machine. And this is where the low-cost of our sensors becomes particularly relevant."

"We are jointly working on developing more such novel improved sensors and exploring more application spaces as well as deployment and field testing of such sensors," he says.