Conductive polymers - 1. QTC: from perfect insulator to very good conductor

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Lab objectives

- Investigate the behaviour of piezoresistive materials based on different charge transport mechanisms.
- Introduce electron quantum tunneling with a hands-on approach
- Identify the necessary requirements for good sensors
- Design, implement and test pressure sensors

Features

Implies possible systematic data collection and analysis with typical school lab methodology; difficulty level: medium/ high.

From the website www.nanolab.unimore.it , in the corresponding section, it is possible to download *the* ***Complete Didactical Guide.*** Inside the guide all the experiments within the thematic area "***conductive polymers"*** are collected and described in a combined and highly integrated way**.** You will also find tips and didactical suggestions, detailed assembly instructions, different options for set ups and procedures, info about finding the necessary materials (outside standard lab equipment) and on available computer simulation or data analysis software. Curriculum alignment tips and examples on how to fit the experiments in usual classroom practice are offered together with references to research materials (external links and background reading).

What's to be observed

Investigating QTC resistance vs pressure, you may observe, differently from other piezoresistive materials, an exponential curve. This is coherent with the hypothesis of quantum tunneling charge transport whithin the polymer .

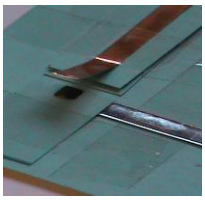
The hypothesis is further supported by the study of the IV Currente-Voltage curve which at intermediate pressure, shows a clearly non linear hysteretic behaviour, negative resistance areas, current fluctuations. All these characteristic features in fact can be easily explained in terms of electron quantum tunneling.

Equipment (for one working group only)

- QTC pill [1]
- 2 copper strips [2]
- sellotape
- Velostat[1]
- scale (±0,1 gr)
- multimeter (as ohmmeter)
- Lab masses, sand (~3 Kg)
- Eon-Tex[1]

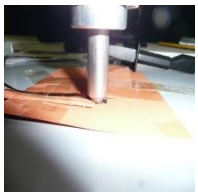
Procedure

A – Embedding QTC into the circuit

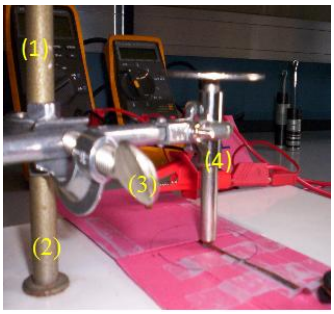


To connect the QTC pill into the circuit, put it between two thin metal strips ("embossing copper" sheets used at school in arts and crafts work fine. QTC should be in contact with the silvery side!). Fix them with tape directly on the table or any other stiff electrically insulating surface (cardboard is ok too). Careful! The two strips must not be touching in any way: Current should flow from one to the other only through QTC !

B – The circuit



Fix an horizontal bar ending with tongs(2) onto a lab post (1) with a double screw clamp (3). Tighten the tongs around a hollow cylinder.. The plate stem (4) should move smoothly through the hole.

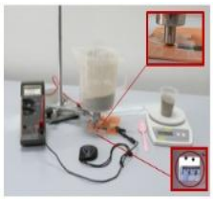


Position the copper sandwiched QTC under the point of the plate stem. Carefully center the QTC pill. Connect the two copper strips to a multimeter in ohmmeter modality. Measured resistance should be in the Mohms order. Check that the contacts work properly by gently pressing on the plate with your hand: resistance should undergo a dramatic drop.

[1] See in *Finding materials and equipment*.

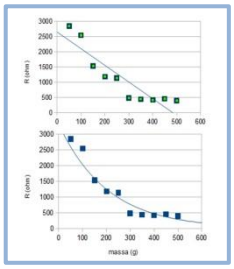
[2] Any other metal is ok. The strips should not be larger than the QTC pill while they can be as long as you like : 0.4 cm X 10 cm strips should be ok .

C-Resistance versus pressure



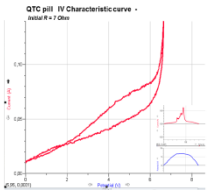
You can use either lab masses or a beaker progressively filled with sand (add a constant quantity each time). At first, when the exerted pressure is still low, the QTC resistance will fluctuate and reach a fixed value only after a while. This is why, when adding a new mass, it's extremely important to have all the readings after the same time has lapsed (say 0,5 or 1 sec). Repeat the experiment with different conductive polymers (such as Velostat or Eontex) and compare results.

D – Searching for the best fitting model



Once you have collected data, search for the theoretical model that fits the resistance VS pressure relationship best. Repeat the procedure for each sample and compare results. You can make use of the best-fit curves functionality in the electronic sheet and of specific control tables.

E – Current VS voltage



Disconnect the ohmmeter from the circuit and connect a power pack in its place. Choose a suitable mass to put on the plate and keep it constant throughout the whole experiment. Application of a mass A will produce a specific initial resistance R. Make use of current (I) and voltage (V) probes for on line data acquisition and then plot the characteristic IV curve of QTC. Repeat the procedure with different initial resistance values (owed to different applied masses). Determine whether QTC pill or alternative materials samples have an ohmic behaviour depending on initial pressure.

Finding materials and equipment

QTC can be purchased at www.mindsetsonline.co.uk £ 0.40 each pill + shipping cost (autumn 2012) – Text "qtc " in the "quick search" slot in the left coloumn.

- From this website you can also buy both a DVD and the SEP leflet -"QTC: a remarkable new material to control electricity"
- Peratech [1] offers evaluation kits to potential customers interested in developing new applications . In the kit QTC sheets and QTC cables are included (approx. 300 £).

Copper electrodes are cut out of copper sheets of the kind used for arts and crafts at school (approx. 1 euro at stationery stores). From each sheet you can get more than forty electrodes.

Velostat for sale at **3M**, or at http://www.plugandwear.com (in the left coloumn: Products→Fabrics →Conductive. ost: 9,60 euros per meter (h 91 cm). It's a traditional

piezoresistive material based on percolation.

Eontex piezoresistive fabric can be purchased at http://www.eeonyx.com/**.** Eontex is a conductive textile based on "thin film coating technology". Its fibers are coated with polypyrrole (PPY), an intrinsically conductive conveniently drugged polymer.