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Low-tech graphite based on strain sensor

Main features

- Low power consumption
- Easy to use
- Thin
- Light
- Low cost
- Flexible
- Portable
- Easily reparable
- Environmentally-friendly

General description

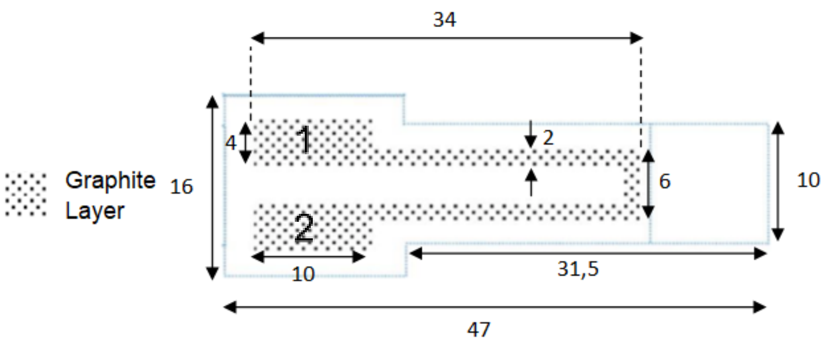
This strain sensor was developed in the Physics Department of INSA Toulouse, based on the article “Pencil Drawn Strain Gauges and Chemiresistors on Paper” published on Scientific Report by Cheng-Wen Lin, Zhibo Zhao, Jaemyung Kim and Jiaxing Huang.

It is well-known that writing with a pencil on a piece of paper lays down a layer of percolated networks graphite on the paper. Thanks to this granularity, the average space between particles changes the electrical conductivity. This average space can easily be modified by deforming the piece of paper. Therefore, we can measure a resistance variation link to the paper deformation and create a strain sensor.

The conductivity depends on the type of pencil. Thus, we characterized the strain gauge sensor for three different types: 2H (hardest), HB (medium), 2B (softest). The measurements are made thanks to a transimpedance amplifier and an Arduino Uno board set on a PCB. The resistivity can be directly read on the OLED screen or on the application developed with the MIT app inventor thanks to the Bluetooth module. To state the quality of this sensor, the results can be compared to the flex sensor by changing the reading mode with the rotary encoder.

Pin Configuration

Pin number	Usage
1	V_{in}
2	$+V_{CC}$



Standard use conditions

	Unit	**Typical value**
Temperature	°C	20 ± 5
Humidity	%	60 ± 5
Air Quality	$\%N_2/O_2$	$80/20$

Specifications

Type	Strain sensor
Materials	• Graphite (9H, 2H, HB, 2B, 6B, 9B) • Paper • Metal clips
Sensor type	Passive: power supply required
Power supply	+5V
Nature of output signal	Analog
Nature of measurand	Voltage
Typical response time	less than 50ms
Typical application	Evaluate a compression or tension deformation

Electrical characteristics

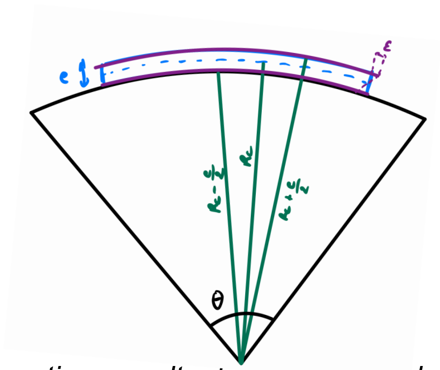
Pencil type	**Unit**	**Value**		
		Minimum	**Typical**	**Maximum**
2H	$M\Omega$	110	260	420
HB	$M\Omega$	30	110	270
2B	$M\Omega$	60	140	290

Strain sensors characteristics

The measurements of the characteristics were realized by measuring the variation of resistance due to deformation with a precise angle. The deformation ε is link to the angle of deformation θ and the paper's thickness e with the formula:

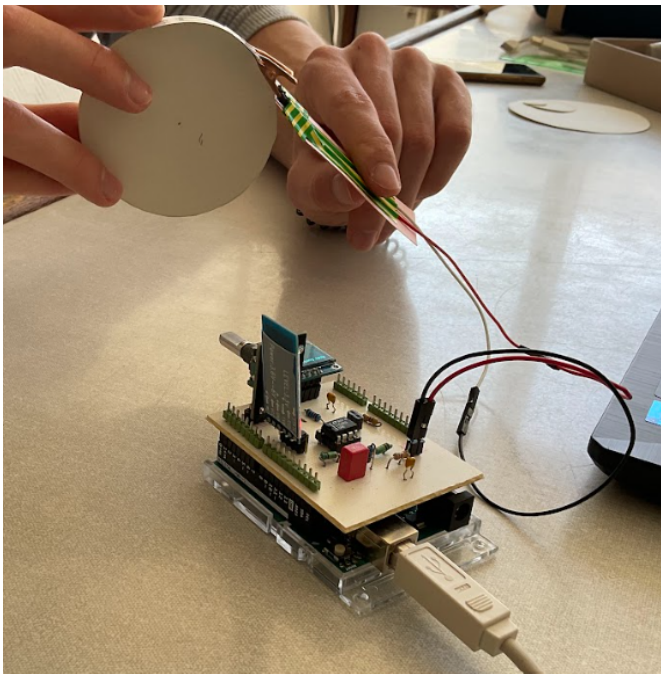
$$\varepsilon = \frac{e}{2 \times R_{curvature}}$$

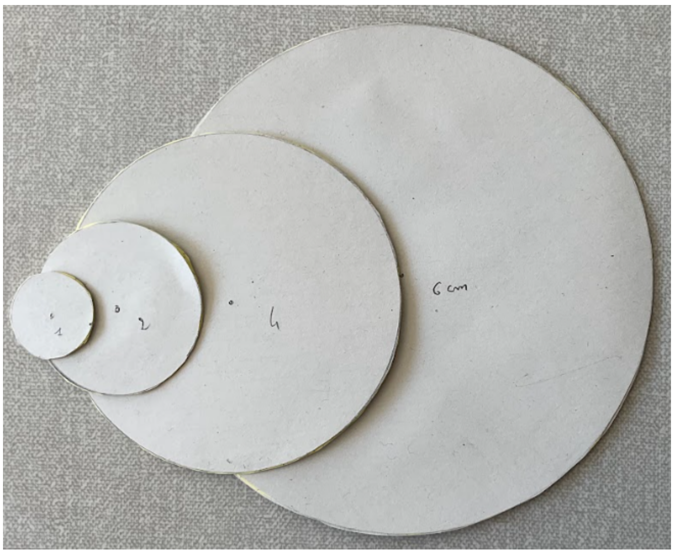
$$\text{with } R_{curvature} = \frac{d}{\theta}, \; e = 0,3\,mm$$



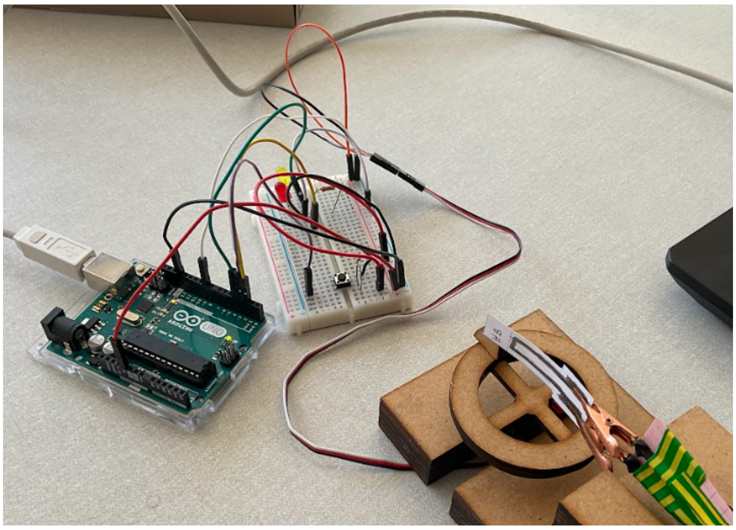
Warning: the presenting results have to be taken carefully because of difficult repeatability of the experiments. The amount of graphite deposited on the paper was not the same for each pencil and this amount decreased with time due to the contact with the metal clips and the fingers.

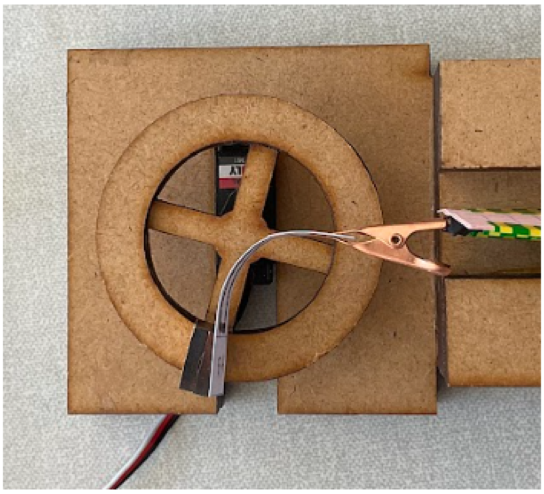
We create 4 different disks with a known radius in order to measure the variation of resistance function of the deformation, as shown on the figure below. The measurements were done in compression and flexion.





We also measured the variation of resistance in function of the angle thanks to a servo motor and an Arduino UNO as shown on the figure below. The measurements were made only in compression.





Variation of resistance in function of the deformation

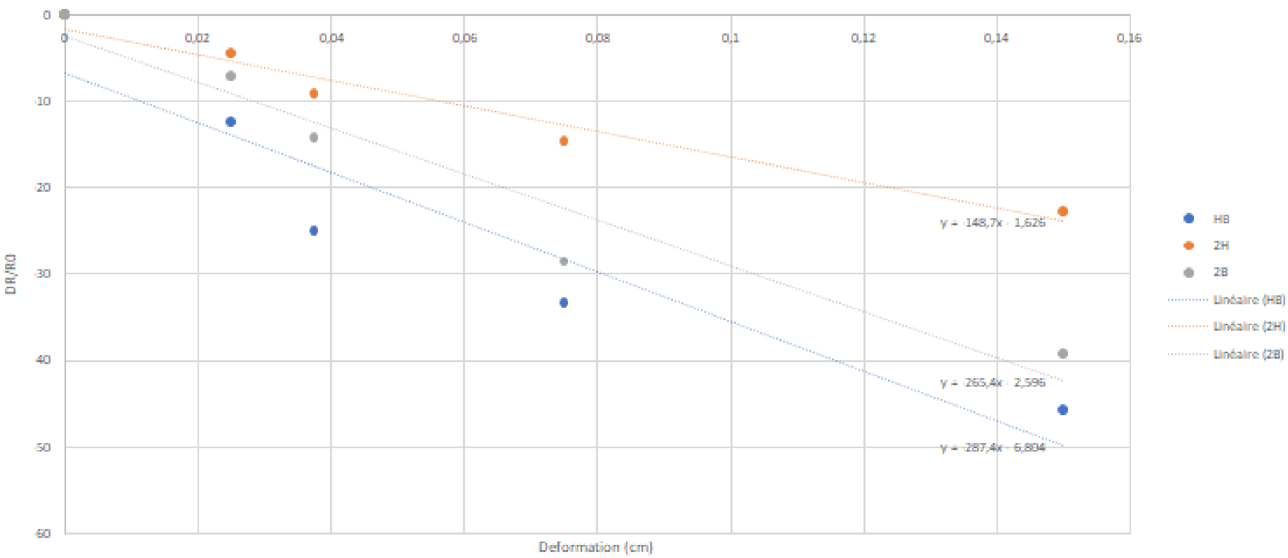


Figure 1: Variation of resistance in function of the deformation (tension)

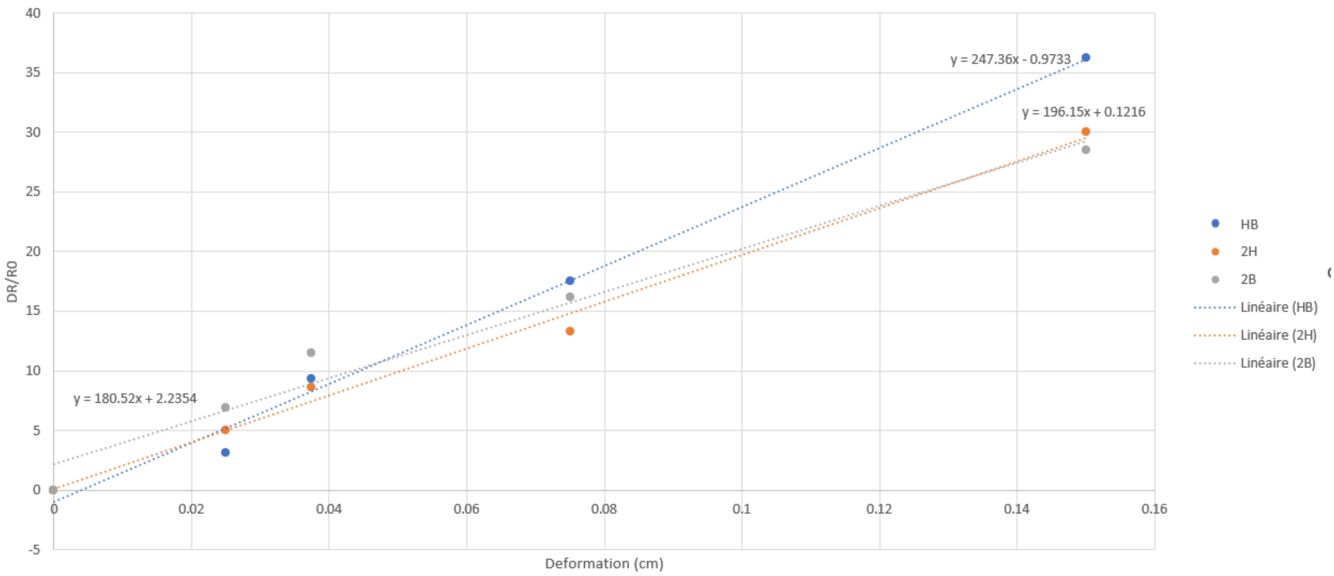


Figure 2: Variation of resistance in function of the deformation (compression)

Variation of resistance in function of the angle of deformation

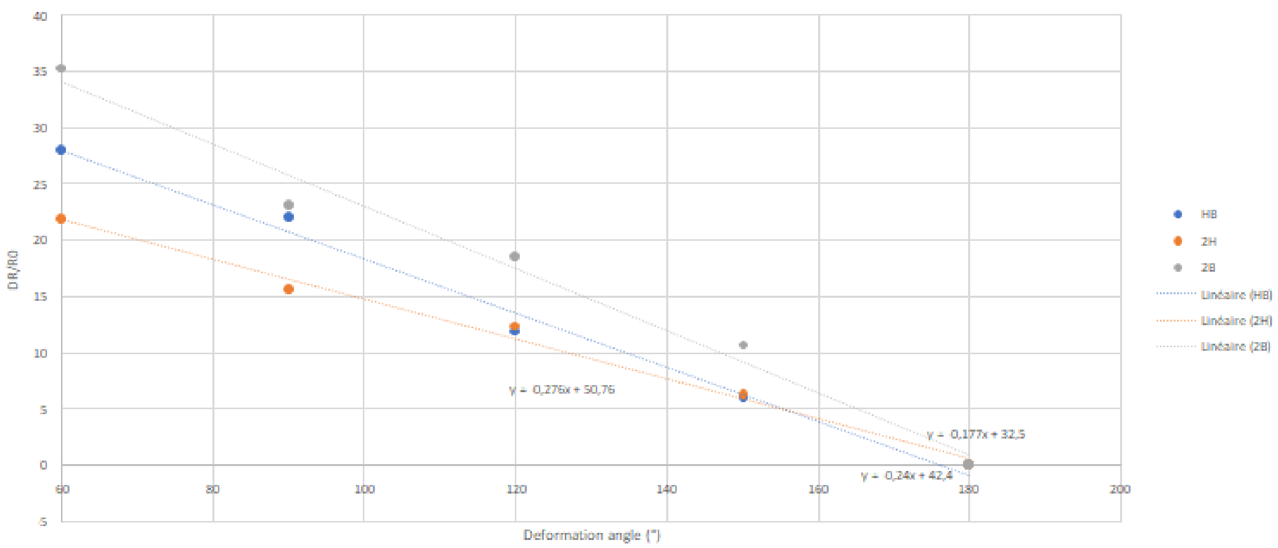


Figure 3: Variation of resistance in function of the deformation angle (compression)

Bluetooth Application

The sensor works also with a bluetooth application developed with the MIT app inventor that works on Android. The application is used to plot the output resistance of the sensor in function of the time. Here below is how the app appears on the phone: