3D graphene grown on a nano-porous backbone: a novel material for food sensing applications

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Outline

Collaboration

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Motivation

Food sensors are known for their pervasive use in the food chain, to ensure the best preservation conditions of the food and the safety of consumers. Sensors detect the presence or concentration of an analyte or a physical parameter:

- Biological (allergens, toxins, pathogens, ...)
- Chemical (heavy metals, pesticides, ...)
- Physical (temperature, humidity, ...)

Selectivity is a key parameter.

Research on new materials and techniques boosting the sensor performance is ongoing.

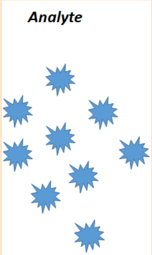
Outline

1. Motivation
   - food sensor concept
2. Porous materials
   - Beyond 2D
   - 3D graphene for sensing devices
3. Sensing food
   - Hazelnuts conservation probe

Working principle

The working scheme of a typical food sensor consists of four main parts:

- target analyte;
- recognition element;
- signal transducer;
- signal processor.



M. Weston, et al. Adv. Mat. Technol. **6** (2021) 2001242

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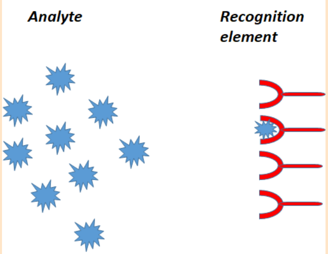

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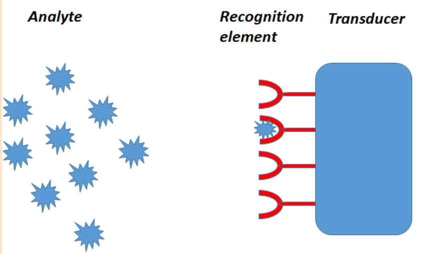

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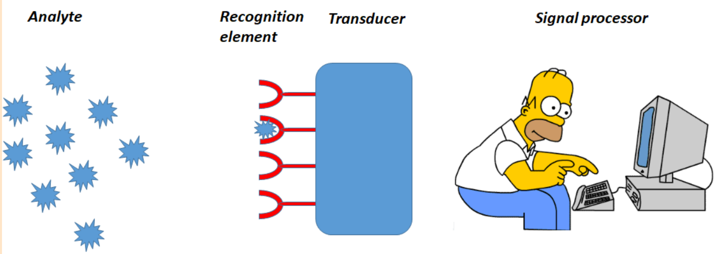

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Detection sensitivity

In order to maximize the detection sensitivity, the probability that a target analyte meets a recognition element must be maximized. This objective can be achieved:

- increasing the efficiency of the active sites;
- maximising the number of active sites per unit of area;
- increasing the useful surface.

Therefore the avaliability of materials with a large surface-to-volume ratio represents a benefit.

Graphene is widely utilized to realize sensors, electrodes, gas storage devices, ...
A three-dimensional arrangement of graphene joins the outstanding properties of this material with the request of a large active surface in developing high sensitivity detectors.

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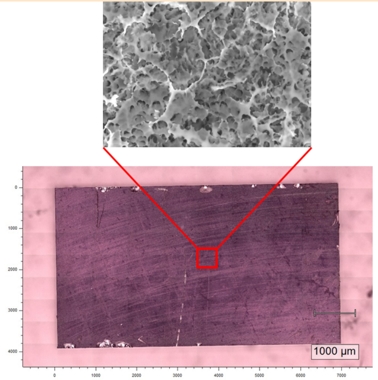
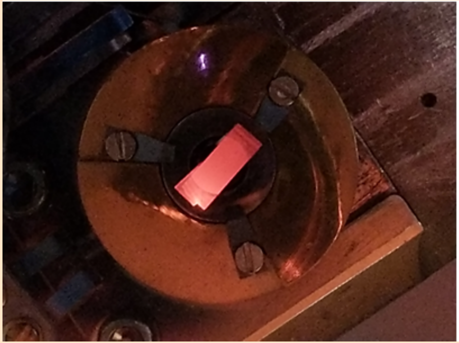
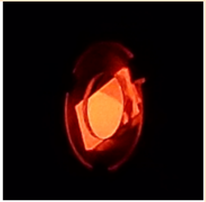
3D graphene

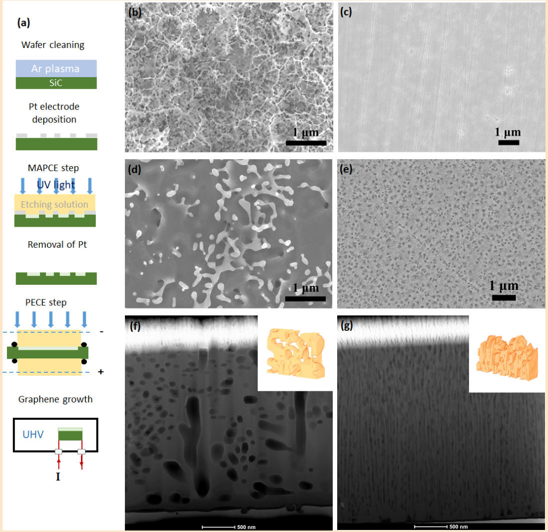
Epitaxial graphene can be grown on 4H-SiC(0001) wafers. 4H-SiC can be porousified via chemical etching. This porous substrate can then be utilized to grow graphene, which coats the surface of all pores, achieving a 3D graphene arrangement conformal to the substrate.







3D graphene



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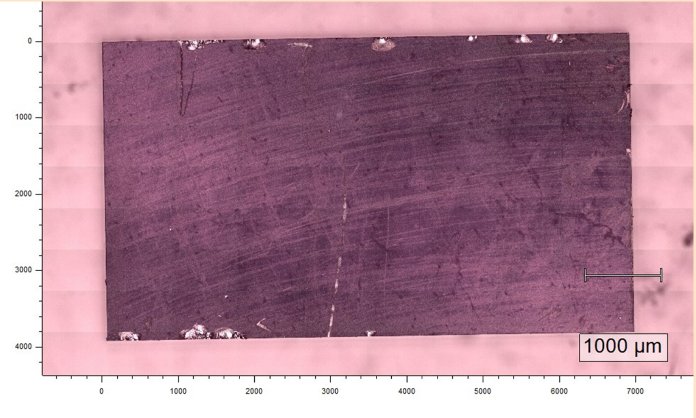
Electron tomography



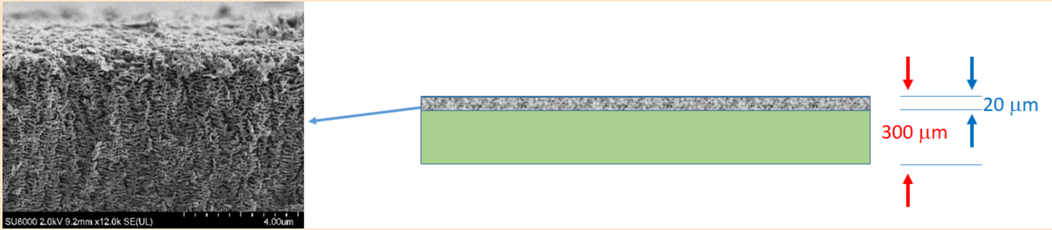
High surface-to-volume ratio

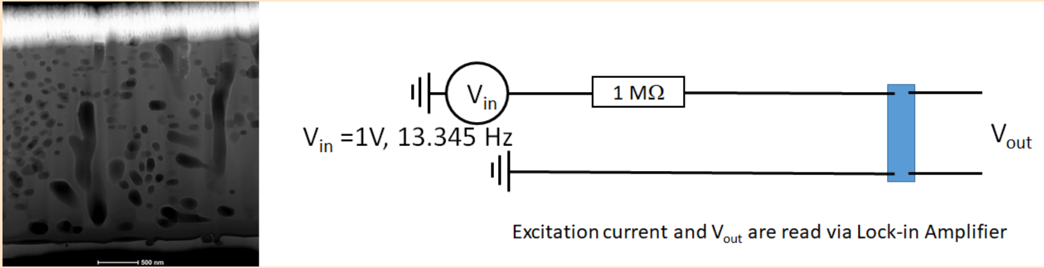
The useful surface of these porous samples ia about 100 times the top surface for every 10 μm of porous thickness.

$\Downarrow$

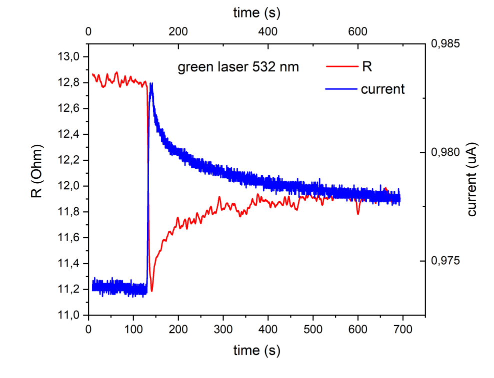
Outline

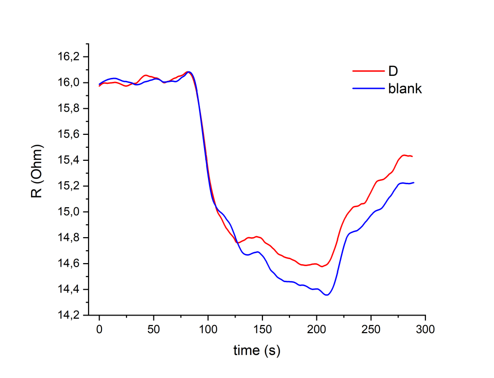
Preliminary tests for sensing devices





Sensing light and hydrogen





Black arrow points at laser off

Black arrows point at hydrogen flux on and off

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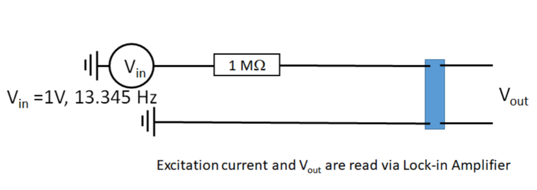
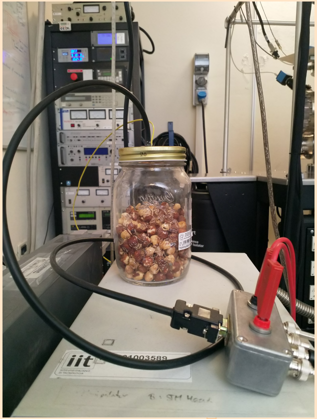
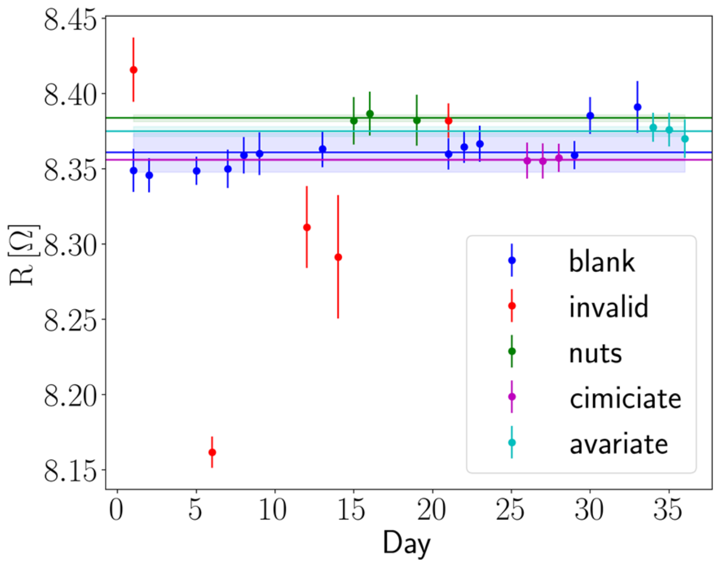
First tests

The first assessment of the performance of the 3D graphene sensor has been performed in a 4-wire configuration without active control of any other physical parameter.

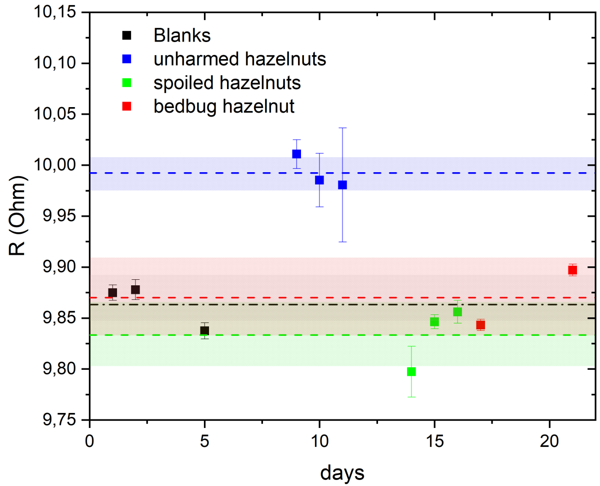




Is the sensitivity enough?



Constant temperature operation



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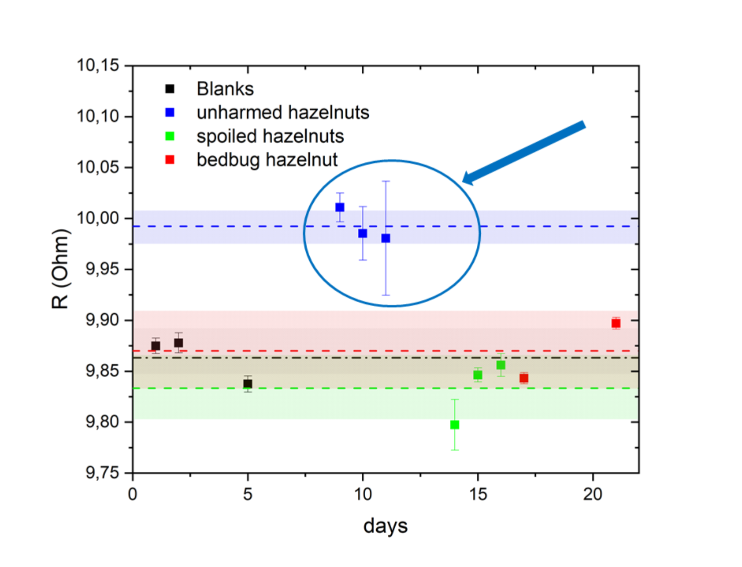

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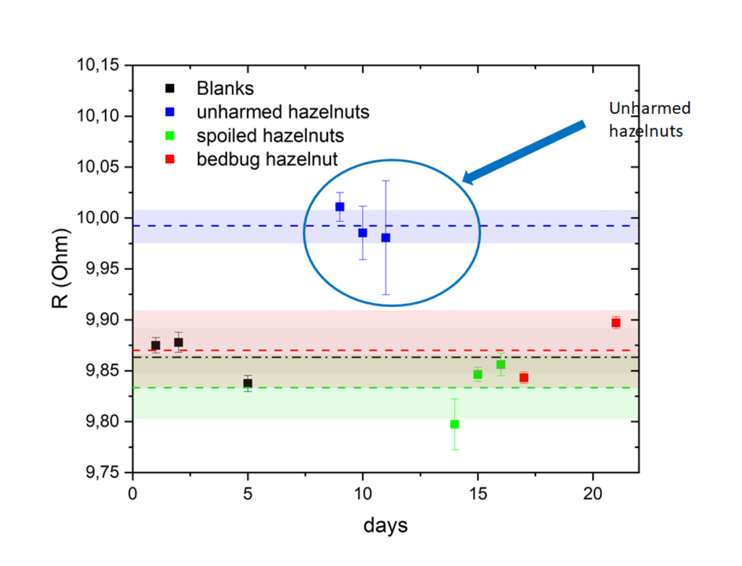

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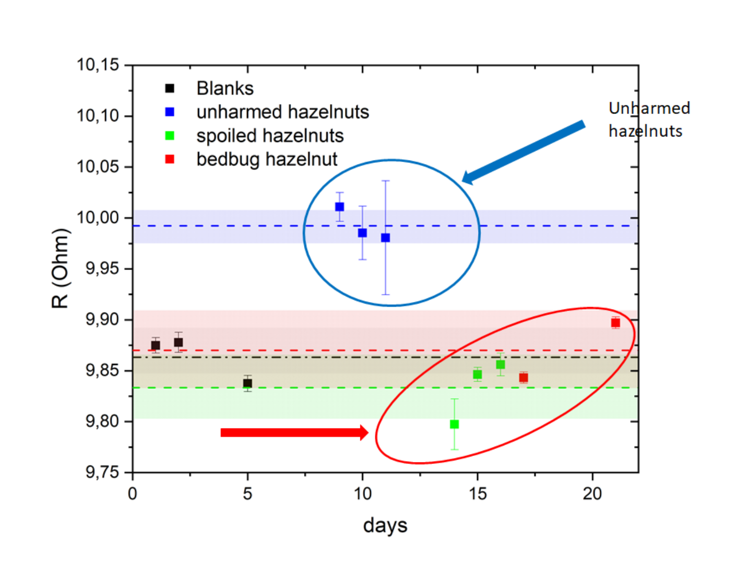

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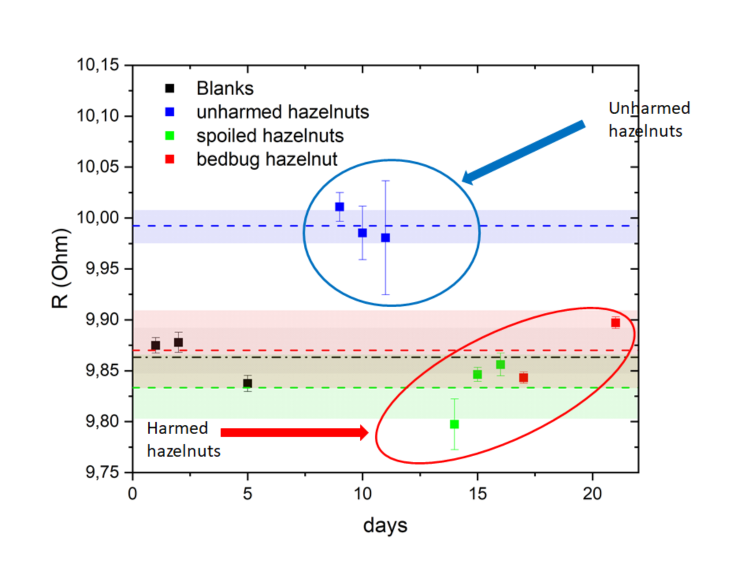

Conclusions and Outlook

The availability of three-dimensional graphene structures conformally grown on porous 4H-SiC, with a large surface-to-volume ratio, allows to fabricate sensors for the food preservation chain.

- differentiation between hazelnuts harmed/unharmed
- sensing layer on a semiconductor substrate
- customizable sensor shape and dimensions

Outlook

- 3D-graphene functionalization (experiments with metal nanoparticles are ongoing)
- implementation of a gas flow analysis for measurements "in the field"
- possibility of readout electronics on the sensor substrate

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Thanks

Thank you for your attention