Stretchable Transistors

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1 Introduction

Stretchable electronics have various important applications; sensors for biological sensing (ECGs), sensor skins for robotics and prosthetic, and biomedical instrumentation. A basic component in electronics is a transistor, making it necessary to have robust stretchable transistors. Currently stretchable transistors are made with fragile or liquid components that reduce their durability, such as: gold thin films or liquid metals. A clean room is also required to manufacture a transistor. We aimed to create a process through which we could fabricate a clean-room free stretchable transistor, and a characterisation rig to test the mechanical and electrical properties of the transistor.

2 Results & Discussion

The characterisation rig uses a combination of a computer and an Arduino Mega to control a stepper motor and to take measurements of the transistor. The Arduino receives commands from the computer through Serial communication and returns the stress and strain readings through serial communication. Commands are given in a "Command Comma Space" format, terminating with an Asterisk (*) e.g. "F100, D1000, B100, T100*". The letters refer to the command and the numbers refer to duration/quantity. F is "forward" or the clockwise direction and B is "backward" or the anti-clockwise direction, the number refers to pulses where 100 pulses is a full rotation. D refers to the delay in milliseconds, where D1000 refers to a 1 second delay and number after T refers to the total data points needed to be recorded. The input in the Python GUI, however only requires F, B and D commands, to set the data points you can fill in the second input box and the terminating character is automatically added. SMU communication was also used in order to measure electrical properties of the transistor, the resistance of a component can easiy be measured alongside stretching, however to measure transfer curves a separate Python program had to be used alongside the main one. Manual control was also added, however the PCB was not designed accounting for a Joystick, so to add Joystick control while maintaining all sensing capabilities the 15 pin connector can be soldered to connect the joystick VDD and GND pins in parallel to the potentiometer (detailed in the connector pin document), some preliminary code for the switching between joystick and python control is included as a comment at the end of the Arduino code.

In order to fabricate the transistor, we first mixed PDMS elastomer base and crosslinker in a 10:1 ratio by mass, using between 15-65g of the elastomer, the mixture is spread over a glass petri dish and placed in the vacuum oven at 65C for 1 hour. The PDMS can then be covered with some Die Tape (which is required in a later step), this can then be laser cut into a base layer and a template. The base layer is pre-strained up to 15% and the 3D printed electrode template is clamped on top, this can be used to pour the gold solution into the template and cured to deposit gold in an electrode pattern. The sample can then be unstretched and coated with uncured PDMS, and the pad-template layer of PDMS can be stuck on top and placed in the vacuum oven to be cured. The strength of this adhesion can be increased with more precise measurements of PDMS when pouring into the petri dishes and spun coat to standardise the process and ensure the PDMS is uniform, this allows the adhesive layer to lie in the mechanically neutral plane. The PEDOT-PSS (an organic semiconductor) is then spin coated on the combined substrate. The die tape ensures that the PEDOT-PSS only goes on the pad positions. The PEDOT is then spin-coated 3 times and the die tape is removed before placing the substrate on a hot bed. The substrate was then tested and the characterisation curves can be measured. Our first batch of 3 resulted in 1 working transistor so the manufacturing process still requires optimisation. (The plot of the characterisation curves are saved on both the computer and the USB drive as "7/27/23/11:21:31AM GM-ID" and "7/27/23/11:25:21AM ID-VDS").

3 Photos and Documentation

The code for this project can be found in the GitHub Repository (https://github.com/Doov14/Stretchy).

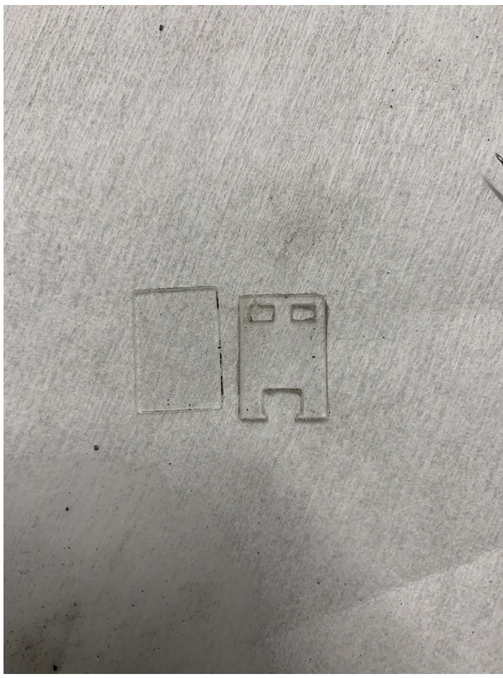
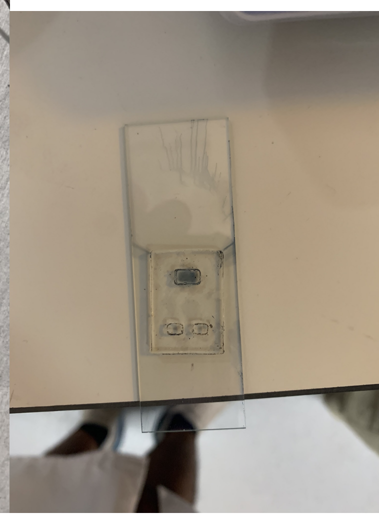
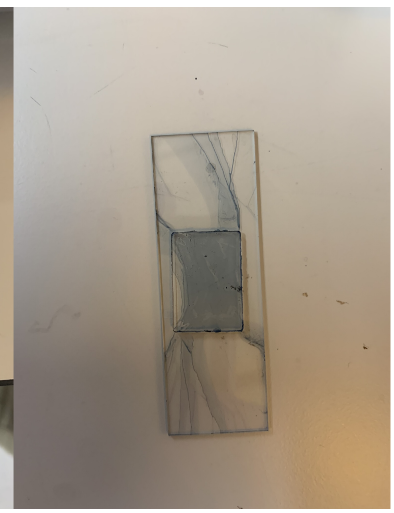
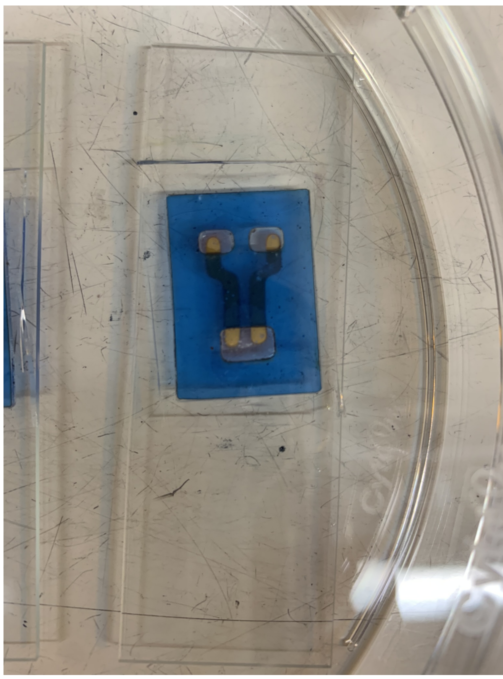




Figure 1: Image of Base and Template Layers of PDMS

Figure 2: Test of PEDOT-PSS Spin Coating

Figure 3: First test of adhered layers with PEDOT



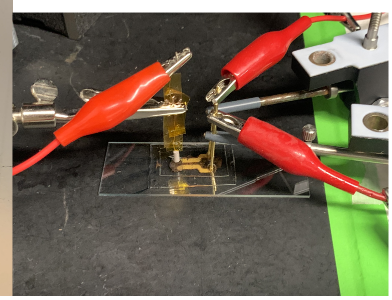


Figure 4: Substrate pre PEDOT coating (with Au deposited)

Figure 5: First sample batch

Figure 6: How first characterisation curve was measured

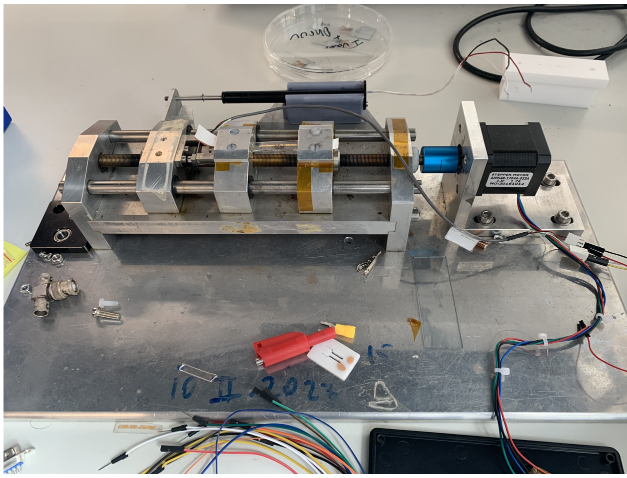
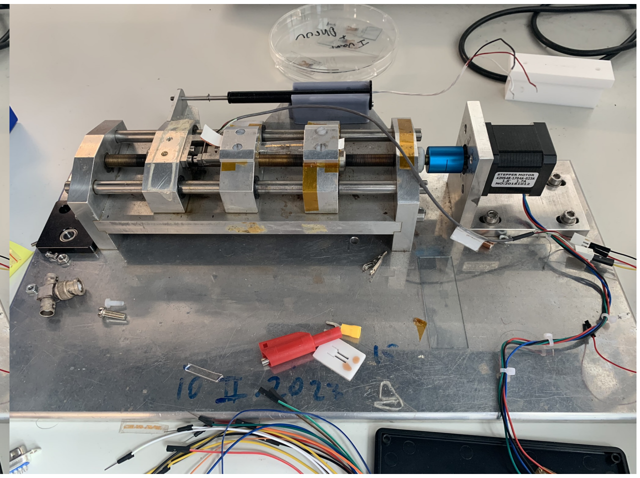



Figure 7: Main Test Rig

Figure 8: Electronics for rig

15 pin connector pin number	Component 2
1	Load Cell Ground
2	Potentiometer Ground
3	Solder Bridge with 2 (Ground for Joystick)
4	Potentiometer VDD
5	Solder Bridge with 4 (VDD for Joystick)
6	Potentiometer Data
7	Joystick Analogue
8	Joystick Button
9	Motor A1
10	Motor A2
11	Motor B1
12	Motor B2
13	Load Cell A+
14	Load Cell A-
15	Load Cell VDD