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MACRO-SCALE CONTACTLESS CHARACTERISATION OF GRAPHENE-BASED TRANSPARENT ELECTRODES

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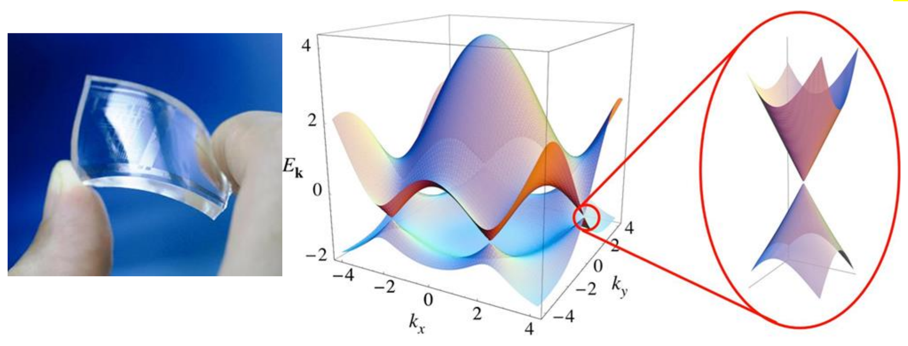
Motivation & Objectives

Why use Graphene? Unique properties[1]:

- Flexibility
- Conductivity
- Transparency
- Mechanical resistance
- No energy gap
- Environmental stability



Desired properties to be used as Transparent Electrode (TE)

Possible technological application

Graphene in Photovoltaic sector[2]: Which technology to be used?

⇨ Low temperature reliable solution: Silicon-heterojunction (SHJ) technology:

☑ Promising approach

☞ To extract the current more efficiently (Not loosing optical performance)

☹ Main bottleneck to reach the industrial production scenario:

→ Quality production control at large areas

→Objective: Efficient macro-scale + non-destructive contactless mapping methods

(1) To evaluate key Graphene performance indicators

(2) To determine Graphene suitability, depending on the field application

(3) To determine the uniformity + quality Graphene-transfer process

GRAPHENE SYNTHESIS AND TRANSFER

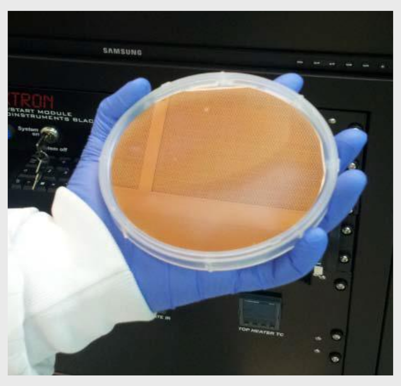
⇨ Aixtron BM Pro Chemical vapor deposition (CVD)

Fabrication steps:

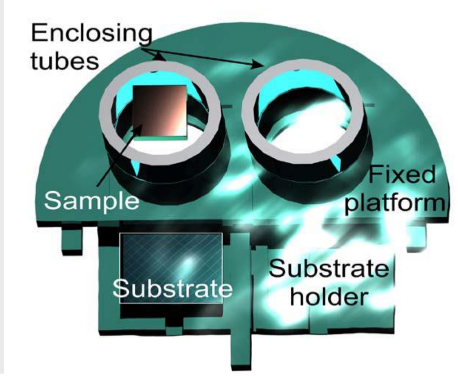
(1) Heating : Ar

(2) Deposition: H_2 +Ar +CH_4

(3) Cooling



- 4-inch substrates: Cu foil or Cu/SiO2/Si(111) wafers
- ✓ Single layer graphene, defect free



Patent ES 2 536 491 B2; WO2015/075292 A1 [3]

Automatic system ensures:

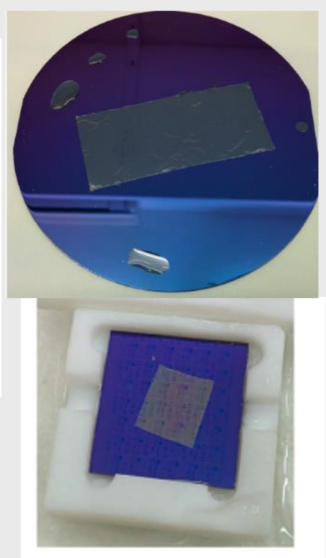
(1) Self-centering system

(2) Liquid flow control

(3) Arbitrary substrate types

(4) Reproducibility

(5) Scalability to technological route

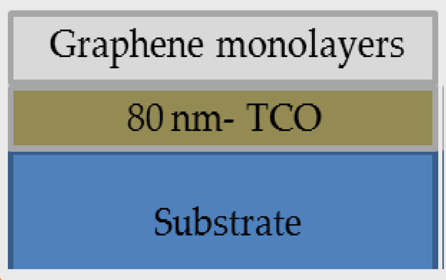


Transferred graphene

✓Single layer graphene, with improved electrical performance

CHARACTERISATION OF GRAPHENE-BASED TRANSPARENT CONDUCTIVE ELECTRODES: Meso-scale contactless mapping methods

Analysed TCE structure



(1) TCE Structure: (i) *Graphene monolayers (GML)*: 3 + (ii) *TCO*: 80-nm thick ITO film[3]

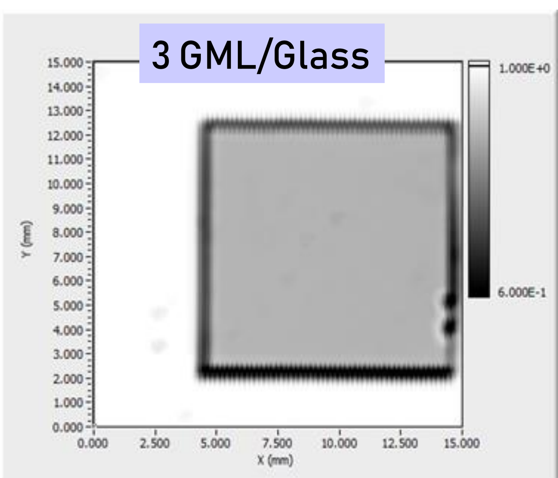
(2) Substrates: Corning glass and Silicon

(3) Application field: Front-electrode for SHJ solar cell technology

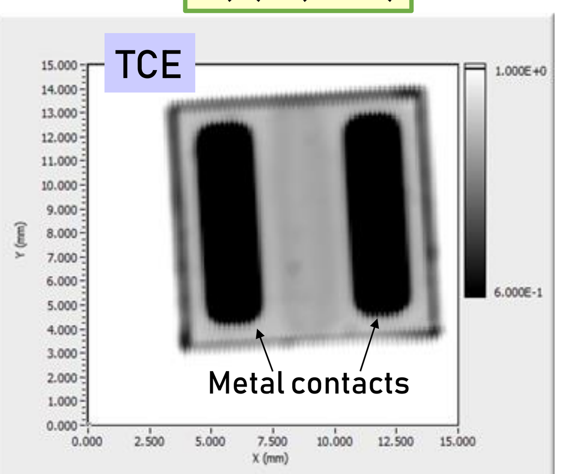
Optical parameters

⇨ Optical transmission mapping home-made system:

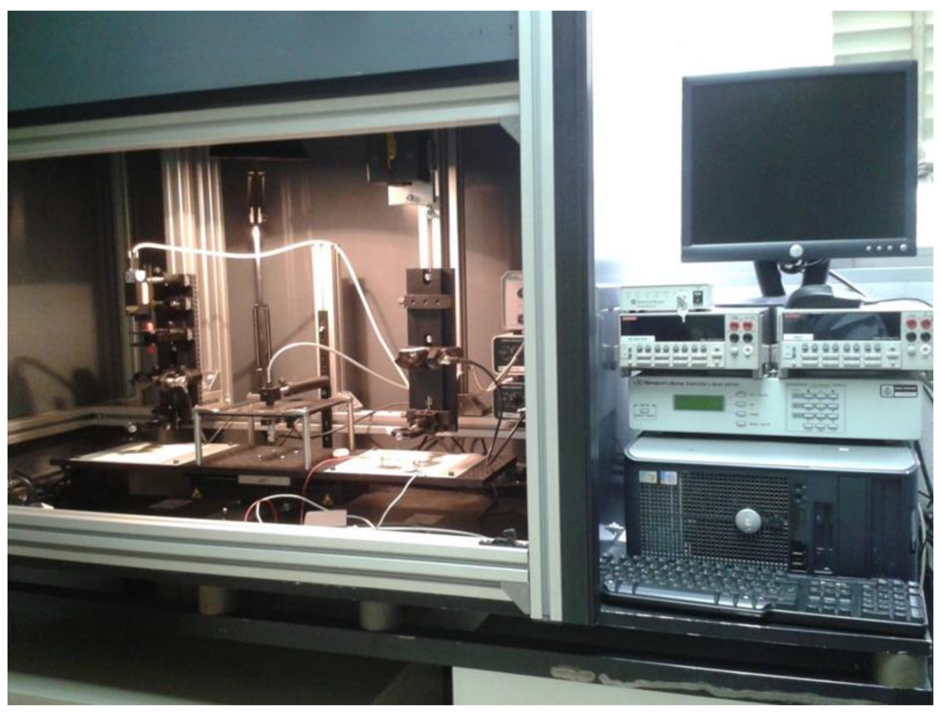
- Focused white-light lamp
- X-Y positioner set
- Current preamplifiers
- Reference photodiode
- Digital voltmeters



T (%) = (93 ± 1)



T (%) = (81 ± 1)



(1) At room temperature

(2) No need sample preparation

(3) Large areas analysed

☞ Good homogeneity in optical maps:

⇒ High *reproducibility* of transfer-method

☞ Transmittance, close to theoretical value:

⇒ High *quality* of Graphene material

Electrical parameters

⇨ ONYX SYSTEM from Company[*]: das-Nano

(1) THz time-domain spectrometer

(2) Contactless and non-destructive

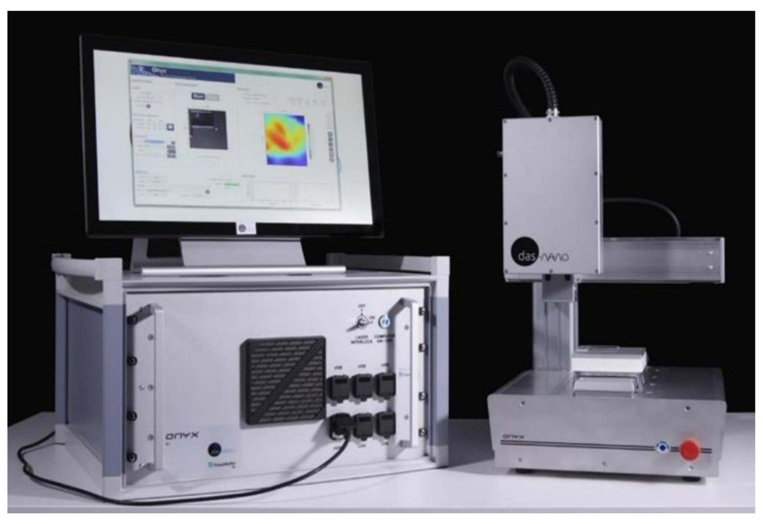
(3) Industrial quality control tool

(4) High speed analysis of large areas

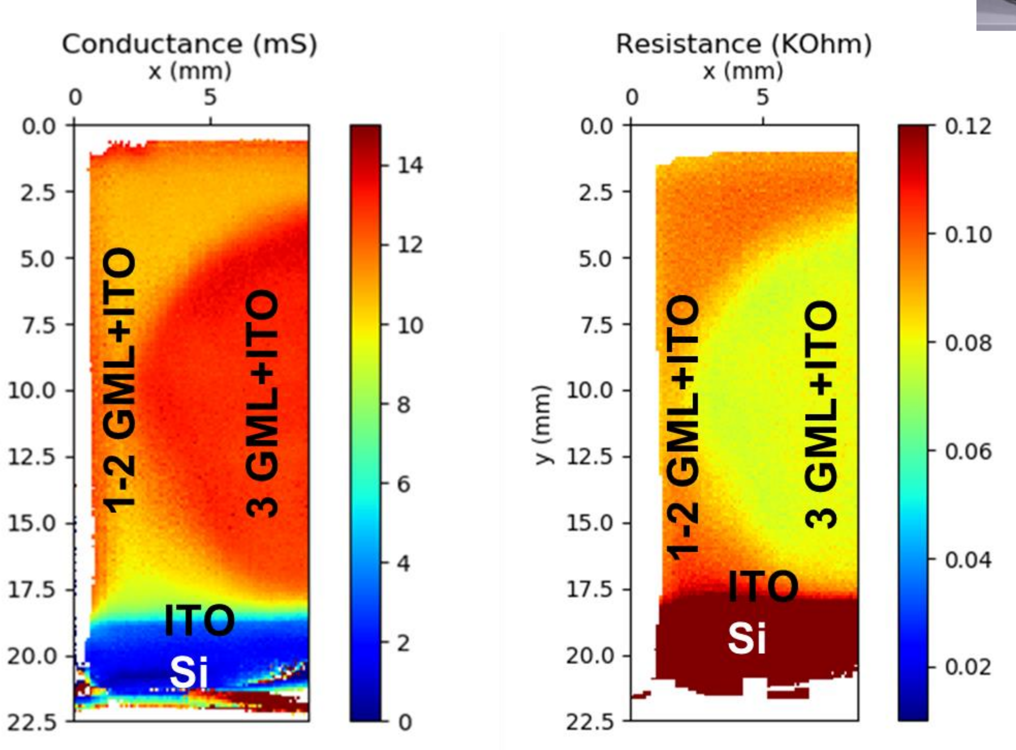
(5) Reflection mode operability

(6) No need for sample preparation

(7) Room temperature measurements



[*] https://www.das-nano.com/



DC Conductance, σ_{DC} DC Resistance, R_{DC}

[*] Azanza, E. et al., S.L. Quality inspection of Thin films materials. US Patent, US 10,267,836 (B2), 2019 April 23: das-Nano

☞ High sensitivity to small variations ⇒ *Goodness* of transfer-method

☞ Determination of electrical parameters ⇒ *Key* Graphene *indicators* + *Suitability* of Graphene-based structures

CONCLUSIONS

⇨ Use of these approaches allows opening new horizons to achieve the definitive take off of Graphene-based technologies.

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[4] A. Bosca et al., Sci. Rep. 6 (2016) 21676.

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