

# Piezoelectric Polymer – FET Devices Based Touch Sensors

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## INTRODUCTION

Tactile sensing is of utmost importance in applications like biomedical, robotics in general and bio-robotics in particular. It is important in view of the rich interaction behaviours exhibited by real world objects e.g. how hard or soft is the object, how its surface feels when touched, how it deforms on contact and how it moves when pushed etc. Touch information plays a fundamental role in the safe interaction of any artificial device with the environment i.e. without causing any harm to the objects with which it is interacting. This work presents a novel method of developing touch sensing arrays which have been designed for robotics applications and their utility can be easily extended to biomedical instruments as well.

## METHODS

The tactile sensing arrays presented here, are based on the ‘sense and process at same place’ concept shown in Fig. 1. The ones presented in this work use piezoelectric polymers - as transducers, directly deposited and coupled to the FET devices in touch sensing array. Besides improving the performance of touch sensing devices, this approach also allows the implementation of distributed computing, thereby, reducing the computational load.

The touch sensing array, as shown in Fig 2, has 25 touch sensors (5 x 5) spaced at a distance of 1mm (center to center). Each touch sensor comprises of piezoelectric polymers (PVDF-TrFE) directly spin coated on the gate area of a MOS device and thus, can be called as POSFET (Piezoelectric Oxide Semiconductor Field Effect Transistor). The charge –proportional to applied force, generated in the piezoelectric polymers is used to modulate the charge carriers in the induced channel of MOSFET, which is then converted into a voltage value by means of readout circuitry - that can be embedded into same chip. Piezoelectric polymer, PVDF-TrFE is preferred because of excellent features like, flexibility, workability, fast dynamic response and the close impedance match with human tissues. The design of these tactile sensing arrays is influenced by system constraints like putting many sensing elements in a limited space, fast response, less wires etc. While the piezoelectric polymer film as sensing element will improve the time response of the sensor; the tight coupling of sensing material (PVDF-TrFE) and electronics using MOS technology will improve force resolution, spatial resolution and signal to noise ratio. In order to have large transconductance, the W/L ratio of the POSFETs was made 300. A Si<sub>3</sub>N<sub>4</sub>/SiO<sub>2</sub> double layer is used as a gate dielectric. The reference fabrication process for this design is the n-MOS technological module of a non standard 4- $\mu$ m Al gate p-well ISFET/CMOS technology [1].

Somewhat similar approach, with piezoelectric polymer present on the extended gates, has been reported in [2, 3] for ultrasonic sensors and in [4, 5] for the touch sensors. While the [2] and [4] used the epoxy-adhered PVDF film; a thin films of PVDF-TrFE directly deposited from solution was used in [4]. In our earlier design, shown in Fig. 3, the electrodes of a 32 element microelectrode array test chip were used as extended gates and were epoxy-adhered with 25  $\mu$ m, 50  $\mu$ m and 100  $\mu$ m films [5]. It is observed that both epoxy and extended gate introduce additional capacitances, which reduce the sensitivity [6].

## RESULTS AND DISCUSSION

Fig. 4 shows the average response of three touch sensing elements - to forces up to 0.4 Kgf, when a sinusoidal force was applied at 15 Hz. The response is linear over a large range of forces. A further characterization is required to study the behaviour of sensing array over broad range of frequency. In the present case, the sensing elements have been realized on silicon substrate and our future effort would be to repeat the approach on flexible substrate. A SOC/SIP implementation of tactile sensing system will further improve its performance. Presence of analog sensor front end, digital core and communication interface along with tactile sensors array on same chip is expected to improve (among

others) speed, bandwidth, signal to noise ratio, overall sensitivity, efficiency and robustness. Apart from these, the SOC approach will lead to use of least number of wires or the use of wireless communication – which is desired in any robotic application.

## REFERENCES

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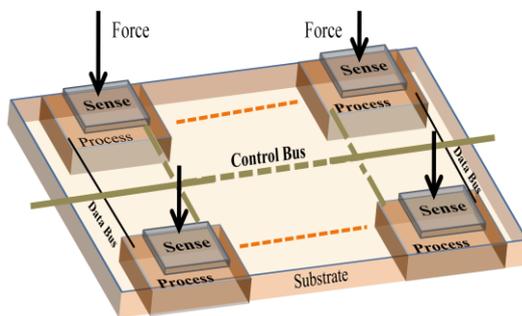


Fig. 1: The concept of large area touch sensing array.

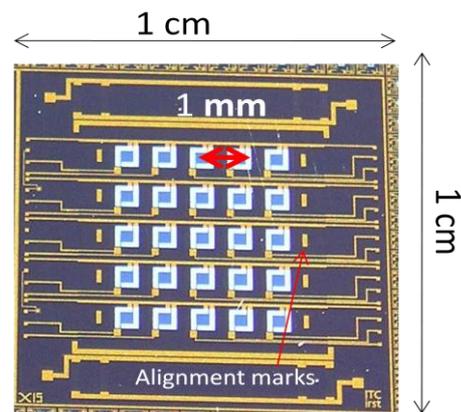


Fig. 2: POSFET based touch sensing array (polymer film is not shown here).

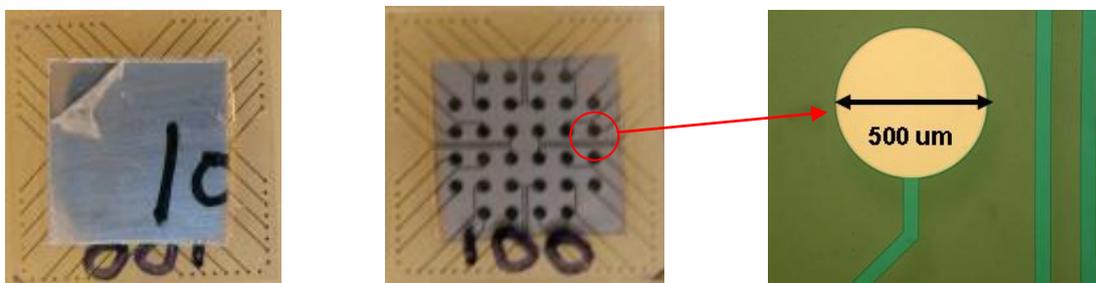


Fig. 3: Front and back sides of Microelectrode arrays (or extended gates) epoxy adhered with 100 $\mu$ m PVDF-TrFE film.

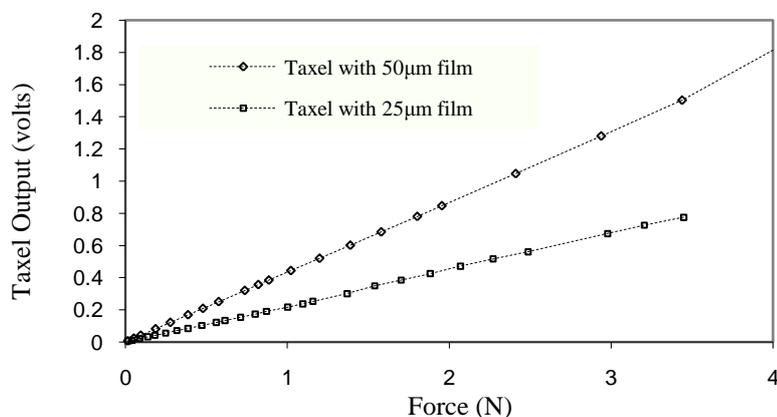


Fig. 4: Average response of touch sensing elements when variable dynamic force is applied at 15 Hz