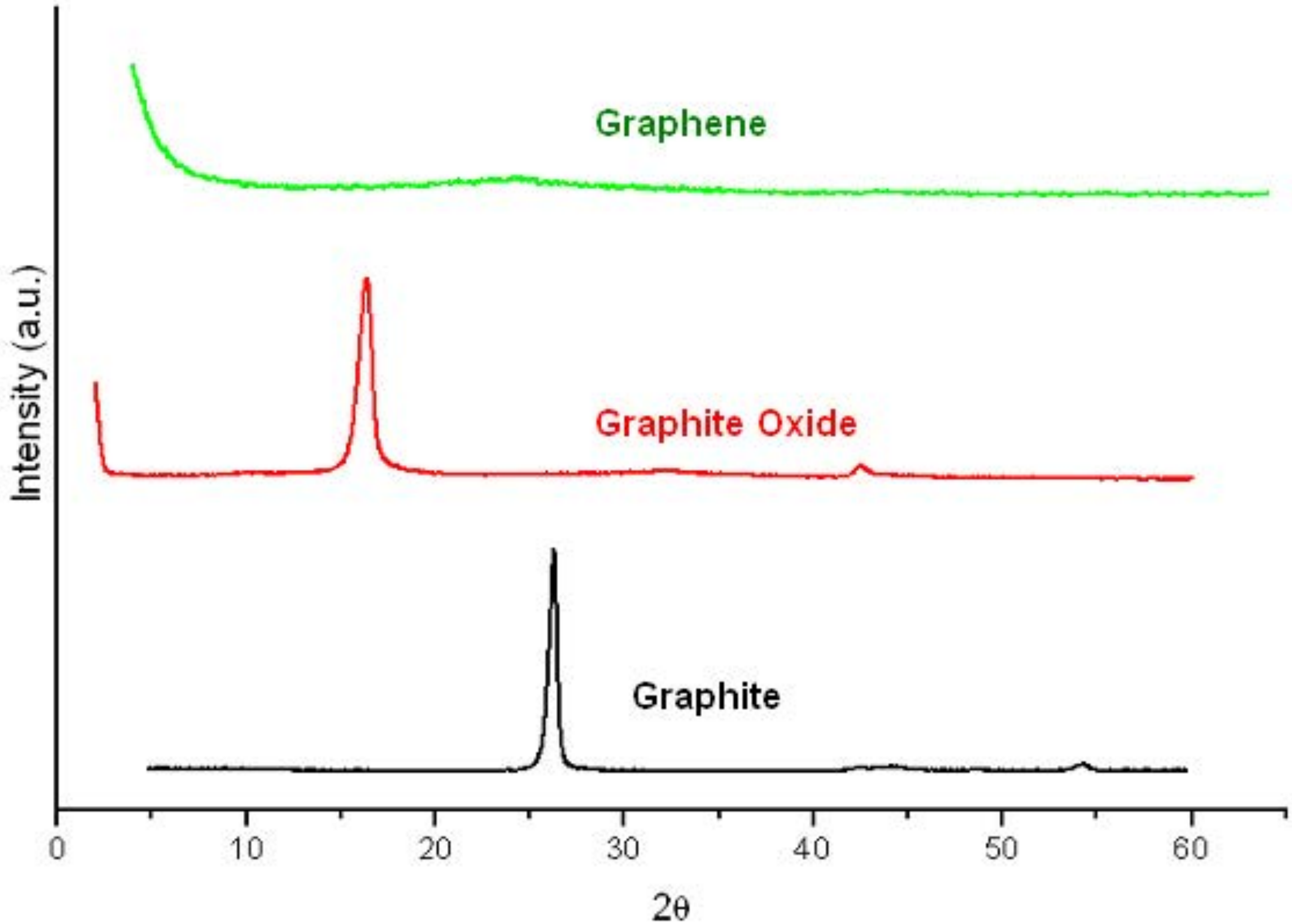
Incorporation of reduced graphene oxide sheets into organic media for the realization of conducting and photoresponsive nanocomposites

Luca Valentini

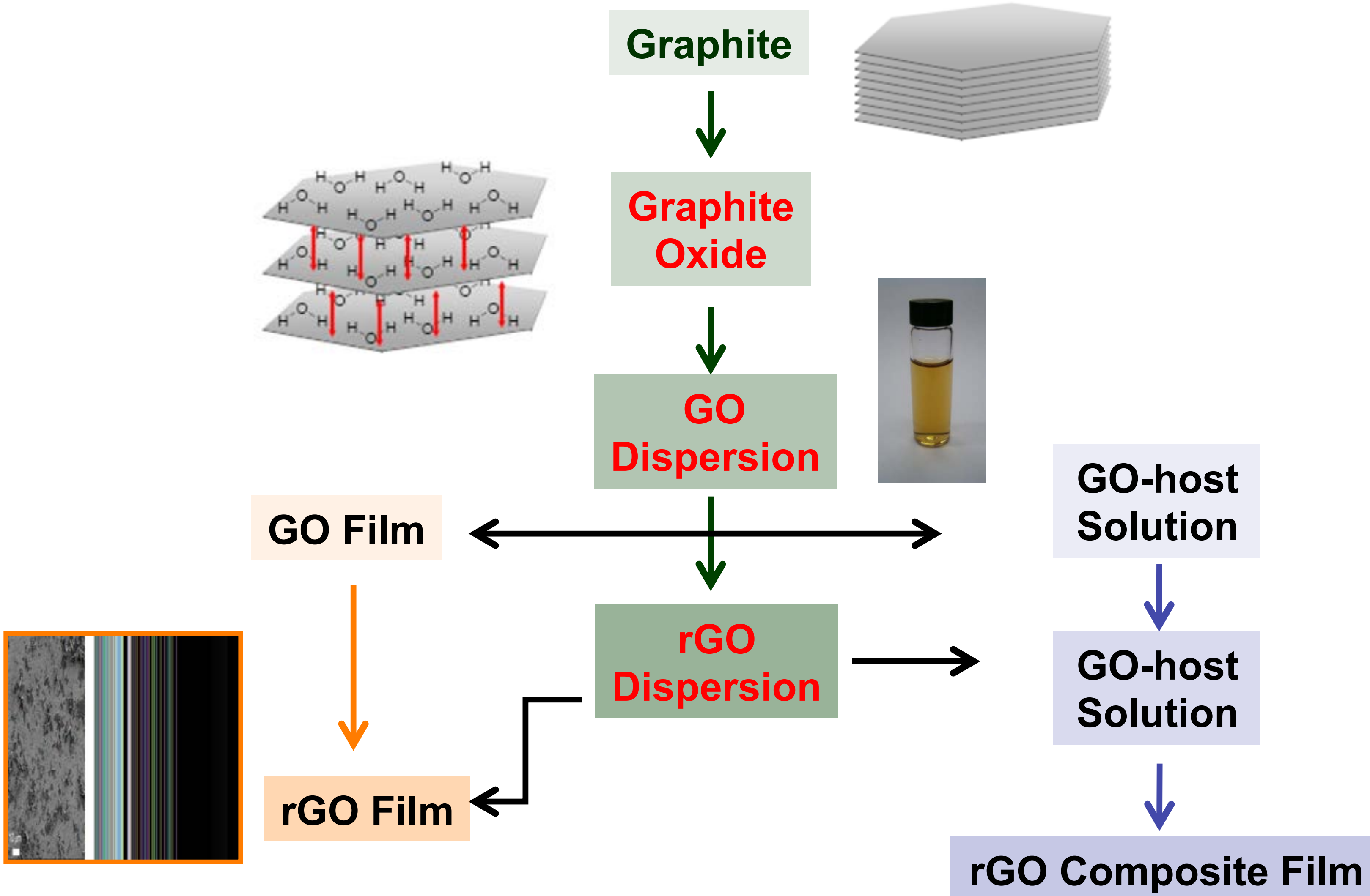
Civil and Environmental Engineering Department, University of Perugia, INSTM - Perugia Research Unit, Strada di Pentima 4, 05100 Terni – Italy

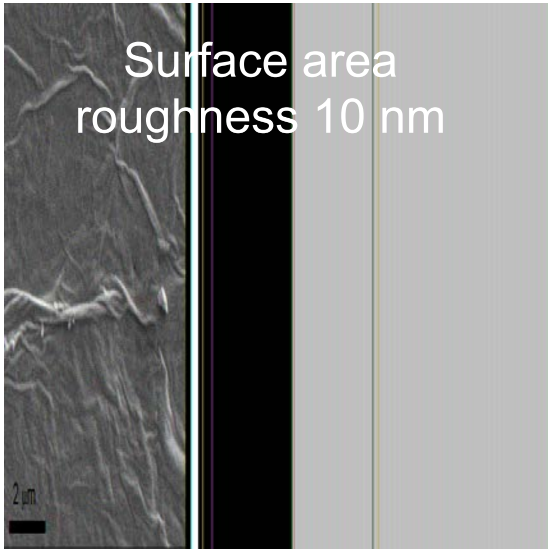
OUTLINE

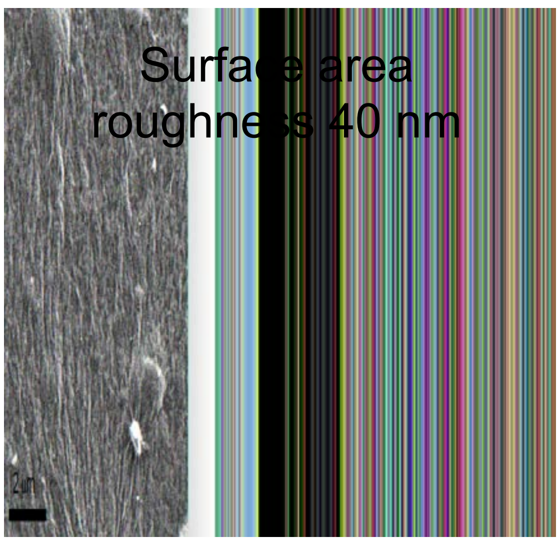
- **What is a *graphene oxide platelet (GOP)*?**
- **How are GOPs made?**
- **Unique features of GOPs.**
- **Potential applications of GOPs in polymer nanocomposite.**
- **Current research issues.**

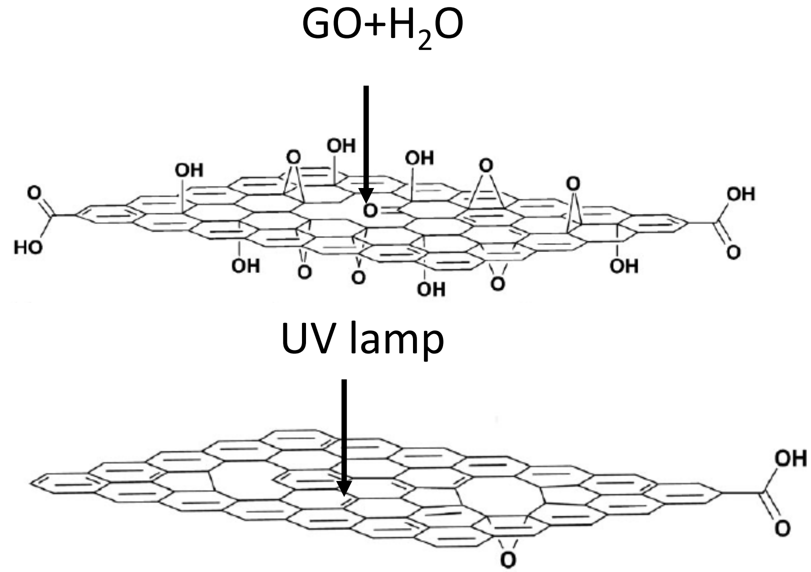

Graphene
Graphite Oxide
Graphite
Intensity (a.u.)
0
10
20
30
40
50
60
2θ

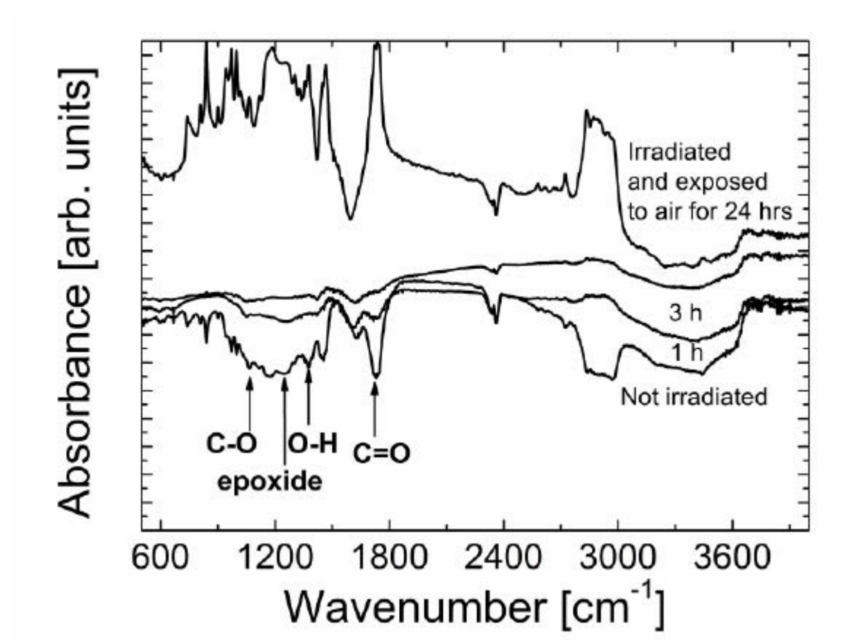
PRODUCTION AND PROCESSING of GRAPHENE OXIDE

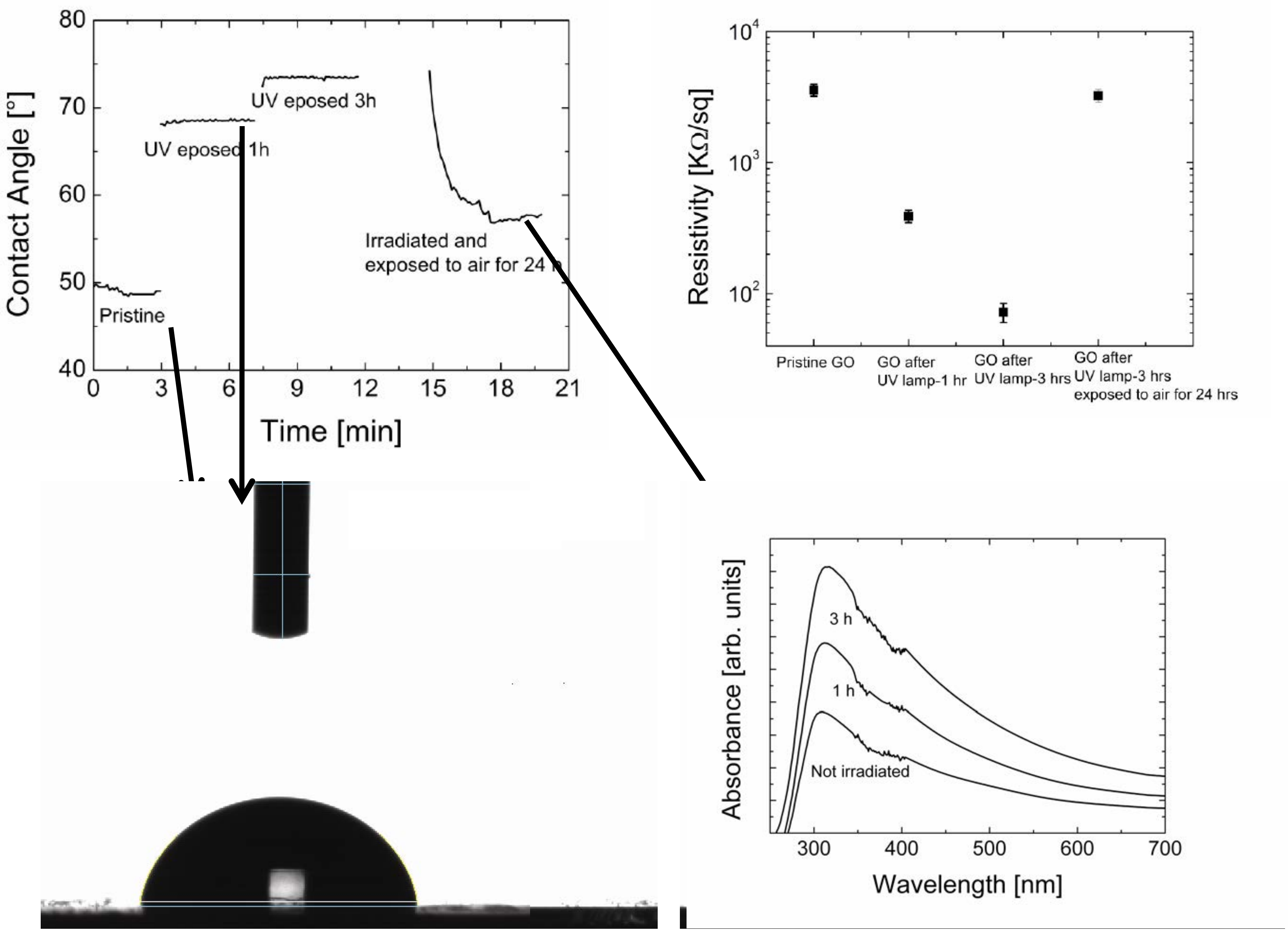



Surface area
roughness 10 nm
2 μm

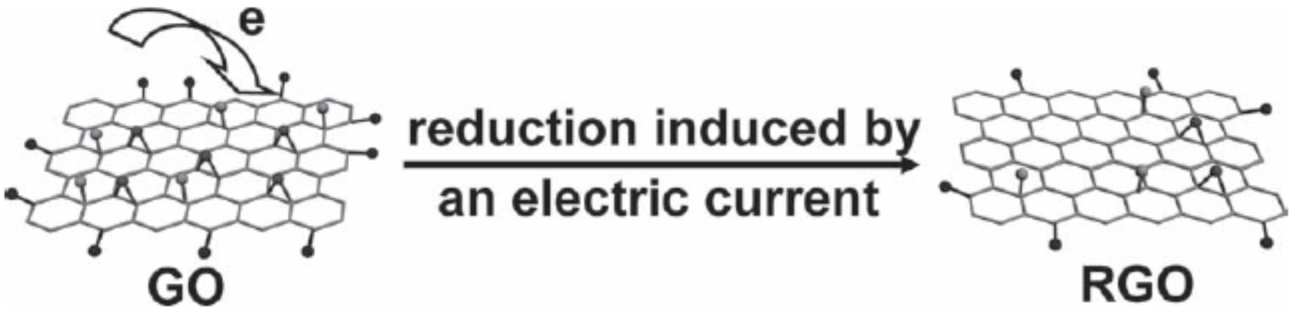

Surface area
roughness 40 nm
2 μm


GO+H_2O
UV lamp
OH
O
HO


Absorbance [arb. units]
Wavenumber [cm^{-1}]
600
1200
1800
2400
3000
3600
Irradiated
and exposed
to air for 24 hrs
3 h
1 h
Not irradiated
C-O
epoxide
O-H
C=O

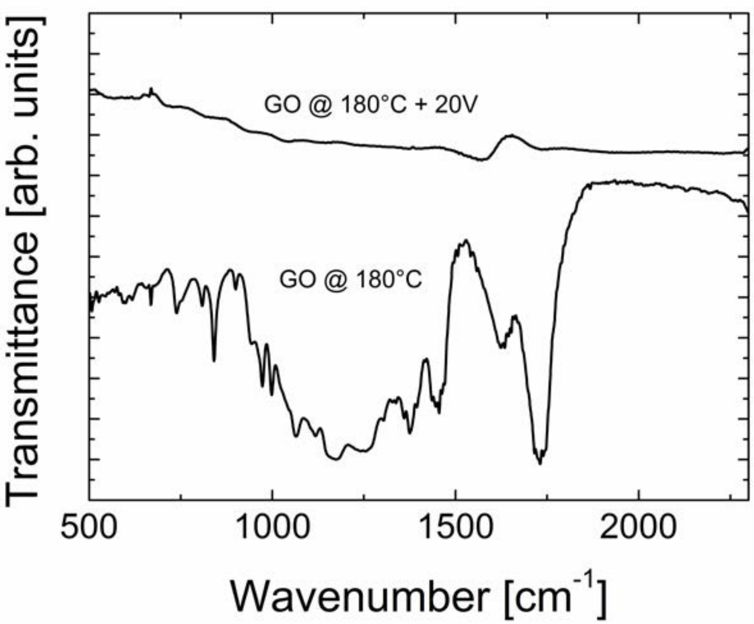


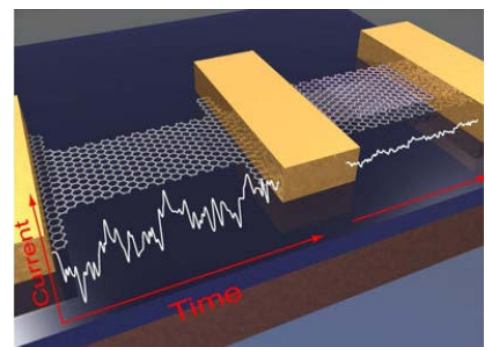
S. Bittolo Bon et al., (in press)



Scheme 1. Reduction of GO by applying an electric current through a GO film. The ball & stick models represent carboxyl, hydroxyl or epoxide groups.

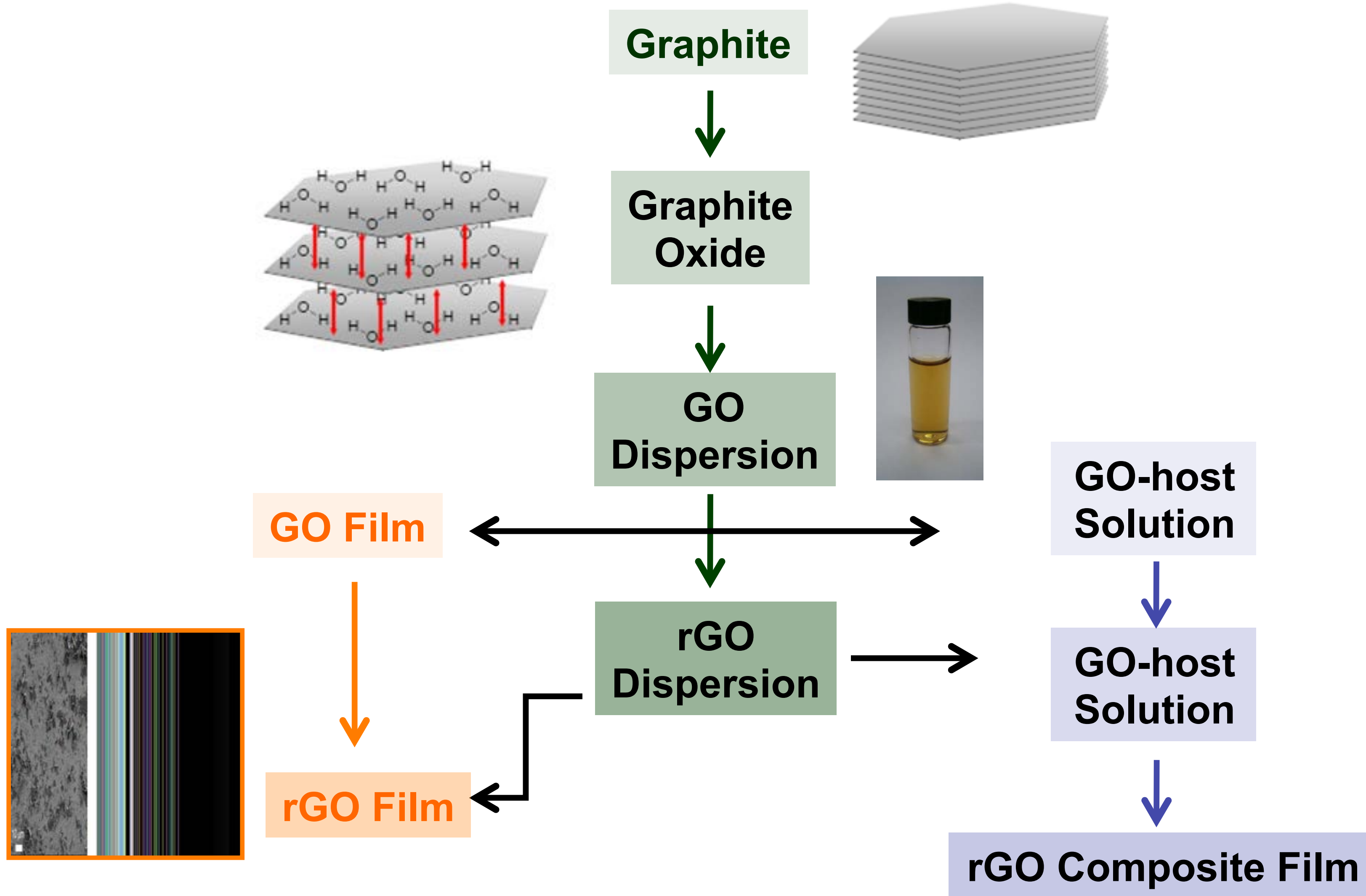
P. Yao et al., Adv. Mater. 2010, 5008 , 22, 5008

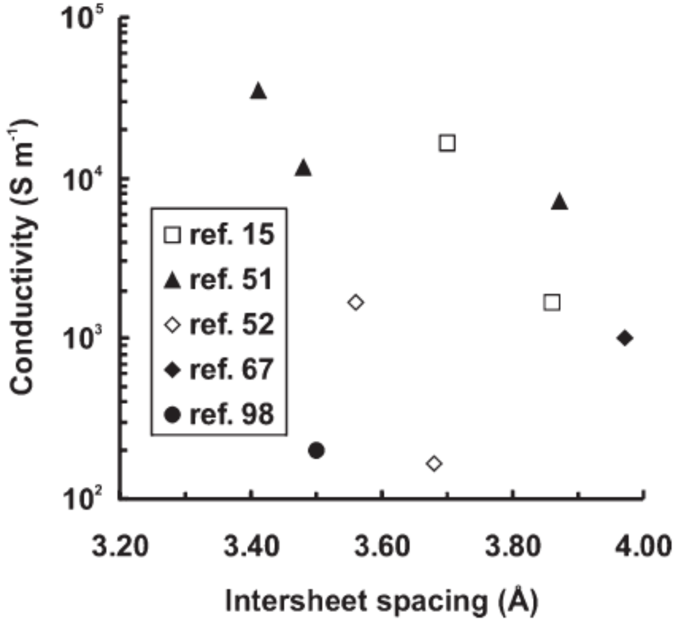




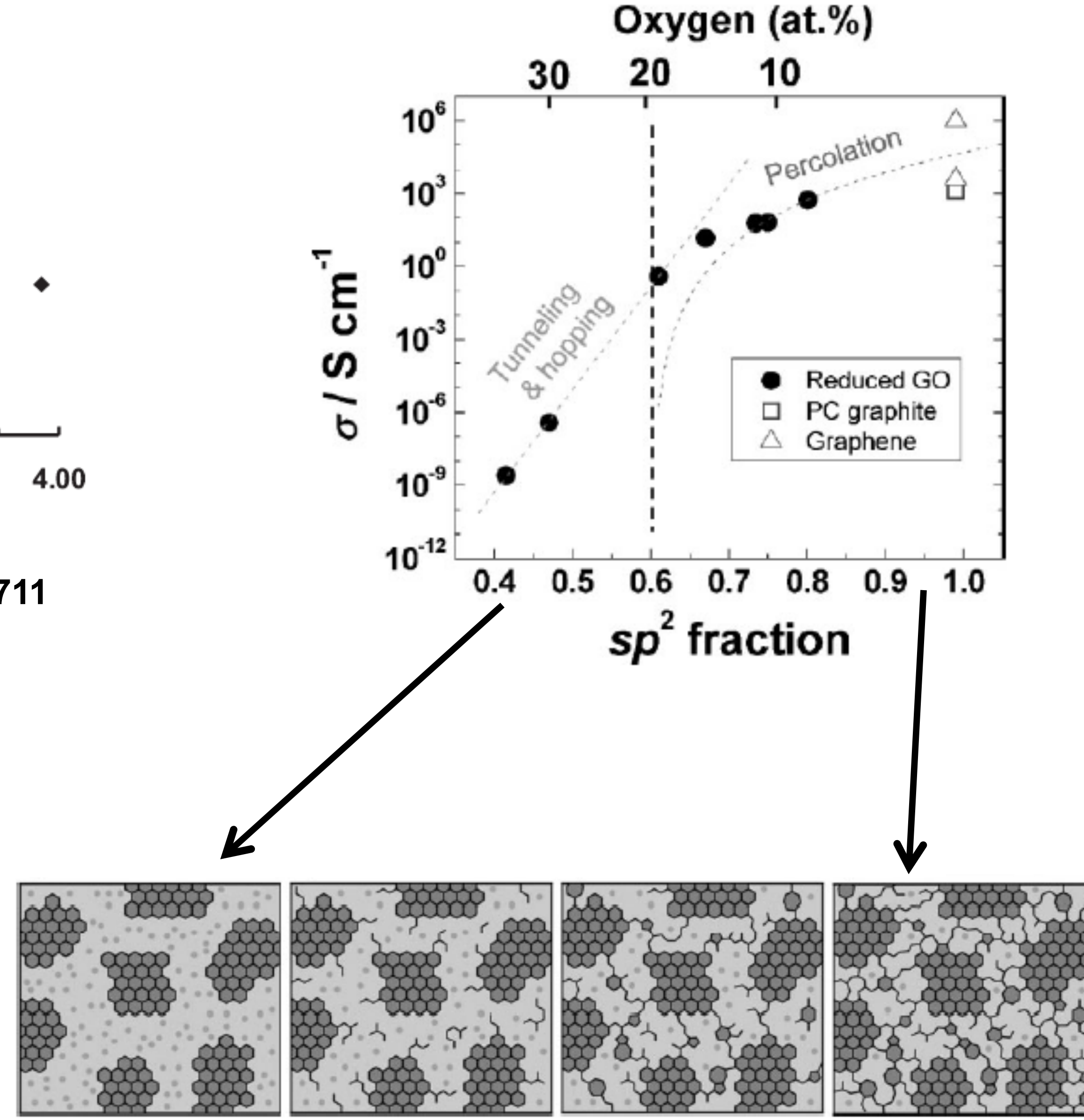
C=O carbonyl stretching at 1733 cm^{-1}
O–H deformation vibration at 1412 cm^{-1}

PRODUCTION AND PROCESSING of GRAPHENE OXIDE



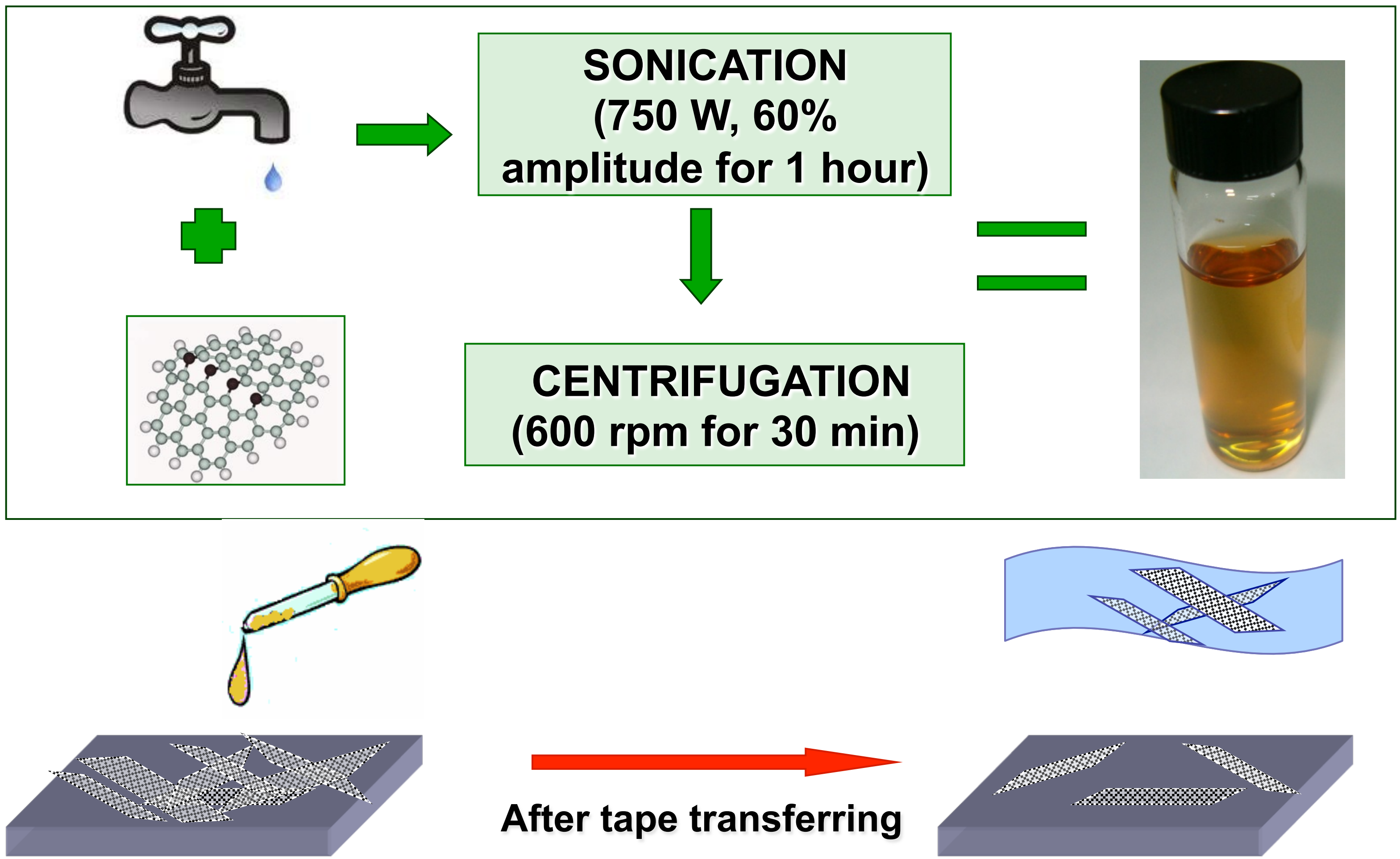


O. C. Compton et al., Small 2010, 6, 711

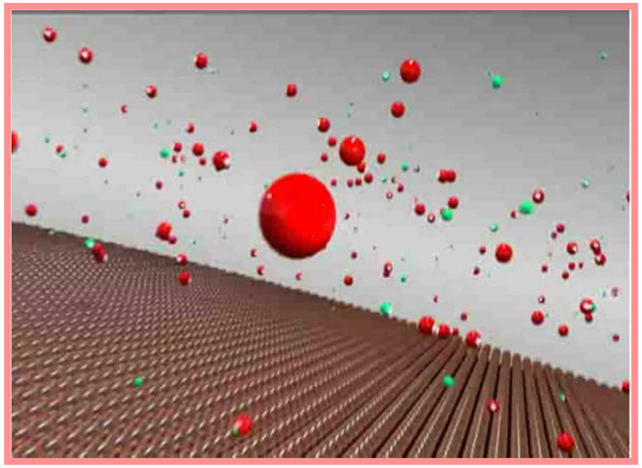


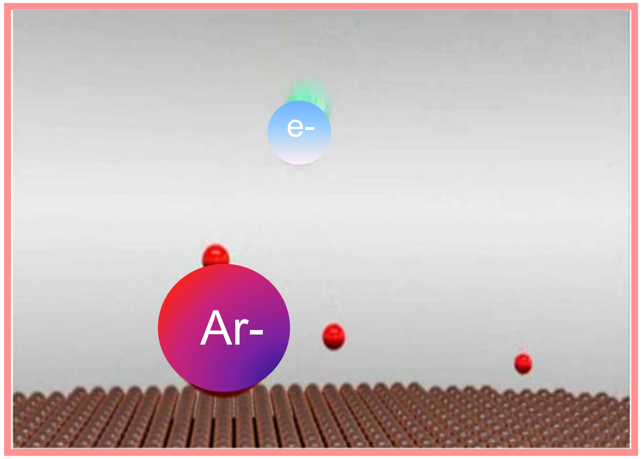
C. Mattevi et al., Adv. Funct. Mater. 2009, 19, 2577

PRODUCTION and PREPARATION of GOPs



PLASMA THINNING



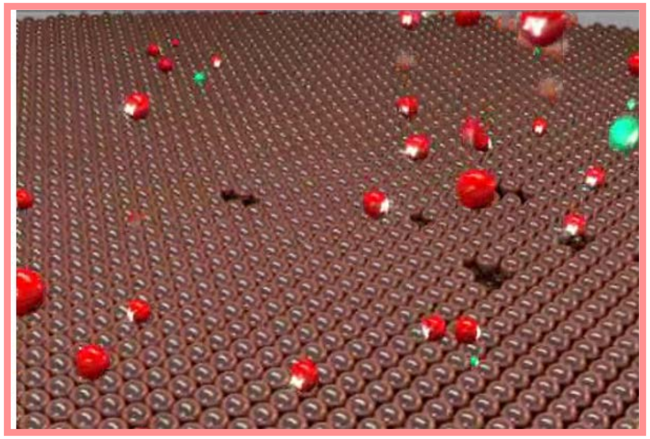


Pressure: 0,2 mTorr

Flow rate: 20 sccm

Power: 25 W

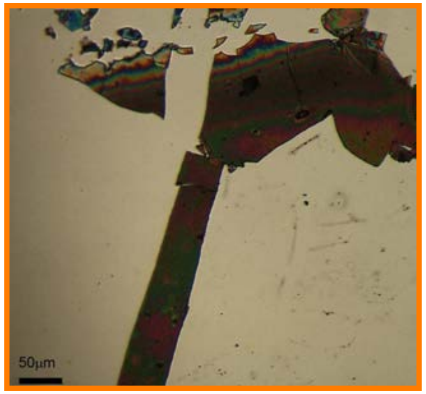
Bias: 200 V



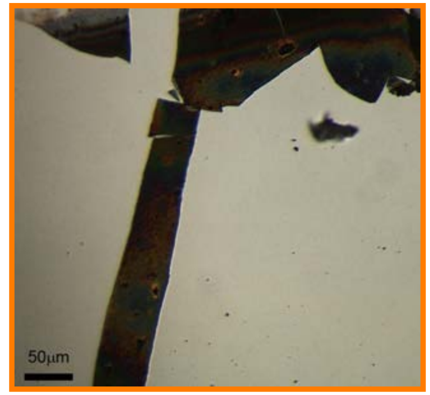
Time of treatment:

5', 20', 40'

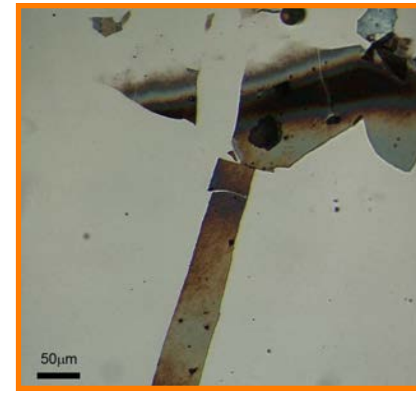
PLASMA THINNING



5 '

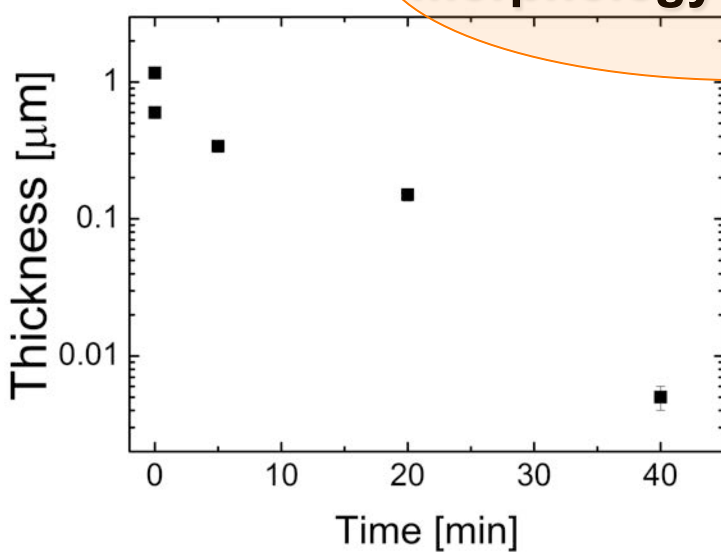


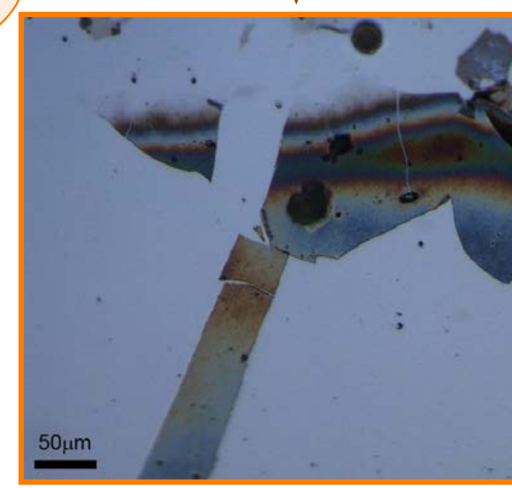
20 '



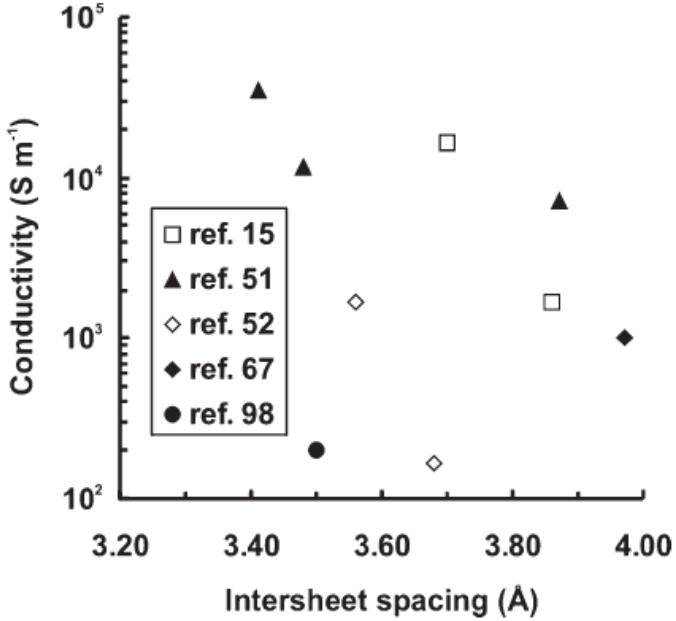
40 '

Plasma effects on morphology and thickness

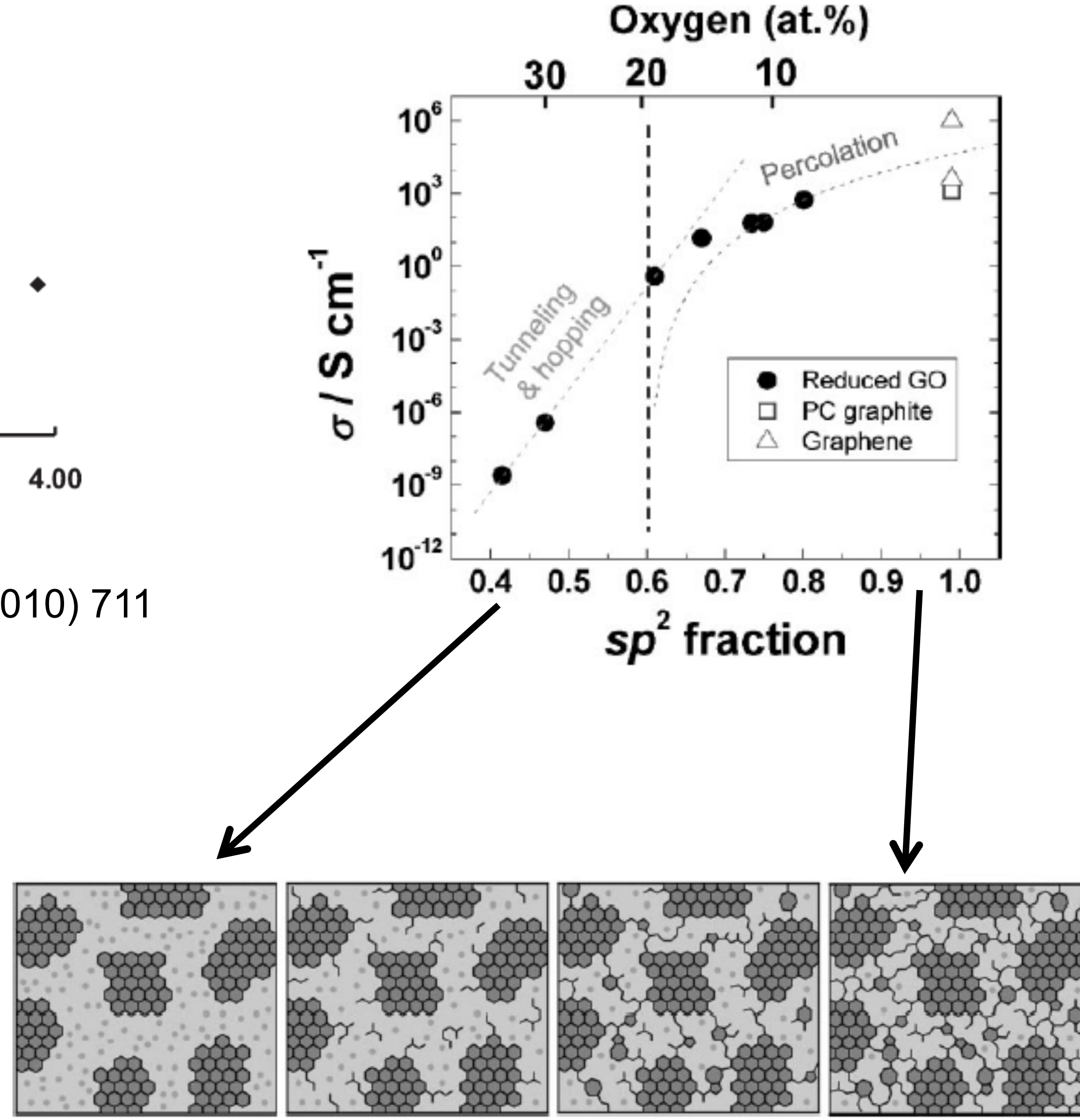




M. Cardinali et al.,
Chem. Phys. Lett. (in press)

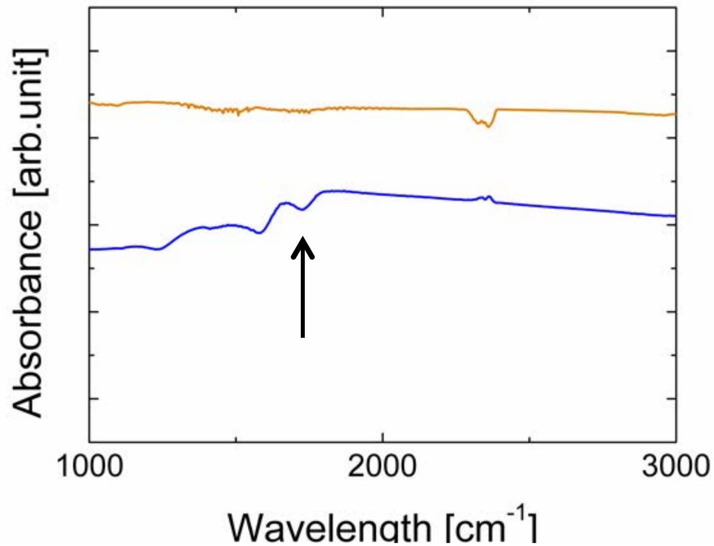


O. C. Compton et al., Small 6 (2010) 711



C. Mattevi et al., Adv. Funct. Mater. 19 (2009) 2577

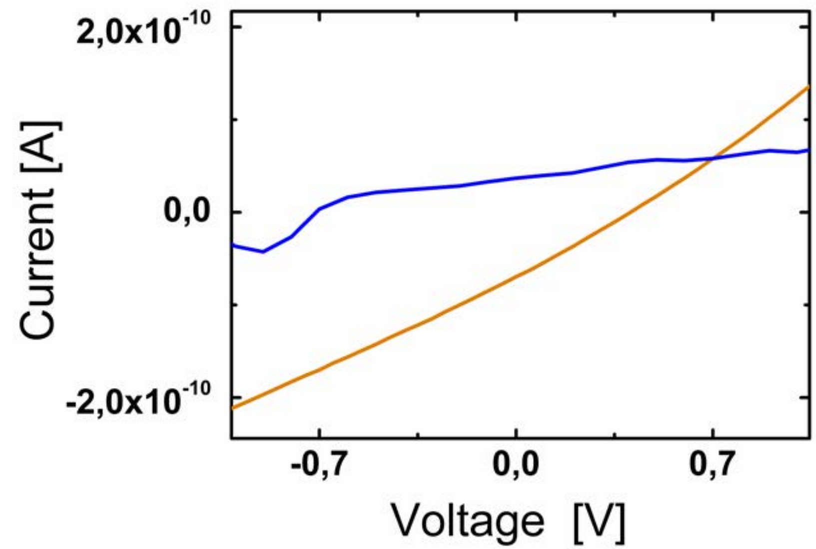
PLASMA REDUCTION



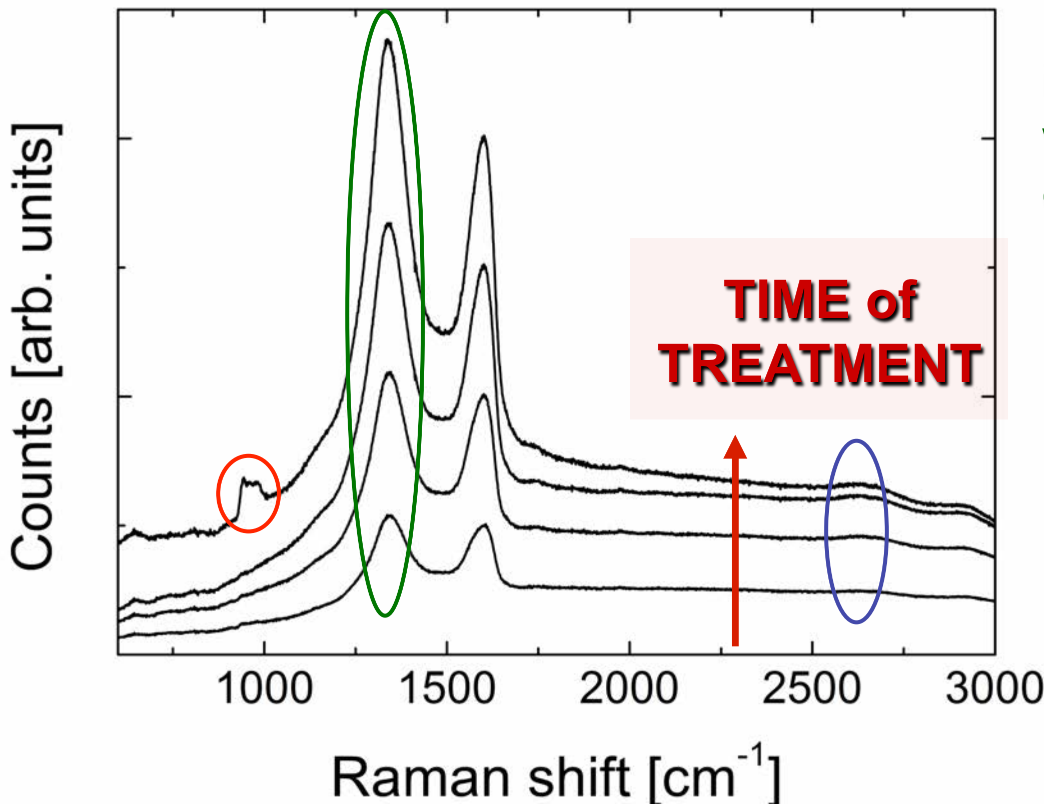
GOPs after 40‘ of Ar PLASMA

UNTREATED GOPs

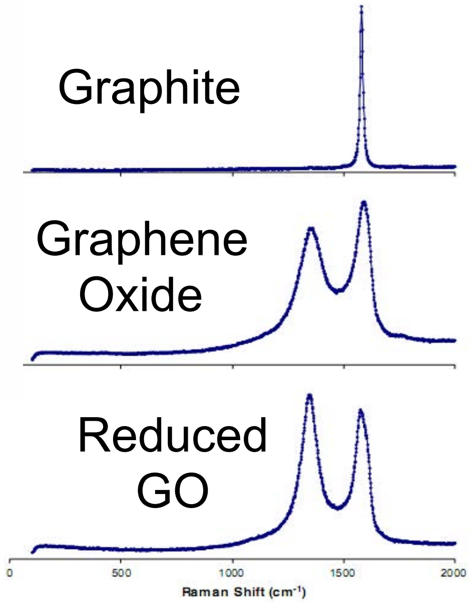
1733 cm^{-1} C=O carbonyl stretching



RAMAN



D peak (~1340 cm^{-1}): increases with disorder (i. e. with the plasma treatment), decrease of FWHM

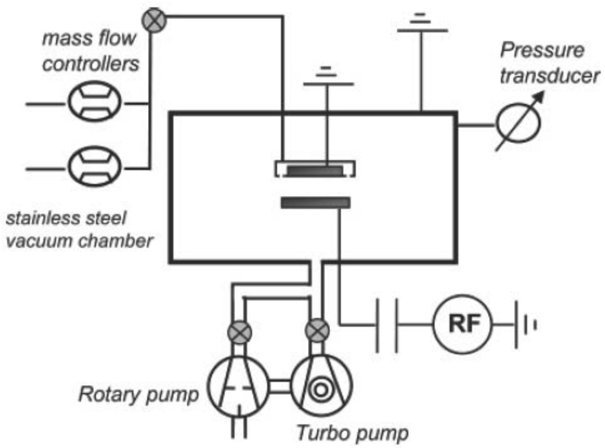


2D peak (~2646 cm^{-1}): induced by layering

Si peak (~960 cm^{-1}): thinning

S. Stankovich et al., Carbon 45 (2007) 1558

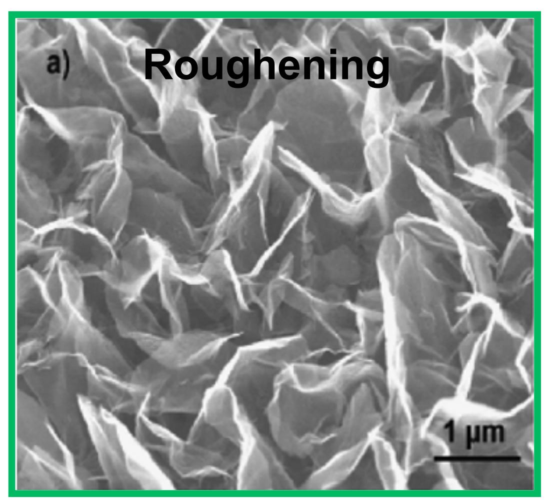
FLUORINATION of GRAPHENE SHEETS (GSs) by PLASMA



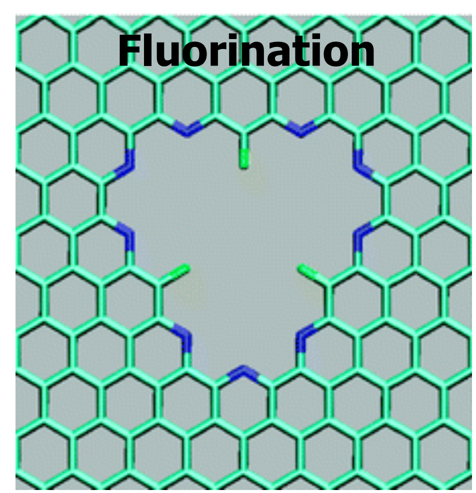
Fluorocarbon plasmas produce fast etching (roughness) and fluorination

CF_4 Plasma

K. Leifer et al., J. Phys. D: Appl. Phys. 43 (2010) 045404



P. Kràl et al., J. Am. Chem. Soc. 130 (2008) 16448



FLUORINATION of GSs (F-GSs): METHOD and SURFACE ANALYSIS

ULTRASONICATION in CHLOROFORM (2mg/20ml FOR 1H)

⇩

DROP CASTING ONTO A METALLIC HOLDER

⇩

ANNEALING (70°C FOR 2H)

⇩

PLASMA ASSISTED DECOMPOSITION CF_4 (13.56 MHz, 21 sccm for 45 min)

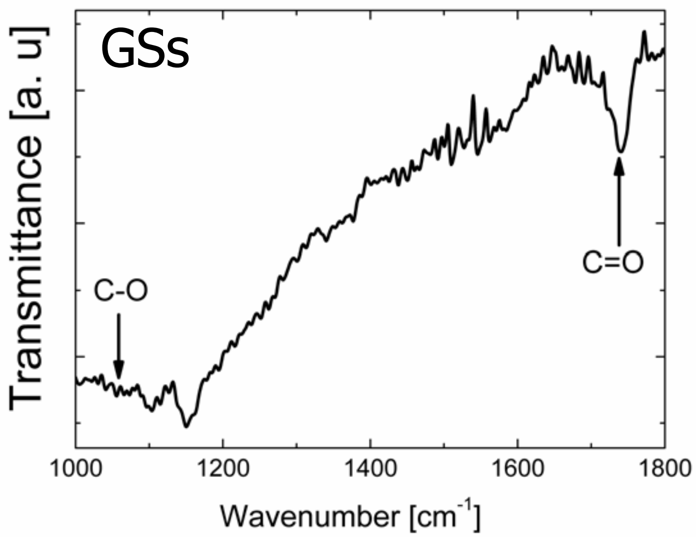
⇩

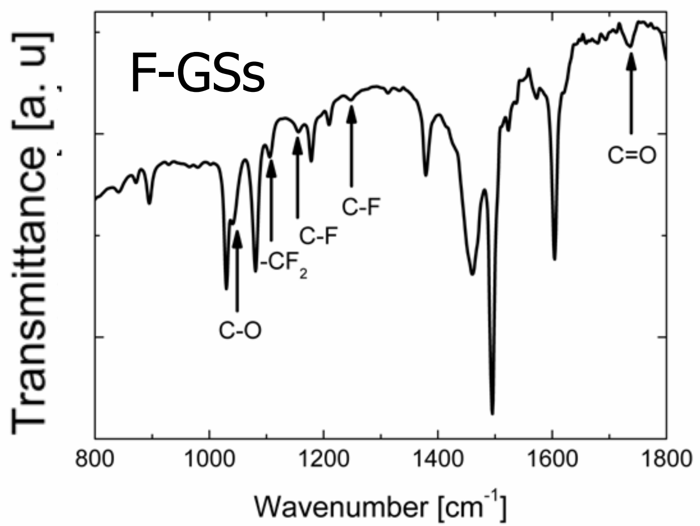
XPS characterization

Table 1 Atomic percentage for the analyzed samples *

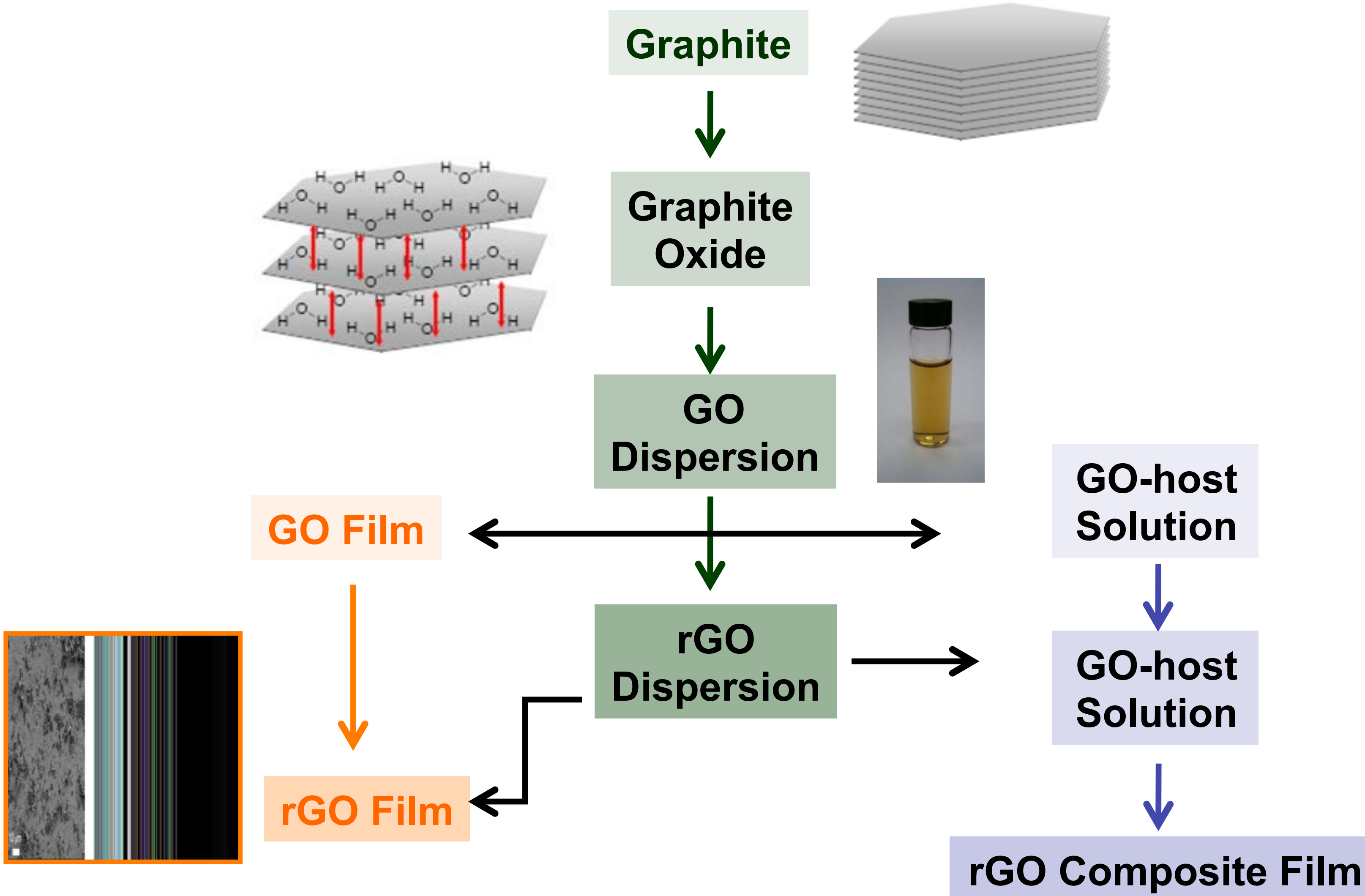
Sample	Atomic percentage
GSs	C/O 1/0.15
F-GSs	C/O/F 1/0.11/1.12

L. Valentini et al., J. Mater. Chem., 2010, 20, 995

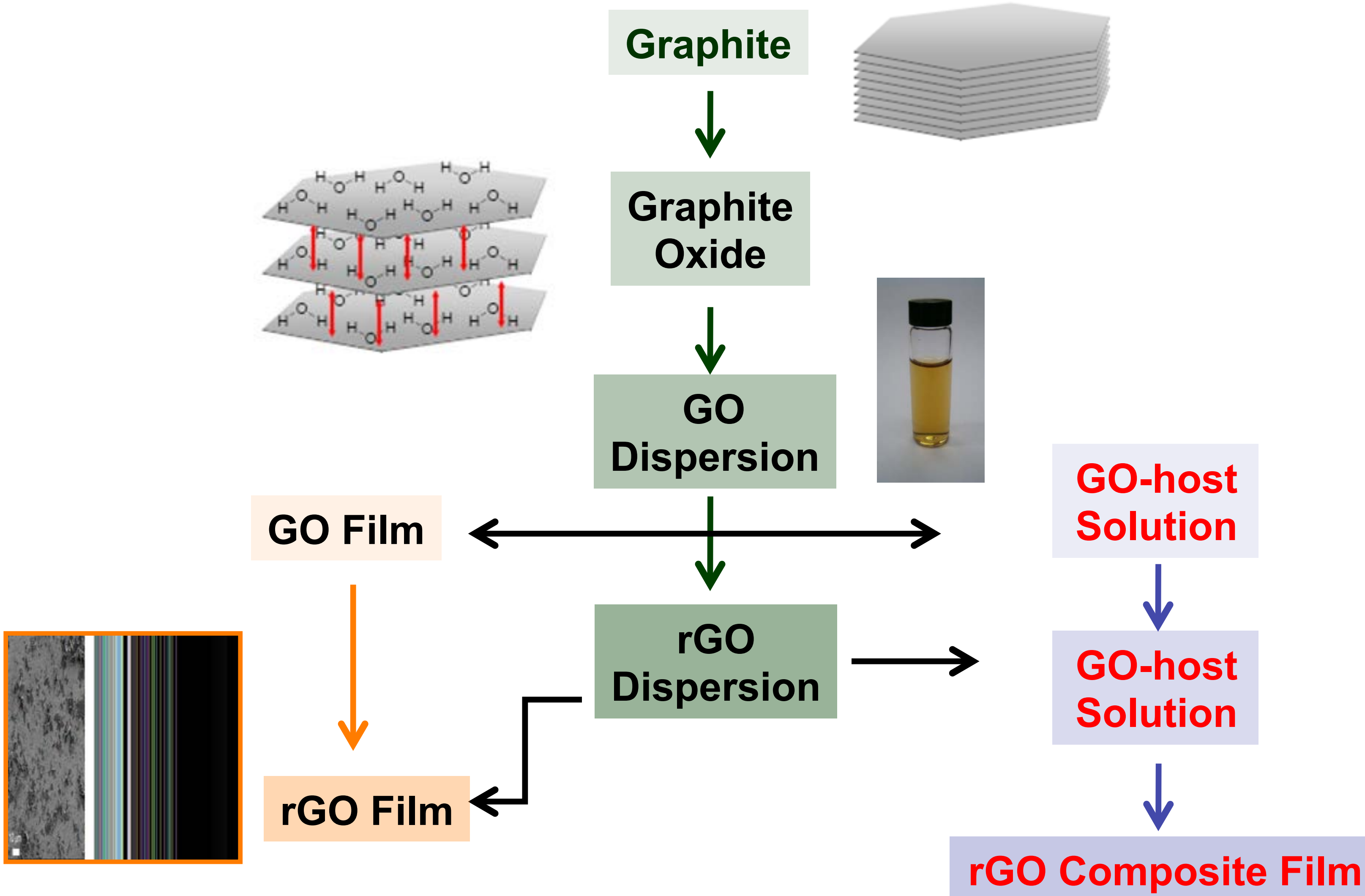




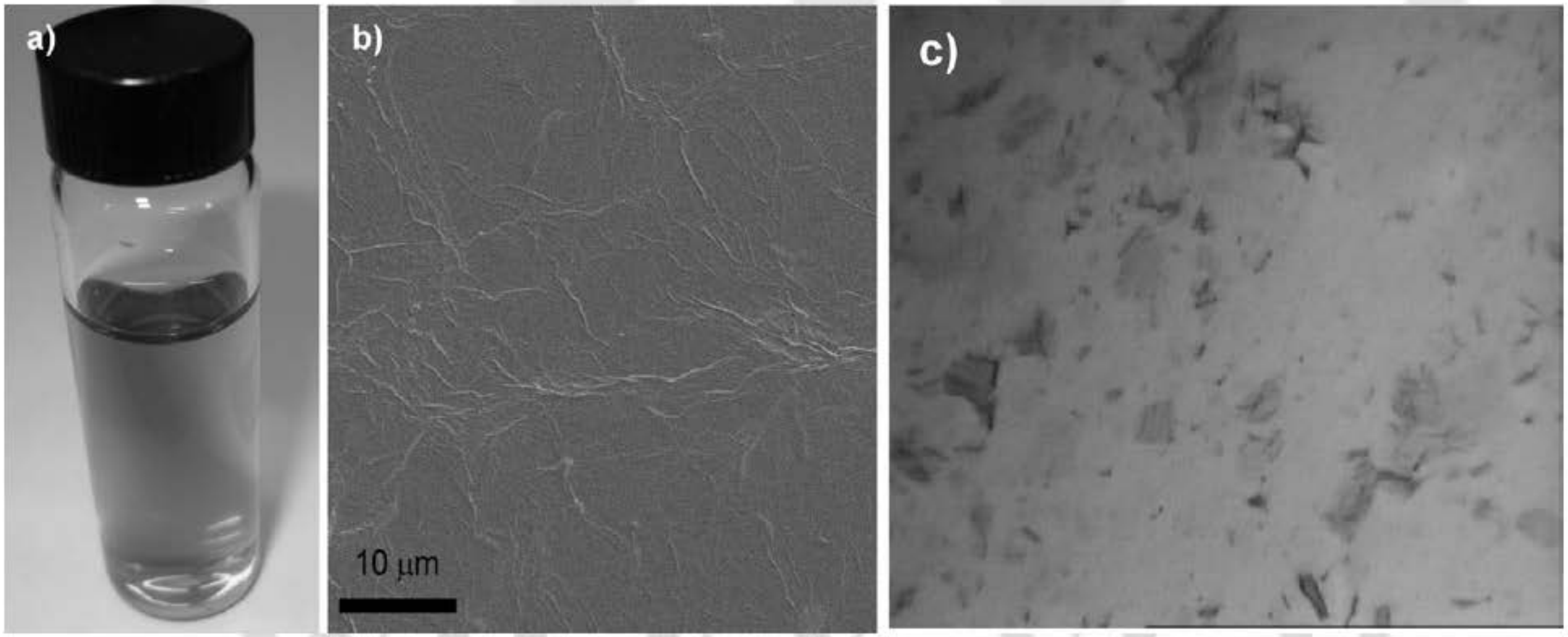
PRODUCTION AND PROCESSING of GRAPHENE OXIDE



PRODUCTION AND PROCESSING of GRAPHENE OXIDE

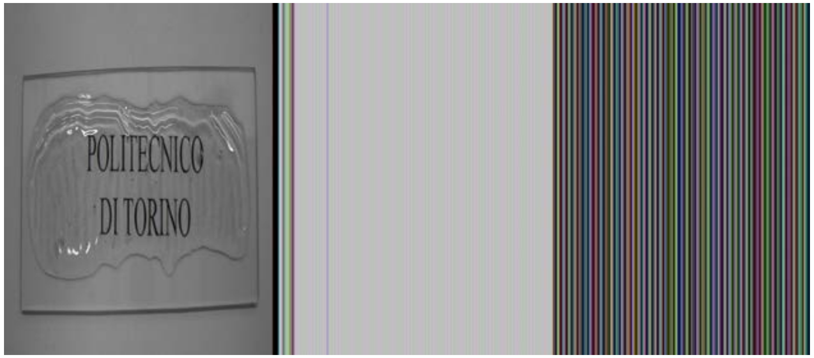


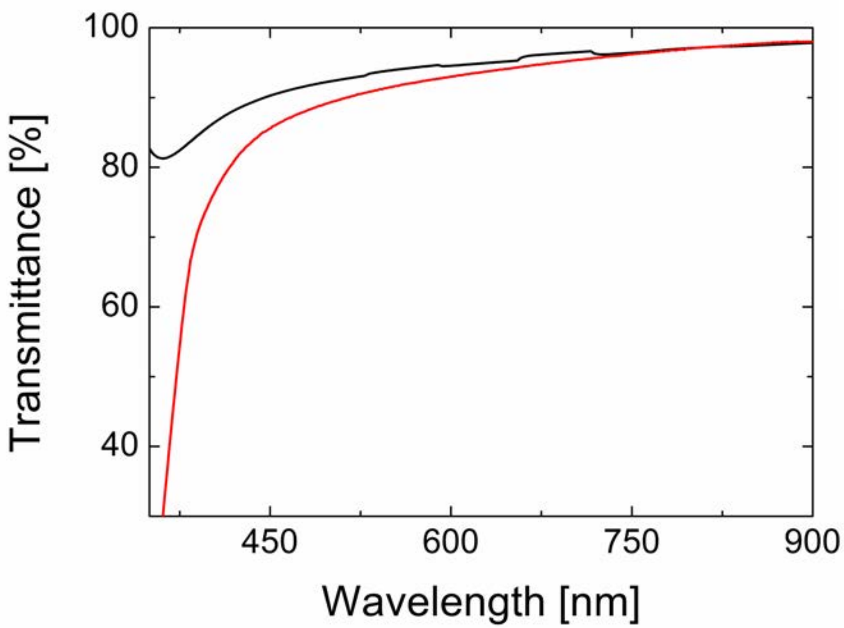
Transparent and Conductive Graphene Oxide/Poly(ethylene glycol) Diacrylate Coatings Obtained by Photopolymerization



(a) Vial containing 0.1mg/ml dispersion of GO in water; (b) FE-SEM image of the extended GO flake obtained from water dispersion and (c) optical micrographs (400 μm X 200 μm) of GO flakes dispersed in UV cured polymer matrix.

Transparent and Conductive Graphene Oxide/Poly(ethylene glycol) Diacrylate Coatings Obtained by Photopolymerization



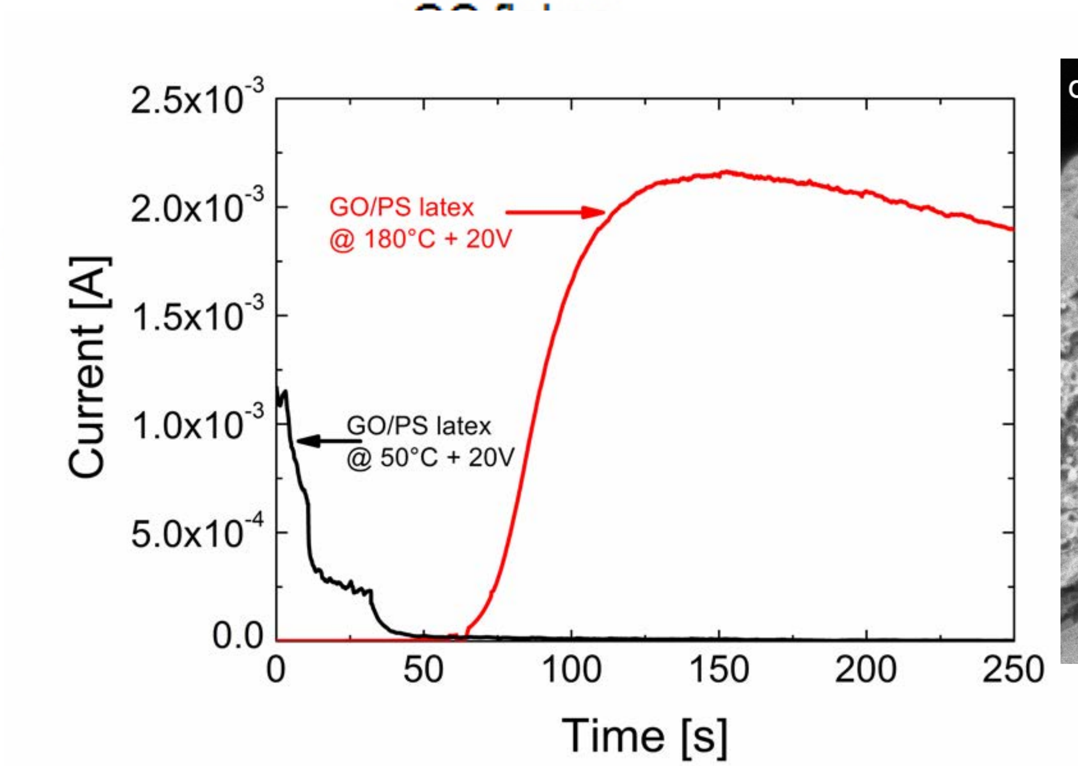


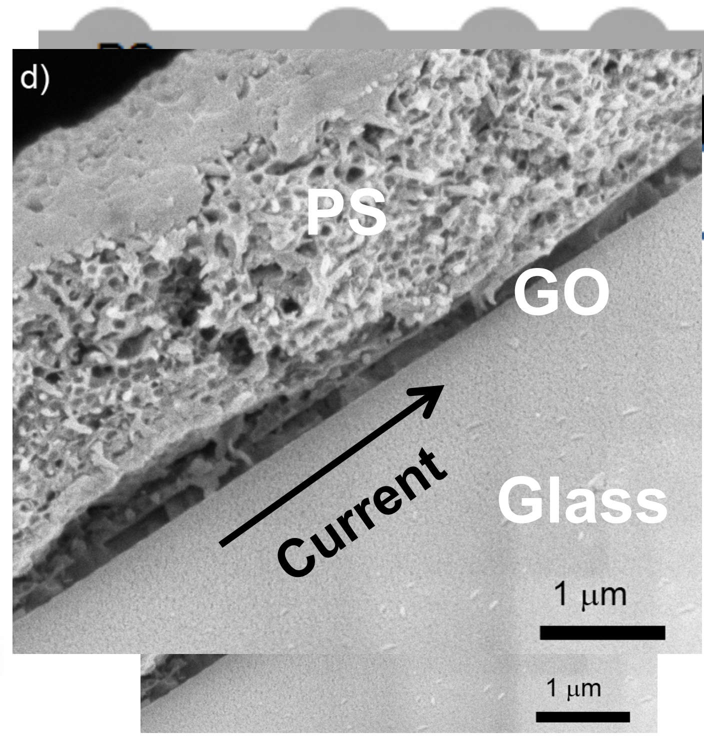
Sample	Gel content[a]	T_g[b]	R_s[c]
	%	°C	$\Omega \cdot sq^{-1}$
PEGDA	98	−45	[d]
PEGDA + 0.5 wt.-% GO	98	−45	[d]
PEGDA + 1 wt.-% GO	97	−45	5×10^6
PEGDA + 2 wt.-% GO	98	−45	6 300

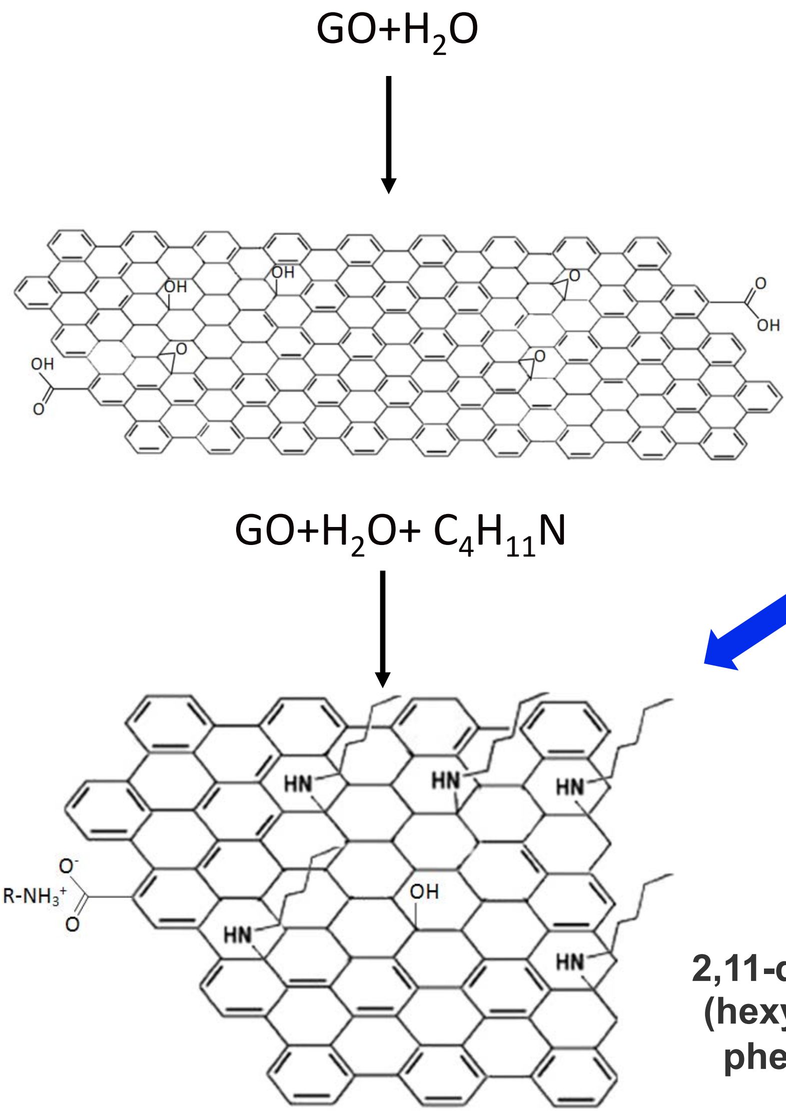
M. Sangermano et al.,
Macromol. Mater. Eng. 296 (2011) 401

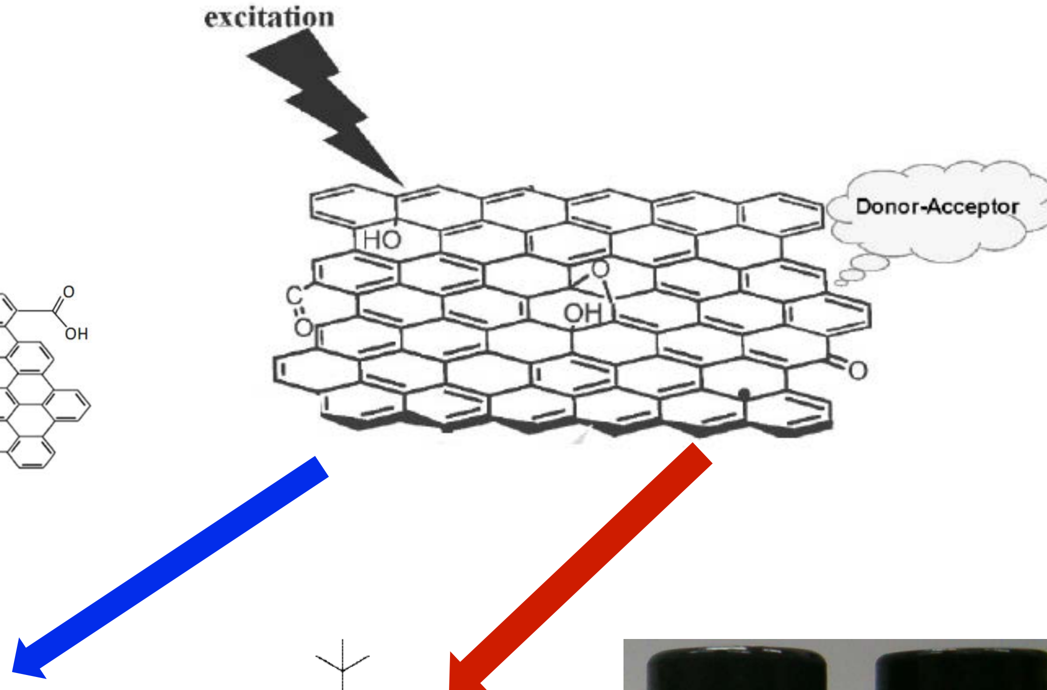
Digital photograph of cured system obtained by adding 2 wt% of GO-water dispersion into PEGDA resin and UV-Vis spectra of cured system obtained by adding 0,5 wt% (black) and 2 wt% (red) of GO-water dispersion into PEGDA resin.

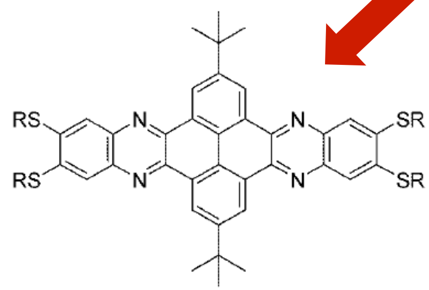
Electric field assisted thermal annealing reorganization of graphene oxide/polystyrene latex films





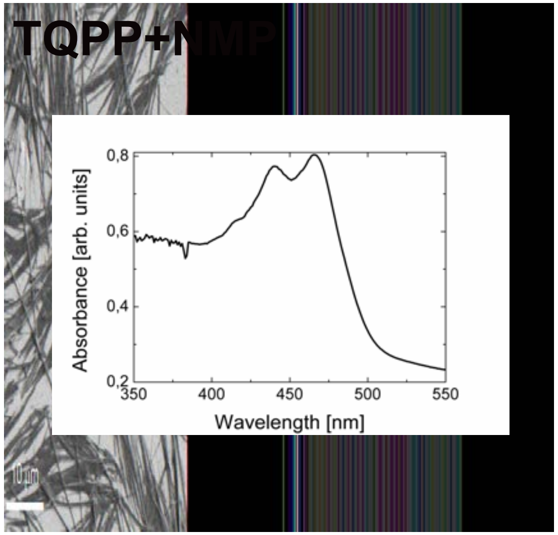


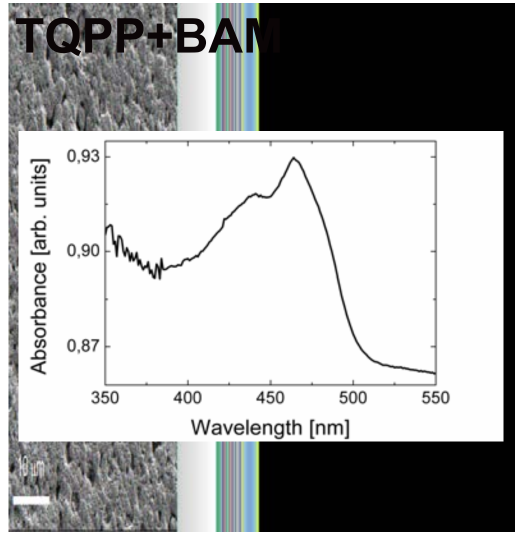


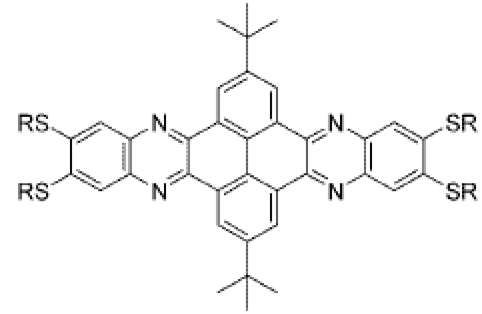


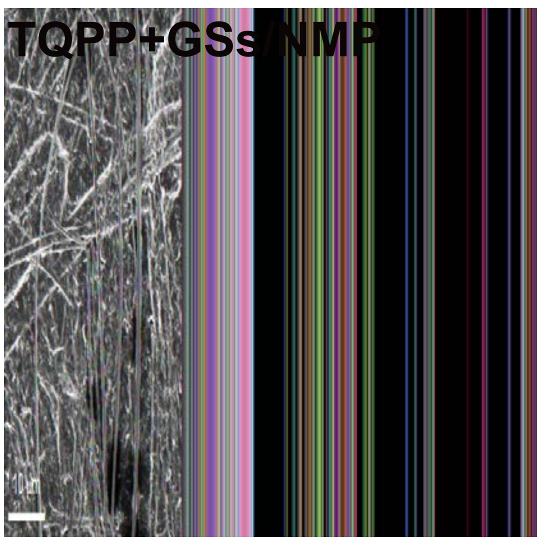
2,11-di-tert-butyl-6,7,15,16-tetrakis (hexylthio)quinoxalino[2',3':9,10] phenanthro[4,5-abc]phenazine (TQPP)

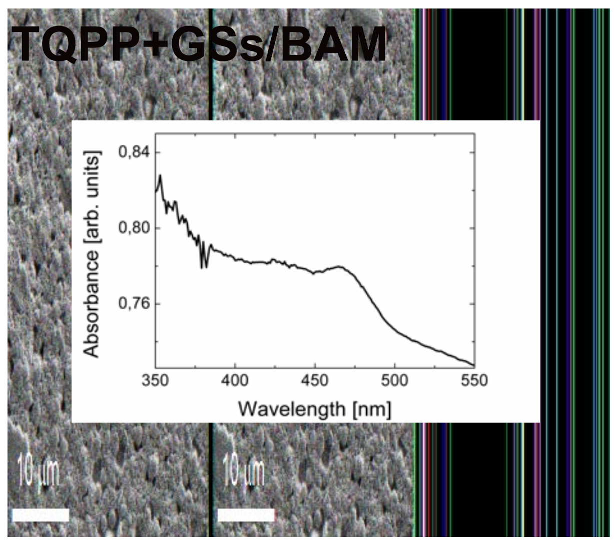
Amino Modified GSs and Pyrene-Based Semiconductor

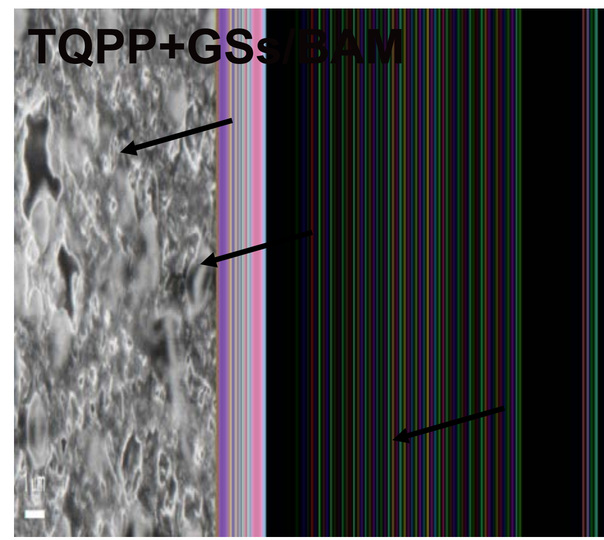






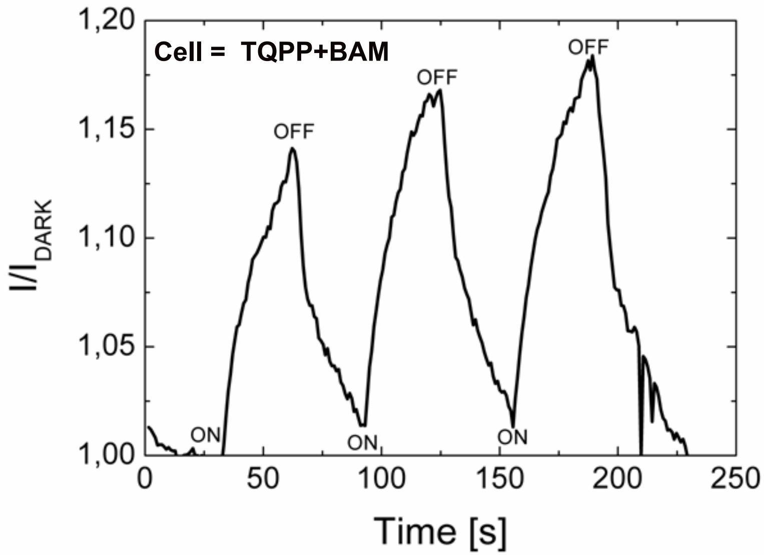


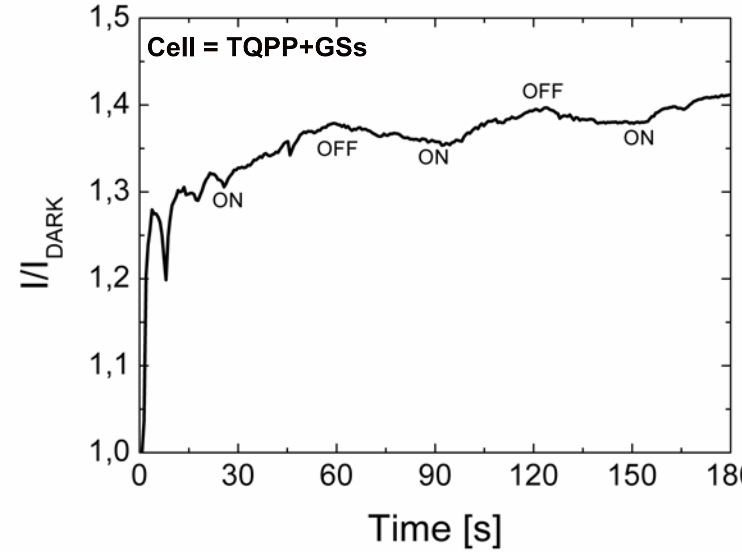


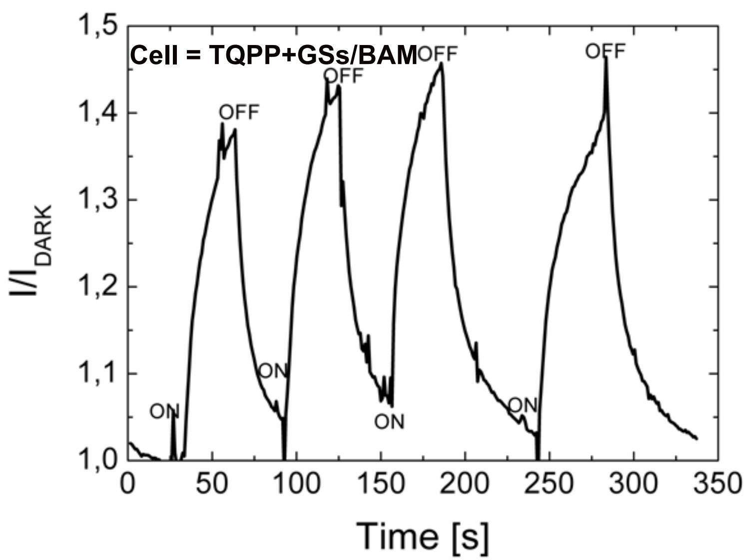


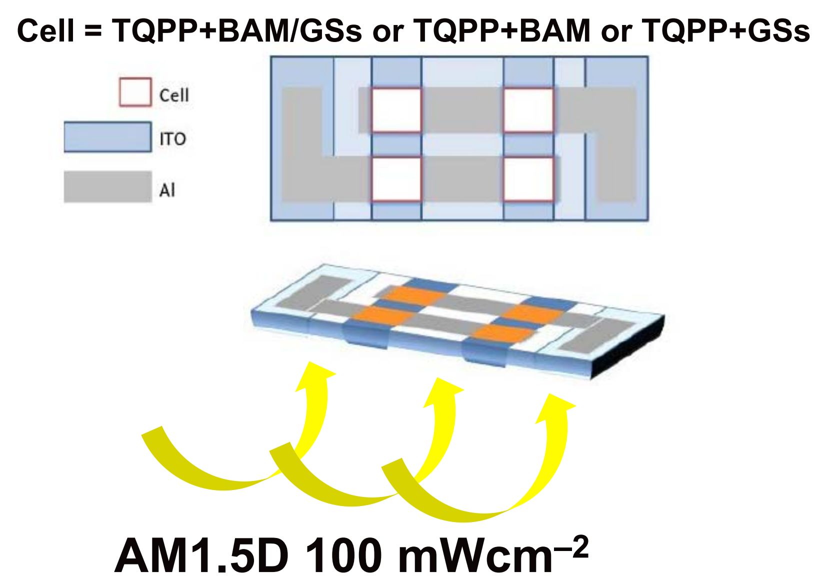
S. Bittolo Bon, et al. J. Phys. Chem. C 114 (2010) 11252.

Amino Modified GSs and Pyrene-Based Semiconductor



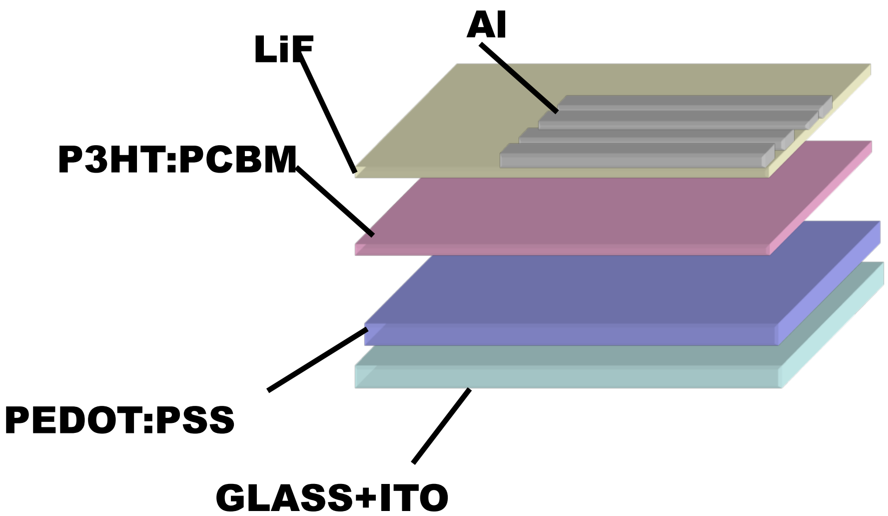


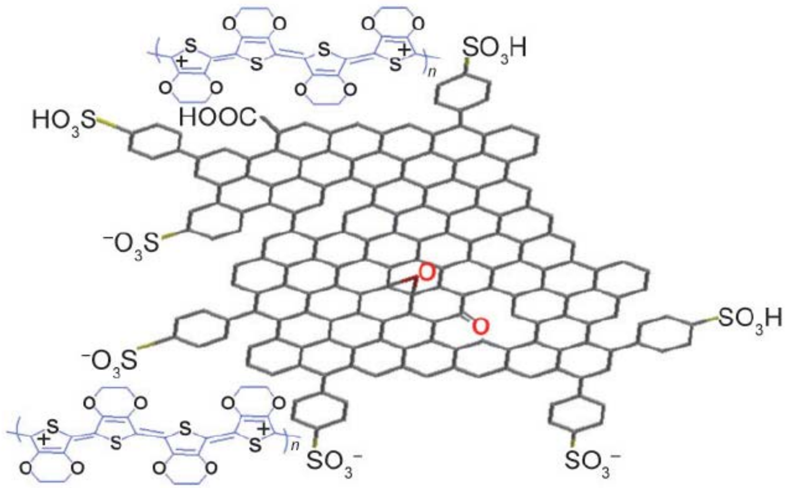




Amino Modified GSs and Pyrene-Based Semiconductor

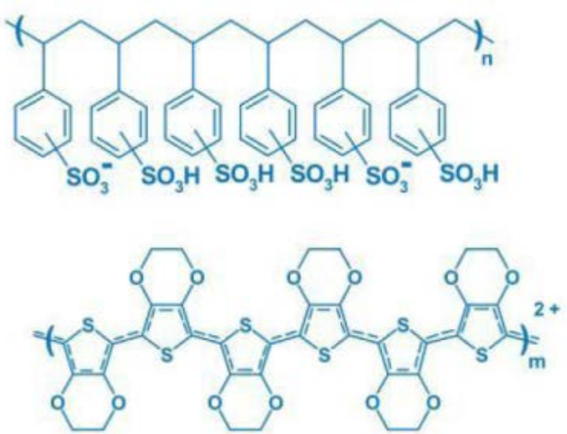
GRAPHENE/PEDOT:PSS COMPOSITE FILMS in POLYMERIC SOLAR CELLS



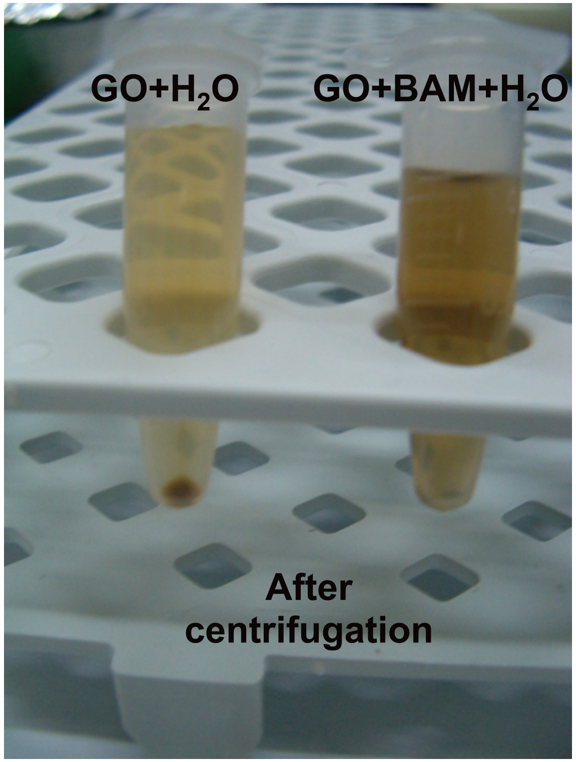


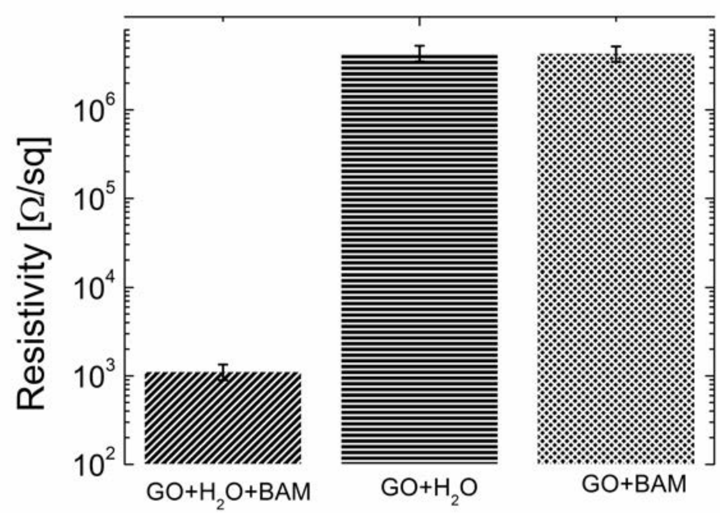
Scheme 1 Schematic representation of part of the structure of graphene-PEDOT

Xu et al., Nano Res. 2 (2009) 343.

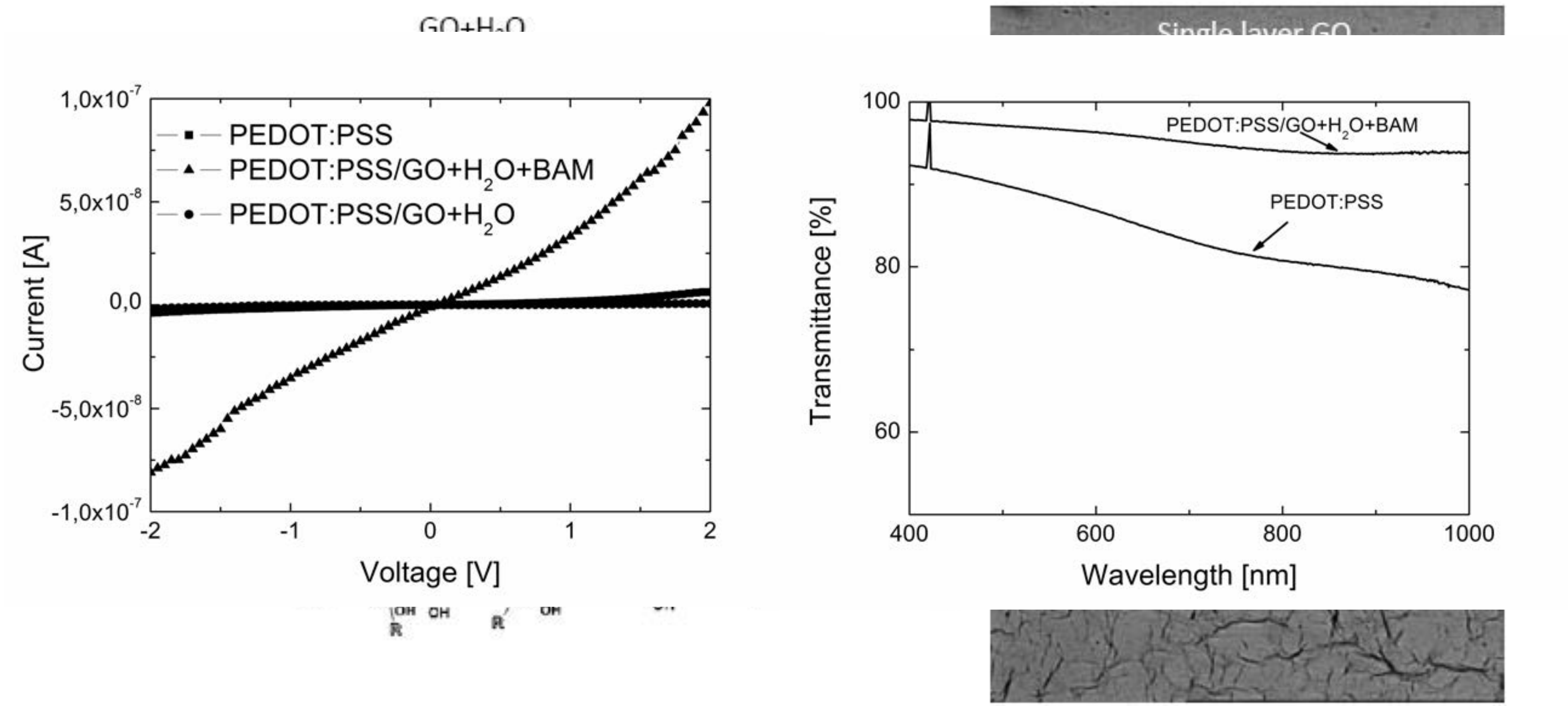


PEDOT:PSS





Preparation of extended alkylated graphene oxide conducting layers and effect study on the electrical properties of PEDOT:PSS polymer composites



S. Bittolo Bon, et al. Chem. Phys. Lett. 494 (2010) 264.

Preparation of extended alkylated graphene oxide conducting layers and effect study on the electrical properties of PEDOT:PSS polymer composites.

CURRENT RESEARCH AND OPEN ISSUES

- Production of large-area graphene sheets for device applications.
- Functionalization and integration of graphene oxide for nanocomposite applications.
- Experimental determination of electrical and morphological properties of GOPs.
- Many unique properties (e.g. for energy applications) have yet to be discovered.

Perugia & Madrid Research Units

Prof. Josè Kenny (Dep. of Civil and Environmental Engineering, University of Perugia and INSTM & Instituto de Ciencia y Tecnologia de Polimeros, CSIC Madrid)
Dr. Silvia Bittolo Bon (Post-Doc, Dep. of Civil and Environmental Engineering, University of Perugia and INSTM)
Dr. Marta Cardinali (Post-Doc, Dep. of Civil and Environmental Engineering, University of Perugia and INSTM)
Dr. Miguel Angel Lopez-Manchado (Instituto de Ciencia y Tecnologia de Polimeros, CSIC Madrid)
Dr. Raquel Verdejo (Instituto de Ciencia y Tecnologia de Polimeros, CSIC Madrid)

The work with the pyrene-based semiconductor was developed with **Prof. Bilal Kaafarani** of the American University of Beirut and was supported by the Petroleum Research Fund (PRF) of the American Chemical Society (grant #: 47343-B10) and the Masri Institute of Energy and Natural Resources.

Acknowledgments