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Tactile sensor acts as a human finger in minimally invasive surgery

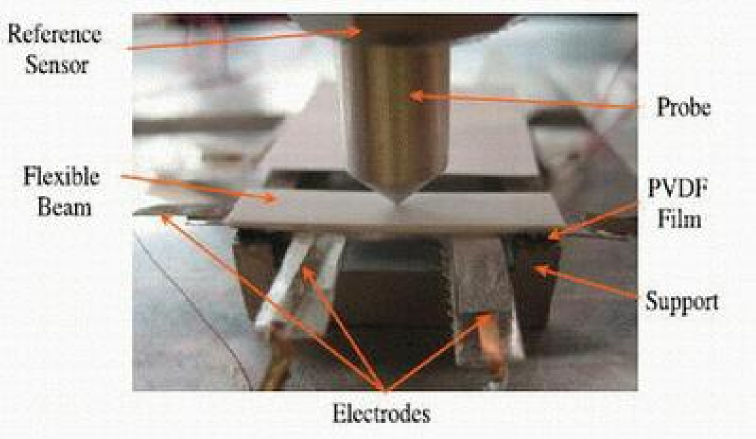

Photo of the tactile sensor. Credit: Sokhanvar et al.

Researchers have designed a millimeter-sized sensor that has many of the tactile abilities of a human finger: it can sense the magnitude and the position of an applied force, slippage of a grasping tool, and the softness of an object, such as a cancerous tumor. The engineers have designed the sensor to be compatible with the grasper of many minimally invasive surgery (MIS) tools, as well as to be easily fabricated by Microelectromechanical Systems (MEMS) techniques.

Concordia University PhD student Saeed Sokhanvar, Associate Professor Muthukumaran Packirisamy, and Associate Professor Javad Dargahi from the Department of Mechanical Engineering have presented their proof of concept model in a recent issue of *Smart Materials and Structures*. The group used analytical and numerical simulations to optimize the characteristics of the sensor, and the results from their prototype appear promising for MIS applications, and also demonstrate potential for robotic applications.

MIS is a type of “teleoperation,” where a surgeon can remotely perform the operation using endoscopic tools without directly using his/her hands at the operation site. The advantages of MIS compared with traditional surgery include fast recovery, less pain, and usually less cost.

However, at present, one of the major disadvantages is that the surgeon’s hands are not at the site of operation. Perception is limited to an image that is transmitted from a video camera located in the endoscope.

“MIS has forced surgeons to rely heavily on visual sense alone, since the ability to perceive information by palpating tissues or organs has all but been eliminated by the use of tiny incisions that do not allow digital palpation,” said Dr. Dargahi, who is the director of CU’s tactile sensing and medical robotic lab. “Development of a smart endoscopic grasper equipped with micromachined tactile sensors would satisfy a great need of surgeons in MIS. Since the sensor is micromachined, it would be mass produced, hence cost effective. In addition, the size of the sensor could be tailored to various types of endoscopic surgery.”

Dr. Dargahi explained that this work is the third generation of the tactile sensors developed in his lab, which is based on one of the results obtained from the PhD work of Sokhanvar, who is supervised by Dr. Dargahi and Dr. Packirisamy. The sensor uses 28-micrometer-thick PVDF (Polyvinylidene Fluoride) films, which is a flexible, biocompatible, and highly sensitive material. After adhering thin electrodes to both sides of the films, the films were then glued to a flexible 0.8-millimeter-thick polystyrene beam and mounted on a platform of solid silicon. An array of these sensors forms the endoscopic tactile sensor, which is then integrated with an MIS grasping device, like teeth in a crocodile’s jaw.

When the sensor comes in contact with a soft object, the beam bends inwards, causing the PVDF film to develop an output electric charge proportional to the bending stress. The scientists found that, depending on the hardness of the object, the different materials and sizes for the beam can be chosen to provide the highest resolution. The sensor could then be adapted to a broad range of objects, such as different tissues.

“The main advantage of this sensor is its multifunctionality,” Dr. Dargahi said. “Compared to other tactile sensors developed for MIS, which are often designed to measure one specific quantity, this sensor is able to report the magnitude of the force, the force position, the softness of the grasped object, the existence of any embedded lump, as well as any slippage of the grasped object. The corrugated shape of the sensor replicates the existing MIS tools and ensures a firm grasping.”

The system can sense the softness of both distributed loads and concentrated loads, the latter of which could represent a lump within soft bulky tissue. Through their simulations, the researchers found that the placement and orientation of the PVDF films was critical for the ability to distinguish a point load at different locations on the beam. With an optimized design, however, the sensor proved to be sensitive enough to be able to identify materials based on their compliance.

Sokhanvar, Packirisamy, and Dargahi plan to further optimize the system by studying the effect of friction, investigate a MEMS-fabricated version for mass production, and take further steps toward device application.

“The future work would be miniaturization of the sensor and its integration with the existing MIS tools,” Dr. Dargahi said. “To do this, PVDF deposition techniques (such as spinning) must be used. Then it would be ready to be tested with animal tissues. Software must also be developed in order to analyze the information gathered by the sensor. Finally, the tactile information must be introduced to the surgeon. Currently the group is working on two types of tactile displays using graphical representation of tactile information and mechanically reproducing the measured softness in which the tactile information can be sensed by touching the device.”

Citation: Sokhanvar, S, Packirisamy, M, and Dargahi, J. “A multifunctional PVDF-based tactile sensor for minimally invasive surgery.” *Smart Mater. Struct.* 16 (2007) 989-998.