Flexible tactile sensors based on polysilicon TFT technology for robotics application

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Abstract

Flexible tactile sensors represent the key element for the development of highly conformable sensor platform that can be defined "artificial skin". In this work, we present the fabrication of a piezoelectric tactile sensor based on piezoelectric PVDF-TrFE film integrated with a low-temperature polysilicon thin film transistor (LTPS TFT) in an extended gate configuration. The piezoelectric PVDF-TrFE properties have been enhanced with a poling procedure, reaching a piezoelectric coefficient of about 25 pC/N. The device has been measured in a source-follower floating gate arrangement, showing an output signal of 0.5mV/N to a normal sinusoidal stimulus at 1Hz.

1. Introduction

A tactile sensor can be defined as a device or a system that can measure a given property of an object or contact event through physical contact between the sensor and the object [1]. An array of tactile sensors can be grouped to form an electronic sensitive skin also called artificial skin. This device is a complex sensors platform that can be integrated in humanoid robots in order to favor the interaction between robots and humans. Although several types of tactile sensors were made exploiting different strategies, the fabrication of a sensitive skin cannot be fabricated with the standard silicon-based electronics.

For this reason many efforts have been made towards the development of a flexible sensor platform based on organic thin film transistor (TFTs) [2-3]. Unfortunately these devices have still severe problems of aging and electrical stability [4]. Moreover, although electrical performance of organic TFTs have been recently considerably improved, they are, at best, comparable to the conventional amorphous silicon technology in terms of field effect mobility.

For this particular application, low temperature polycrystalline silicon (LTPS) TFTs based electronics can represent a very attractive solution, since it combines good electrical characteristics (field effect mobility above 40 cm^2/Vs) and excellent mechanical and electrical stability with the compatibility to fabricate devices directly on flexible substrates [5-6]. In the following section we present the fabrication and the characterization of flexible piezoelectric tactile sensors integrated with LTPS TFTs. These devices are made on ultra-thin polyimide substrate (<10 um) and can be easily miniaturized and adapted to non-planar surfaces like for instance the fingertips of a robot.

2. Experiment

By adopting a non-self-aligned top gate coplanar architecture, we fabricated LTPS TFTs directly on polyimide as described in our previous work [5] . The TFTs have a W/L= 40 and show a mobility of about 40 cm^2/Vs, a threshold voltage of 7 V and an on-off ratio of 10^6. These values can be deduced from the output and transfer characteristic reported in fig.1a-b, and they allow to use the flexible transistors as read-out interface for the piezoelectric sensor. The devices did not show appreciable variations in the electrical characteristics after mechanical stress tests with bending radii up to 1.3 cm. After completing the TFT fabrication, the piezoelectric capacitor was formed by evaporating a bottom electrode in chromium followed by by spin-coating deposition of a film of PVDF-TrFE, 2 um thick, and defining the upper electrode, also in chromium (see fig.2). We used the same PVDF-TrFE film as passivation layer, to protect the underlying polysilicon based electronics.

3. Poling procedure

After fabrication process, PVDF-TrFE capacitors on polyimide, were cut, detached from the rigid carrier and singularly tested. No tensile or compressive mechanical stress was observed on freestanding devices. In order to improve the piezoelectric properties of the films they need to be polarized (poling). Poling was performed on each PVDF-TrFE capacitor, by applying an appropriate sequence of voltage steps up to 160 V (80 V/um) [7]. No electrical breakdown or evident damages were observed and the maximum leakage current recorded during poling process was below $3x10^{-5}$ A/cm^2. To further enhance the poling procedure, the substrate was heated up to 80°C and then cooled down during the final voltage step, according to a procedure described in previous works [7].

4. Electromechanical Test

By using a small vibration exciter from TIRA, controlled by a commercial dynamic force sensor from PCB Piezotronics, we performed electromechanical tests on these devices according to the set up outlined in fig. 3. We adopted a source follower circuit configuration and we obtained an output signal of 0.5mV/N to a normal sinusoidal stimulus at 1Hz, as shown in Fig. 4. Other measurements were recorded at higher frequencies up to 10 Hz. After the tests no damages or changes in electrical behavior were observed on LTPS TFTs.

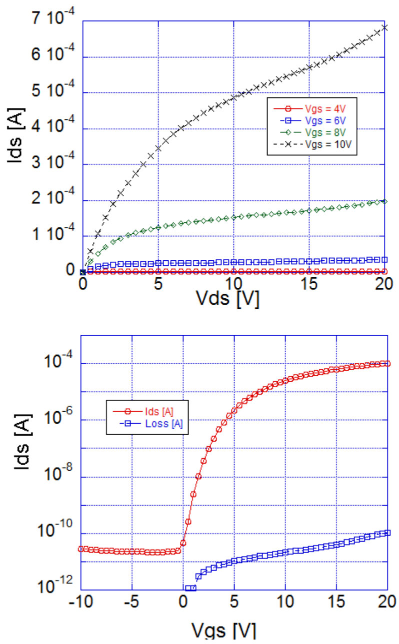

Fig. 1. (a) Output characteristic for a TFT with W/L=40, (b) transfer characteristic of the same device, measured at room temperature after the detach from the rigid carrier.

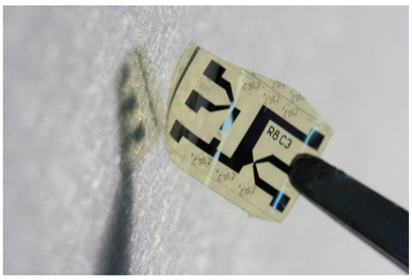

Fig. 2. A photograph of the pressure sensor integrated with the LTPS TFTs fabricated on polyimide after the detach from the rigid carrier.

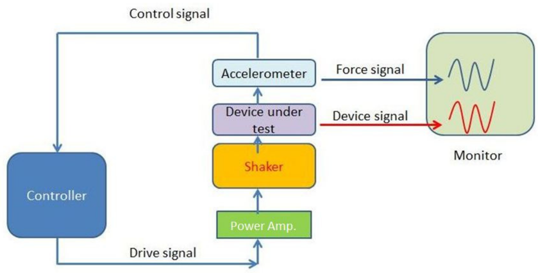

Fig. 3. Schematic of the experimental set up used for the electromechanical test.

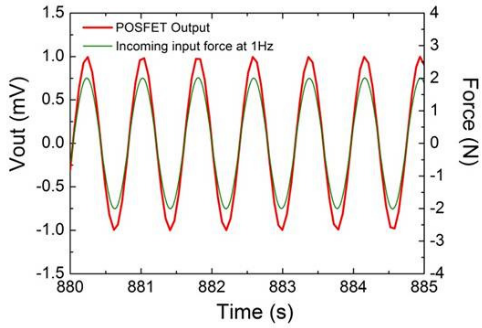

Fig. 4. Flexible touch sensing device response for a sinusoidal signal of an amplitude of 4 N, at a frequency of 1 Hz measured with a |Vdd| of 13V and an external load of 2.7 kΩ.

5. Summary

In conclusion, we successfully designed and fabricated a flexible tactile sensor on an ultra-thin polyimide substrate, exploiting an electronics based on LTPS TFTs. The piezoelectric properties of the sensor were enhanced by a poling procedure, reaching a d33 of 25 pC/N. We also performed electromechanical measurements obtaining an output signal of 0.5mV/N to a normal sinusoidal stimulus at 1Hz. This kind of device can represent a good solution for the development of sensitive artificial skin.

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