DCU | Water Institute

MESTECH
Marine & Environmental Sensing Technology Hub

ANTIFOULING STRATEGIES FOR SENSORS IN THE AQUATIC ENVIRONMENT

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An Chomhairle um Thaighde in Éirinn

OUTLINE

- What is biofouling
- Biofouling impact on deployed systems and sensors
- Associated problems with biofouling
- Antifouling strategies

- Silica based sol-gel coatings
- Why sol-gel coatings?
- Self cleaning sol-gel material for solar panels
- Doping antimicrobial nanoparticles into sol gels
- Deployment screening method
- Sensor antifouling assessment on Smart Bay's facilities

FOULING COMMUNITY

Microfouling

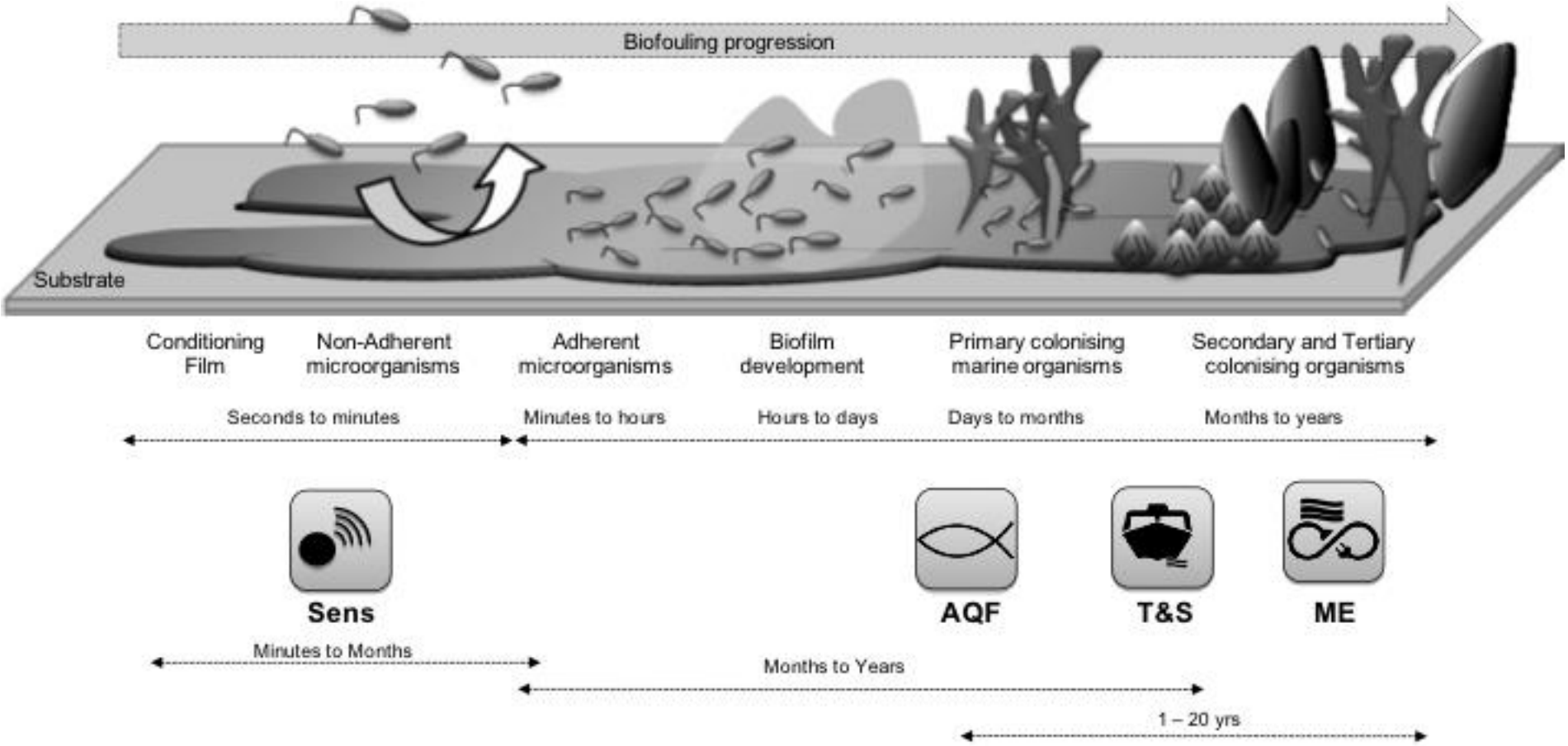
- Biofilm formation
- Bacterial adhesion

Macrofouling

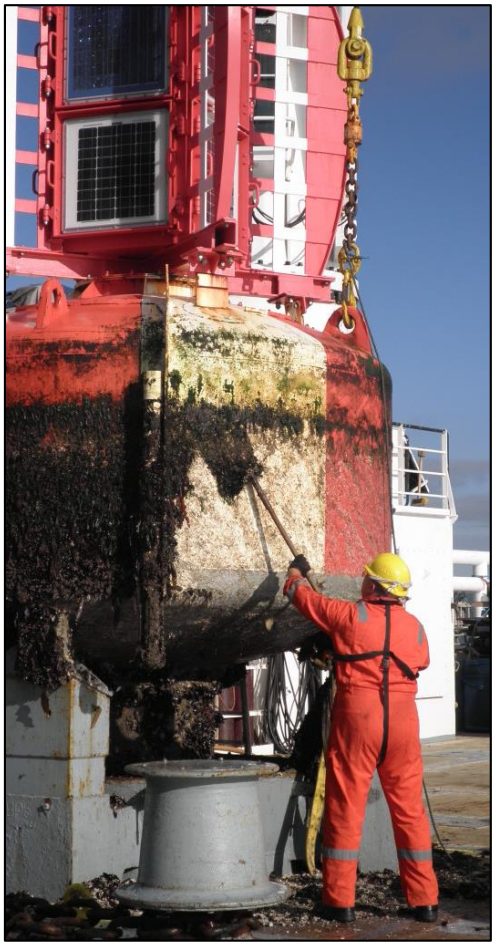
- Attachment of layer of organisms

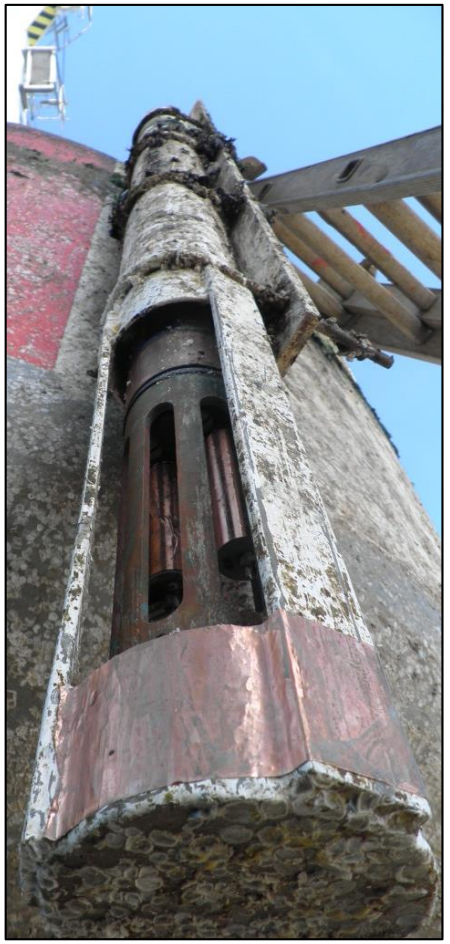
  Examples:
  Barnacles
  Anthropods
  Mussels
  Seaweeds
  Bryozoans

HOW IT HAPPENS?



DEPLOYED SYSTEMS IMPACTED BY BIOFOULING – CIL MARKER BUOY





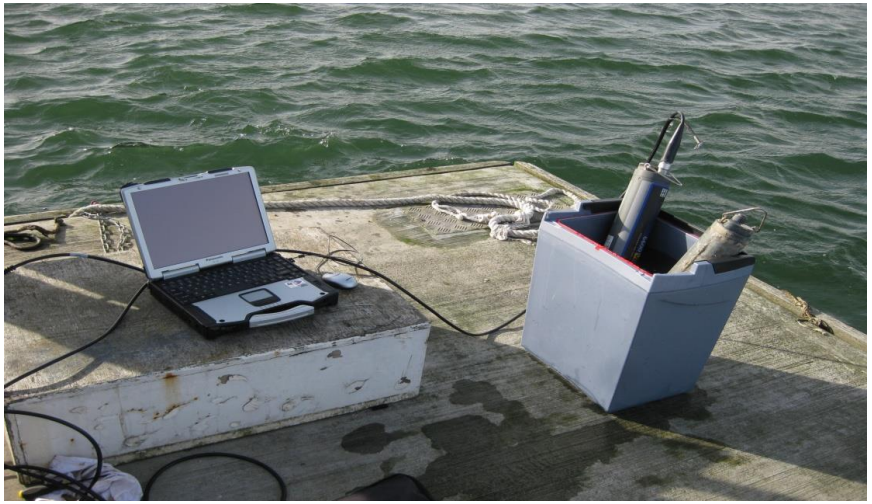


ASSOCIATED PROBLEMS

- Increase cost of maintenance
- Increase cost in ownership
- Data loss

ON-SITE MAINTENANCE PROTOCOL

1. Collect data before cleaning
2. Clean sensor
   - Collect data after cleaning
3. Calibrate sensor
   - Collect data after calibration



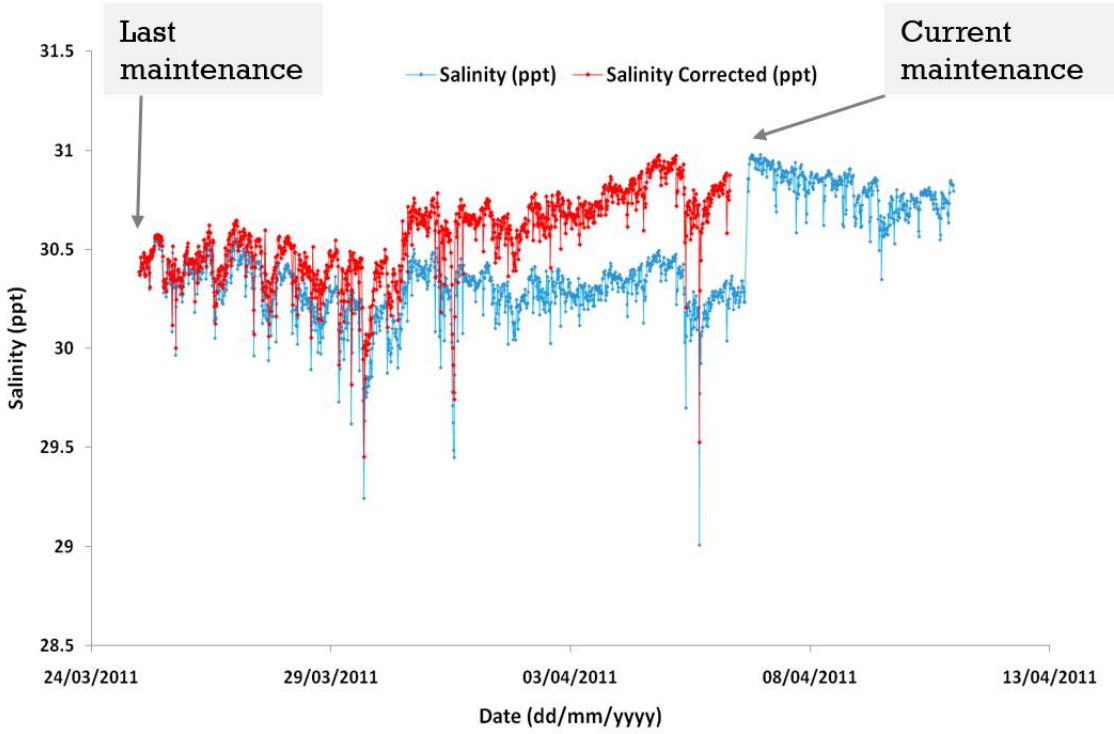
R.J. Wagner, Guidelines and standard procedures for continuous water-quality monitors: station operation, record computation, and data reporting, US Department of the Interior, US Geological Survey, 2006.

DATA CORRECTION DUE TO SENSOR DRIFT

Assuming the sensor drift proceeds linearly:

$$V_c = V + (V_f - V_s)[(T_f - T)/T_f]$$

- V_c is the drift corrected value,
- V is the original measured value,
- V_f is the response of the sensor immediately before cleaning and validation at the end of the correction interval;
- V_s is the response of the sensor after cleaning and calibration;
- T_f is the total time interval for which the correction is applied
- T is the time between the end of deployment and the measured value



Drift correction applied to salinity data between 25 March (last maintenance date) and 06 April 2011.

R.J. Wagner, Guidelines and standard procedures for continuous water-quality monitors: station operation, record computation, and data reporting, US Department of the Interior, US Geological Survey, 2006.

C. Briciu-Burghina, T. Sullivan, J. Chapman, F. Regan, Environ. Monit. Assess., 186 (2014) 5561-5580.

TACKLING THE PROBLEM

- ANTIFOULING STRATEGIES

Nano scale

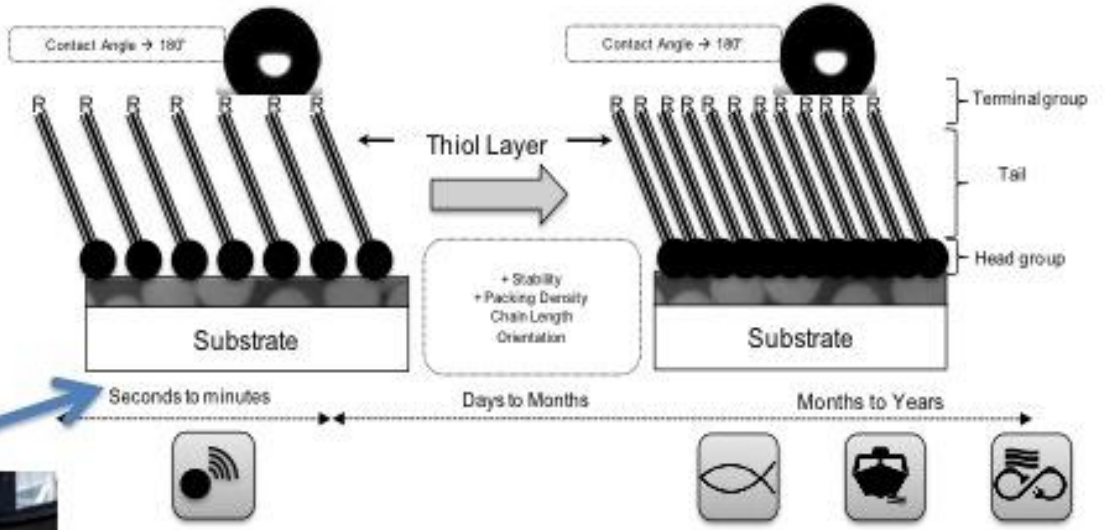
(A)

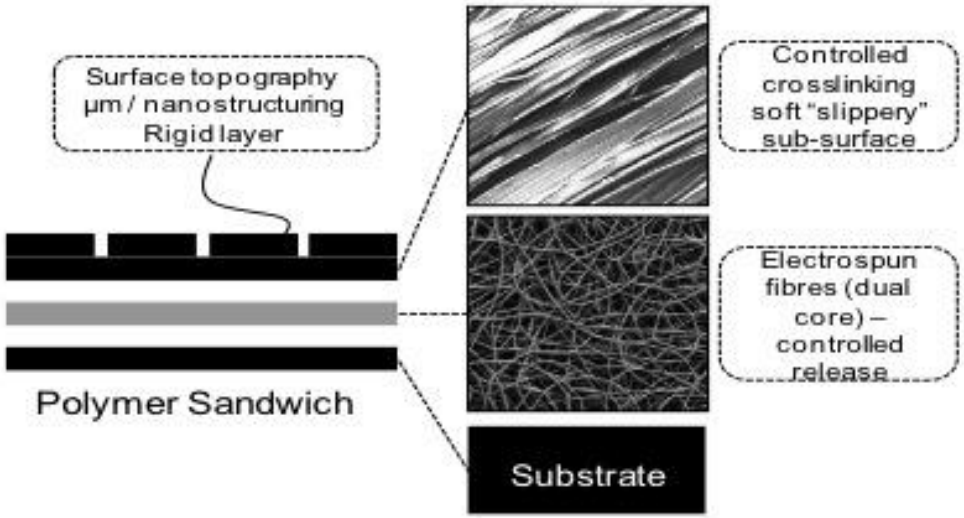
Foul release with molecular layers, natural products, nanoparticles, brush structures (sensing/aquaculture)

(B)

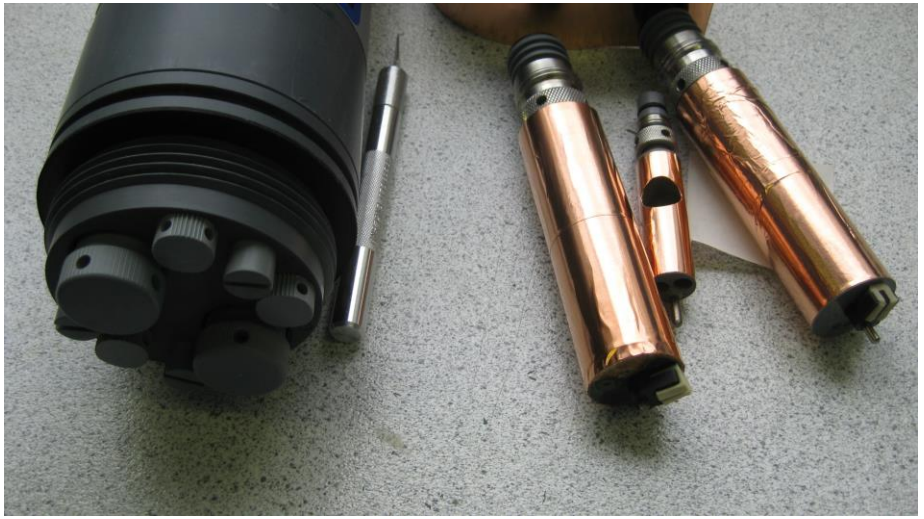
Layered structure for fasters speeds and/or longer time frames (Transport/energy)

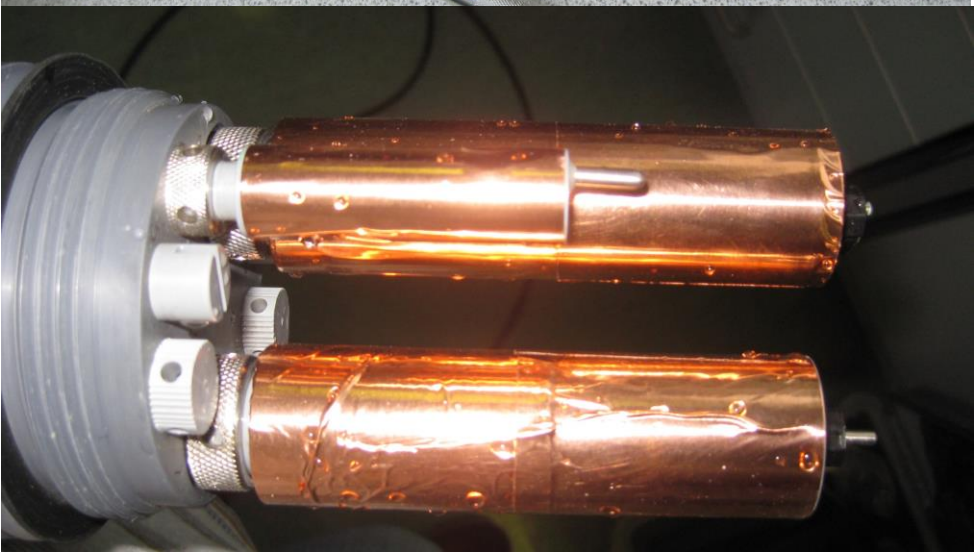
Micro scale





CURRENT STRATEGIES...





SILICA BASED SOL-GEL COATINGS

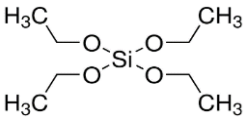
WHY SOL-GEL BASED COATINGS?

- ❑ Easy/ friendly chemistry
- ❑ Endless possibilities for tuning the sol-gel to suit the application (precursor choice, ph, ageing time, application method, solvent…)
- ❑ Long shelf-life stability (days/years)
- ❑ Easy to apply to surfaces (spin/dip/spray coating)
- ❑ Dense thin films or soft/porous/self-polishing coatings
- ❑ Can produce
  - robust, transparent and ultrahydrophobic coatings (optical windows in sensors)
  - robust,superhydrophobic and anticorrosive coatings

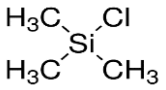
SOL-GEL CHEMISTRY

$$Si(OR)_4 + H_2O + H^+ \xrightarrow{C_2H_6O} HO-Si-(OR)_3 + R-OH$$

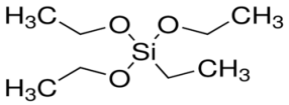
$$(OR)_3-Si-HO + HO-Si-(OR)_3 \longrightarrow [(OR)_3-Si-O-Si-(OR)_3] + H_2O$$



Tetraethyl orthosilicate (TEOS)

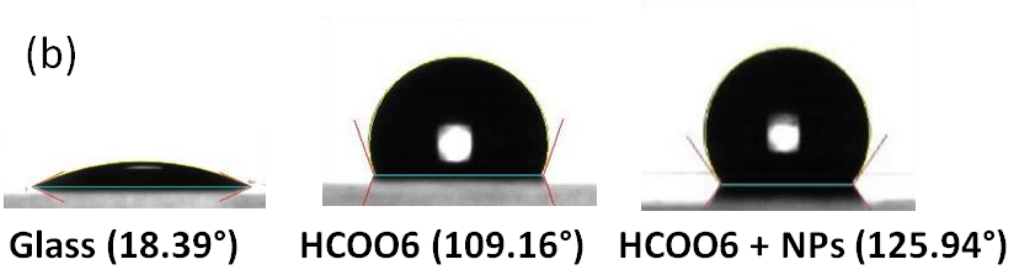


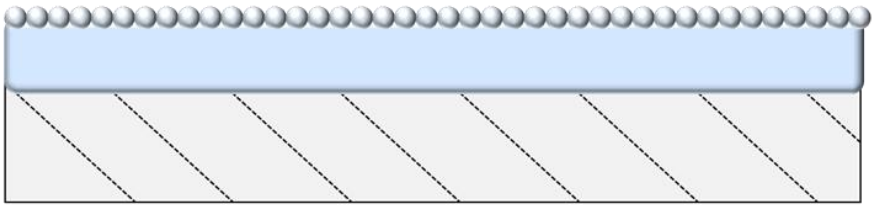
Trimethylchlorosilane (TMCS)

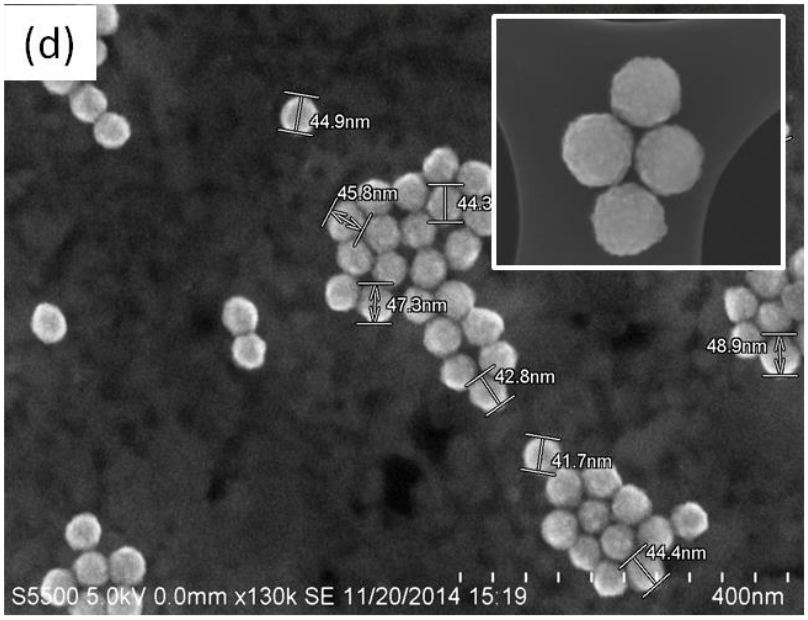


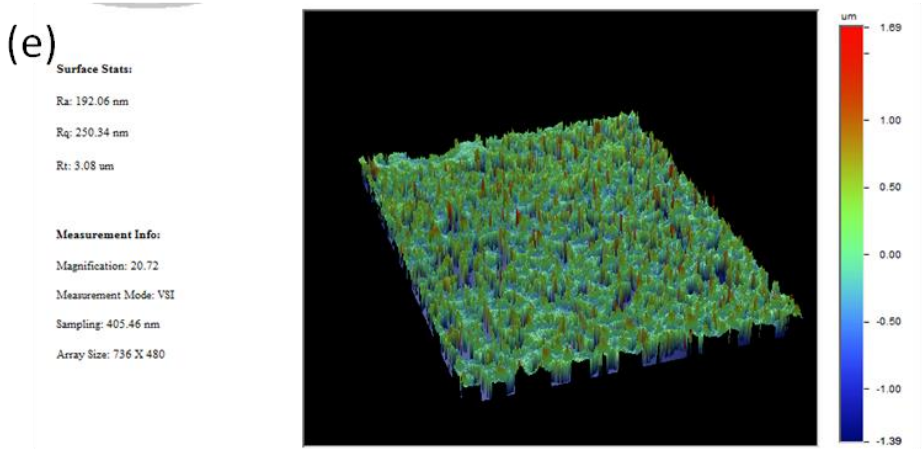
Ethyltriethoxysilane (ETEOS)

TUNABLE CHEMISTRY TO SUIT THE APPLICATION

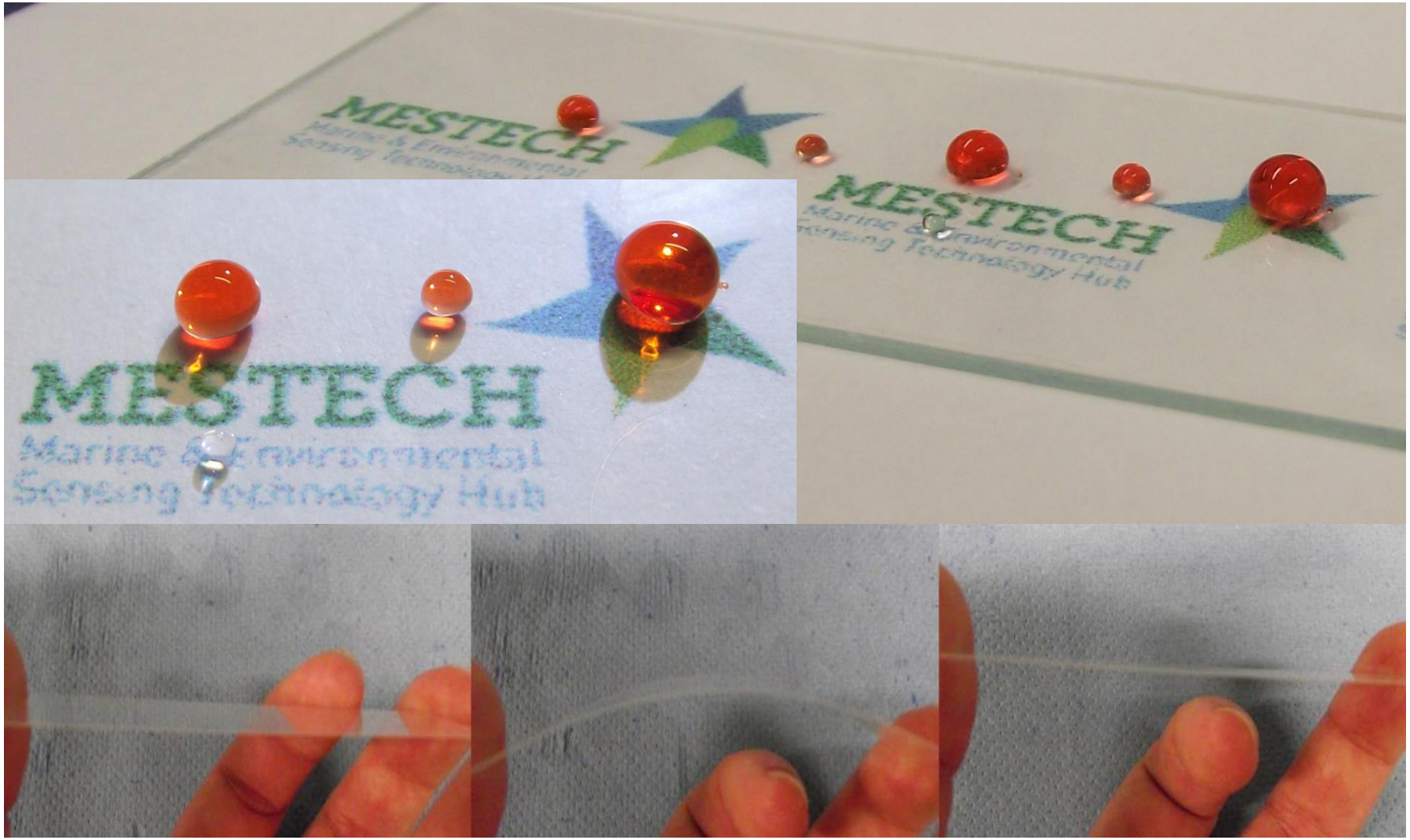








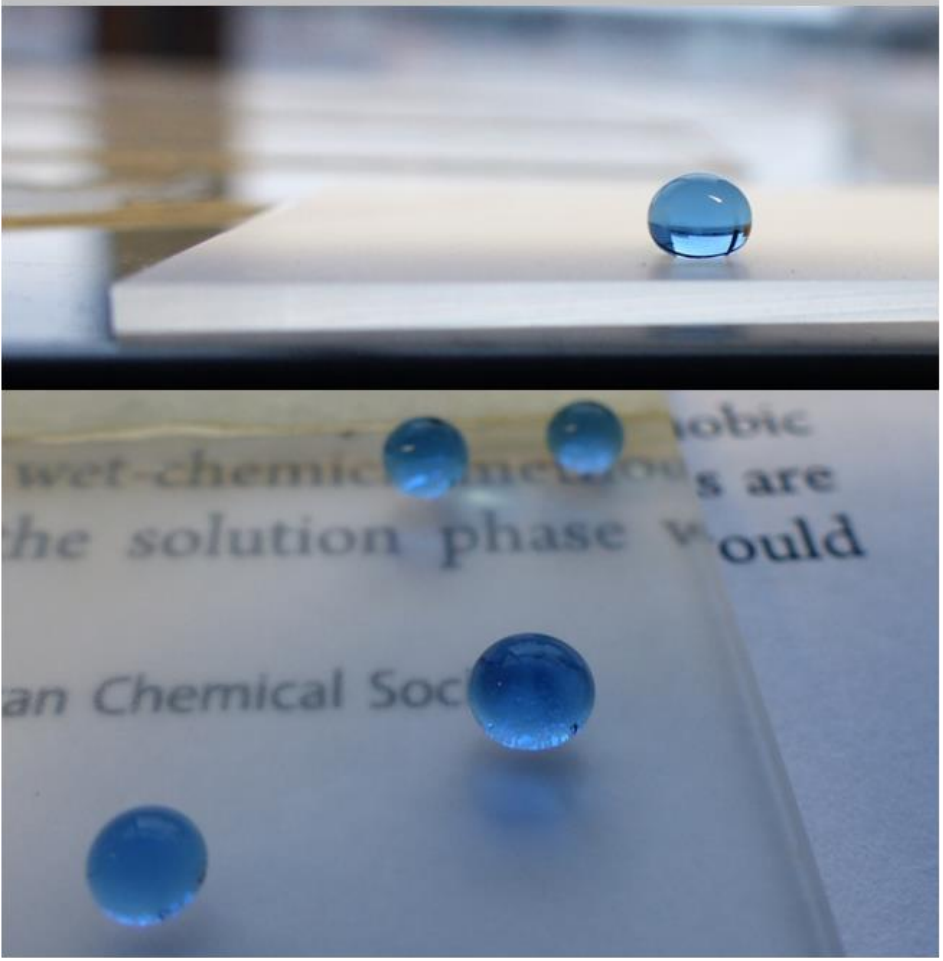
SELF CLEANING COATINGS FOR SOLAR PANELS



A. Power, A. Barrett, J. Abubakar, L. Suarez, L. Ryan, D. Wencel, T. Sullivan, F. Regan, Advanced Engineering Materials (2015)

VALVES IN MICROFLUIDICS AND WATER PROOFING

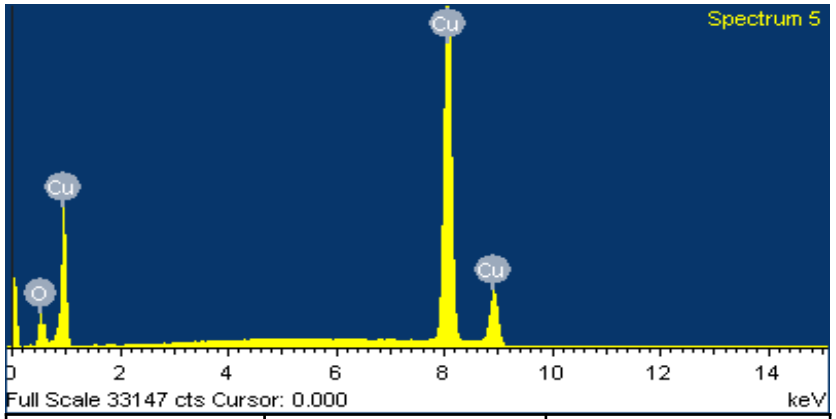
Sol T8 on PMMA



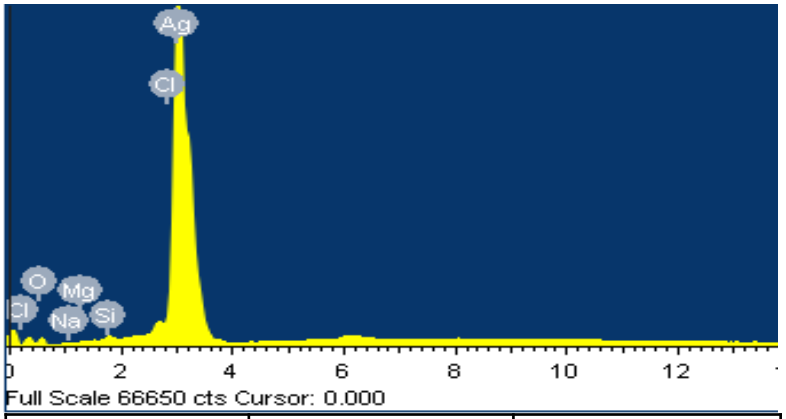
Sol P1 on polyester fabric

BIOFOULING PREVENTION IN SOL-GEL COATING USING NANOPARTICLE DOPING

COPPER AND SILVER PARTICLES

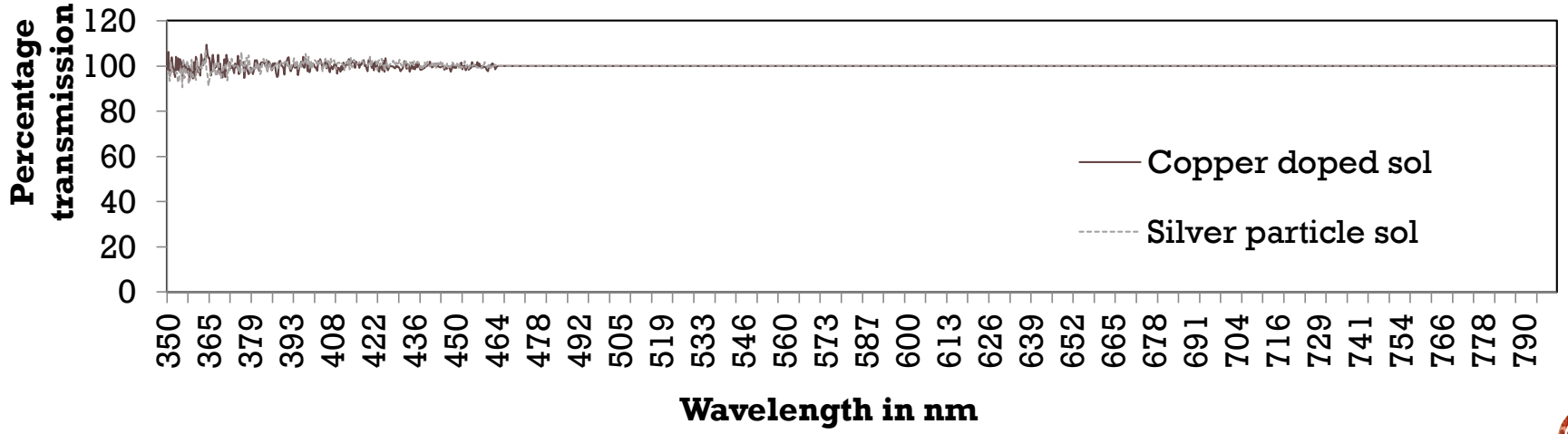


Element	Weight%	Atomic%
O K	**6.30**	**21.07**
Cu K	**93.70**	**78.93**



Element	Weight%	Atomic%
O K	**5.81**	**28.51**
Ag L	**92.87**	**67.57**

Copper and Silver doped Sol transmission spectra



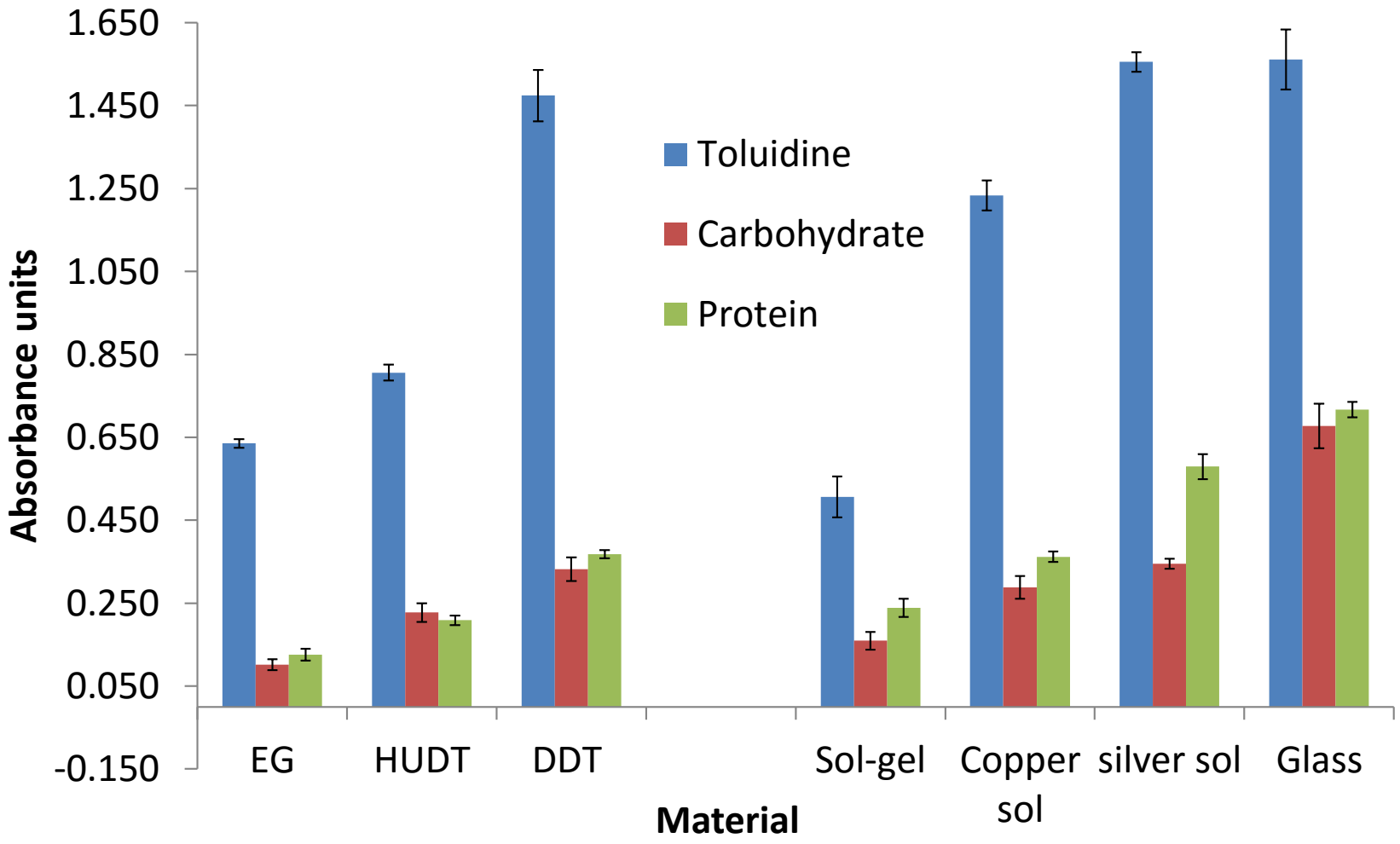
SHORT TERM DEPLOYMENT ASSESSMENT

BIOFOULING ASSESSMENT PROCEDURES

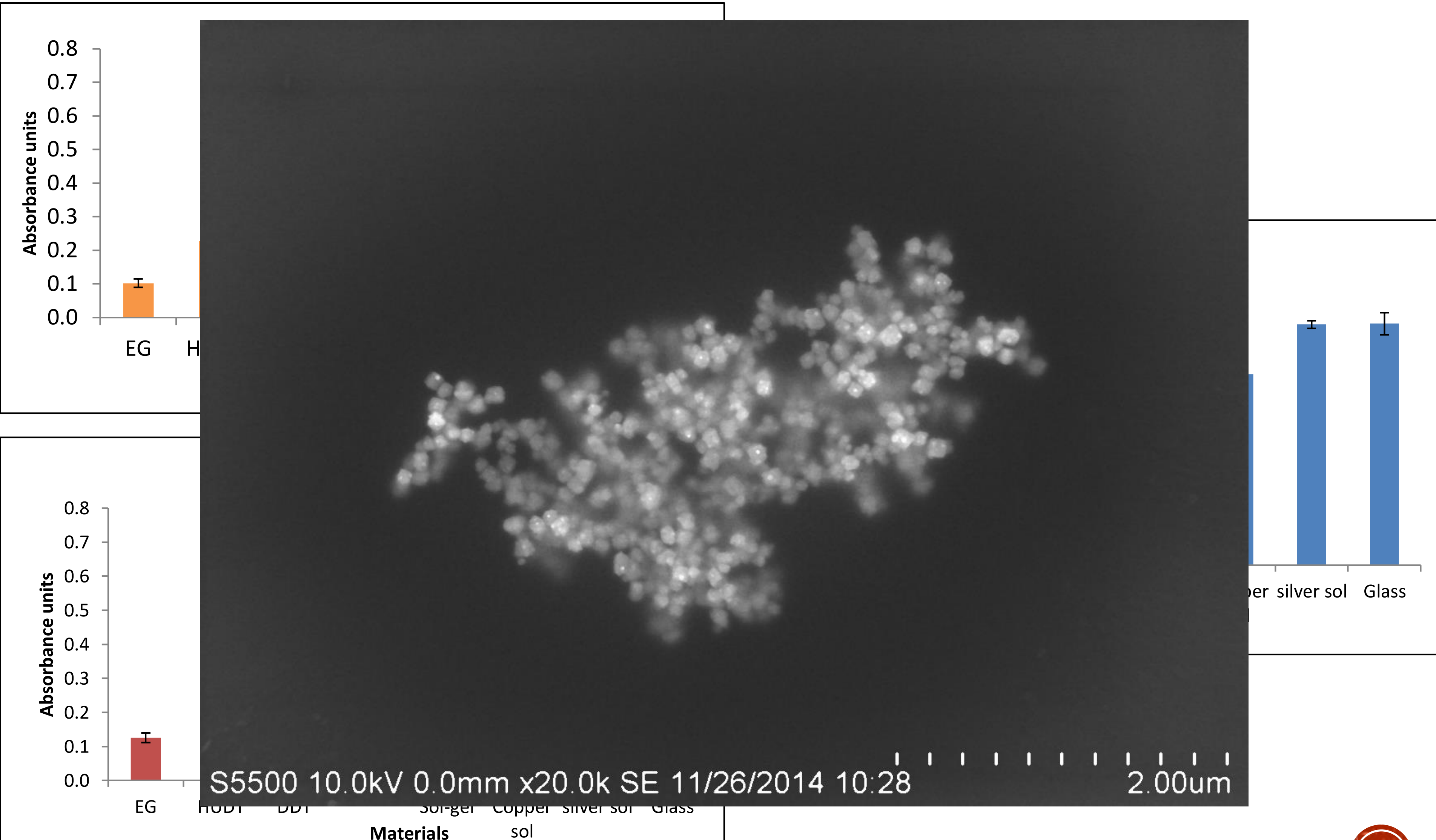
Biochemical assays

- Lowery method adhered protein quantitation
- Colorimetric method for carbohydrate determination
- Toluidine blue glycoprotein quantitation

DUBLIN BAY DEPLOYMENT RESULTS



DUBLIN BAY DEPLOYMENT RESULTS



FUTURE WORK

- Doping antimicrobial MNPs in sol-gels coatings (strong & soft) as a dual strategy (low surface energy + biocidal activity)

- Testing
- Testing
- Testing
- Testing

- Testing

ACKNOWLEDGEMENTS

- Irish research Council
- Smart Bay
- Prof. Fiona Regan
- Dr. Aoife Power
- Dr Tim Sullivan
- Dr James Chapman
- Mr Brendan Heery
- Mr Jaime Moreno
- Mr. Declan Mcglade