



GOBIERNO  
DE ESPAÑA

MINISTERIO  
DE CIENCIA  
E INNOVACIÓN

**Ciemat**

Centro de Investigaciones  
Energéticas, Medioambientales  
y Tecnológicas

**ANM** 2018

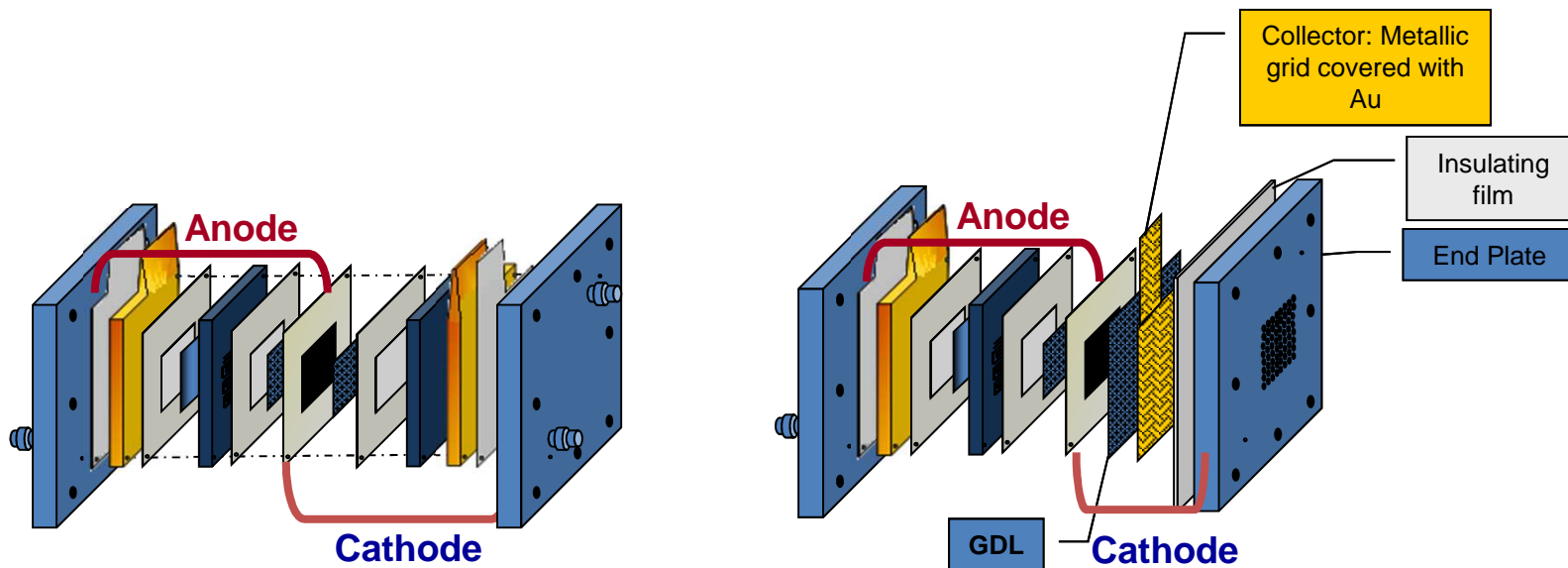
18-20 July 2018

University of Aveiro, Aveiro - Portugal

# GRAPHENE AS CORROSION PROTECTION FILMS FOR METAL SURFACES

A. Fernández Sotillo, A. Martínez Chaparro, P. Ferreira Aparicio  
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT),  
Avda. Complutense, 40. E-28040 Madrid

# *Low temperature fuel cell*



Conventional Fuel Cell

Air-breathing Fuel Cell



# Problems

**Water Management**

**Metallic components corrosion**

ip

# Introduction

# Methods

# Results

# Conclusions



# Introduction

# Methods

# Results

# Conclusions

- ✓ Production
- ✓ Surface preparation



- ✓ Vacuum pump
- ✓ Vacuum chamber
- ✓ Laser ¿?
- ✓ Reactive Gas



- ✓ Pressure
- ✓ Substrate
- ✓ Filament
- ✓ Reactive Gas

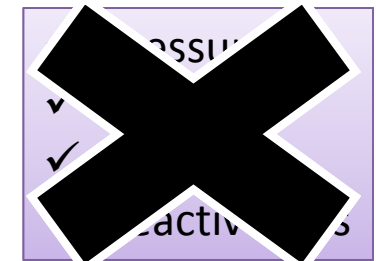
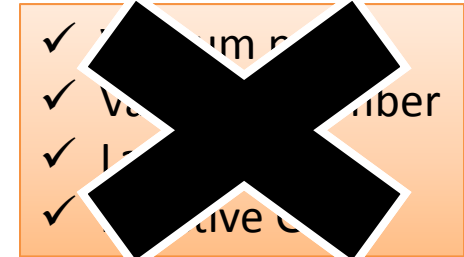
# Introduction

# Methods

# Results

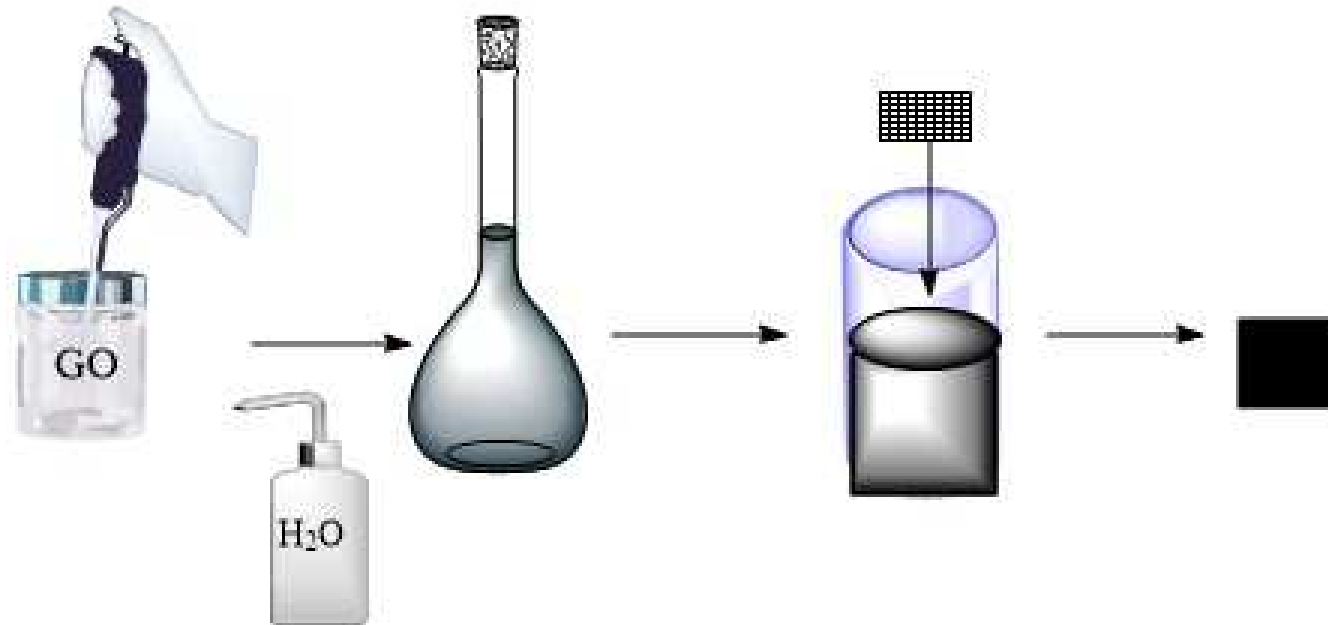
# Conclusions

- ✓ More production
- ✓ Less surface preparation
- ✓ Large surfaces

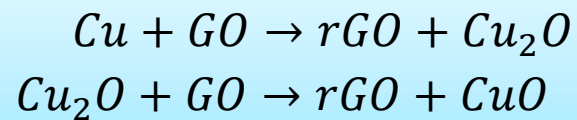


Cheaper and easier!

## *SARA-GO synthesis process*



### Reactions



$$t_{\text{rGO on Cu}} = f(t, T, c)$$

*SARA-GO = substrate-assisted reduction and assembly of GO*

Hu, C., Zhai, X., Liu, L., Zhao, Y., Jiang, L., & Qu, L. (2013). Spontaneous Reduction and Assembly of Graphene oxide into Three-Dimensional Graphene Network on Arbitrary Conductive Substrates. *Scientific Reports*, 3, 1–10.



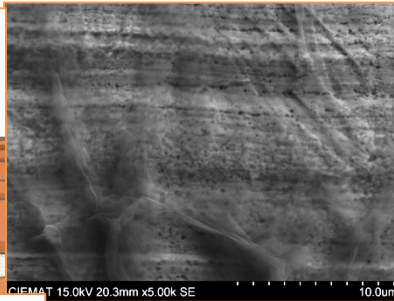
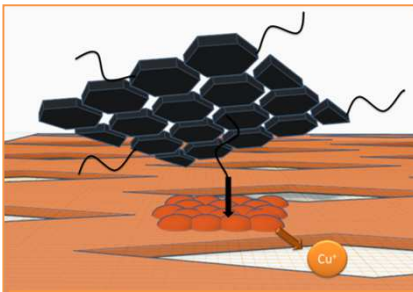
# Introduction

# Methods

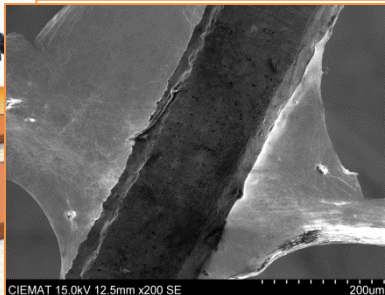
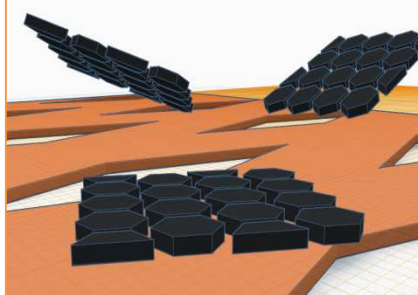
# Results

# Conclusions

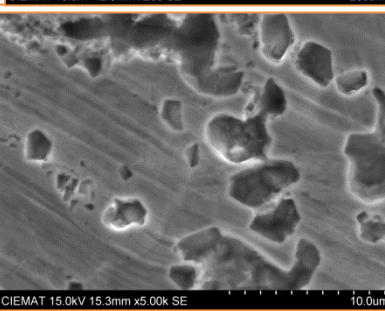
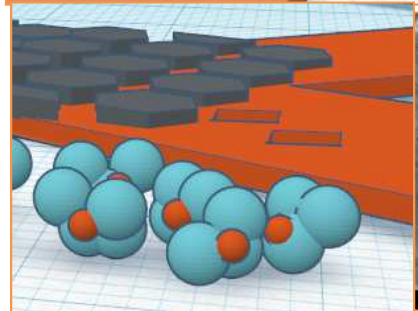
1



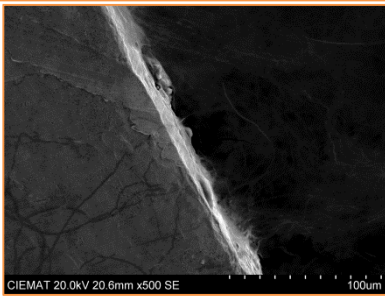
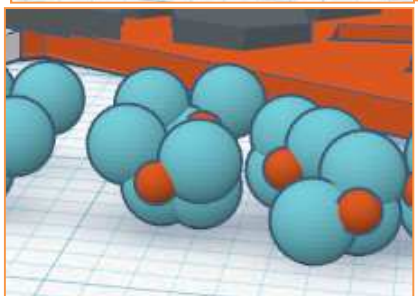
2



3



4



GO adsorption/reduction on the Cu surface and simultaneous copper oxidation

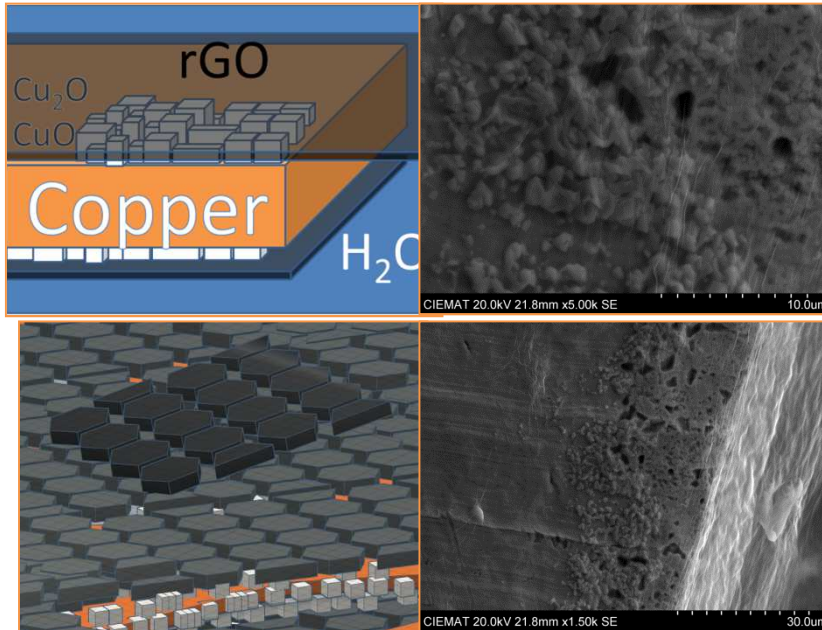
Self-assembly of graphene platelets covers the copper grid and the voids

Oxidation of copper generates geometric holes on the metal surface.

Solvated copper ions diffuse from the point of their formation to the edge of the grid to the aqueous solution.



5



Local pH increase may cause copper oxides to precipitate between the grid surface and the graphene over layer.

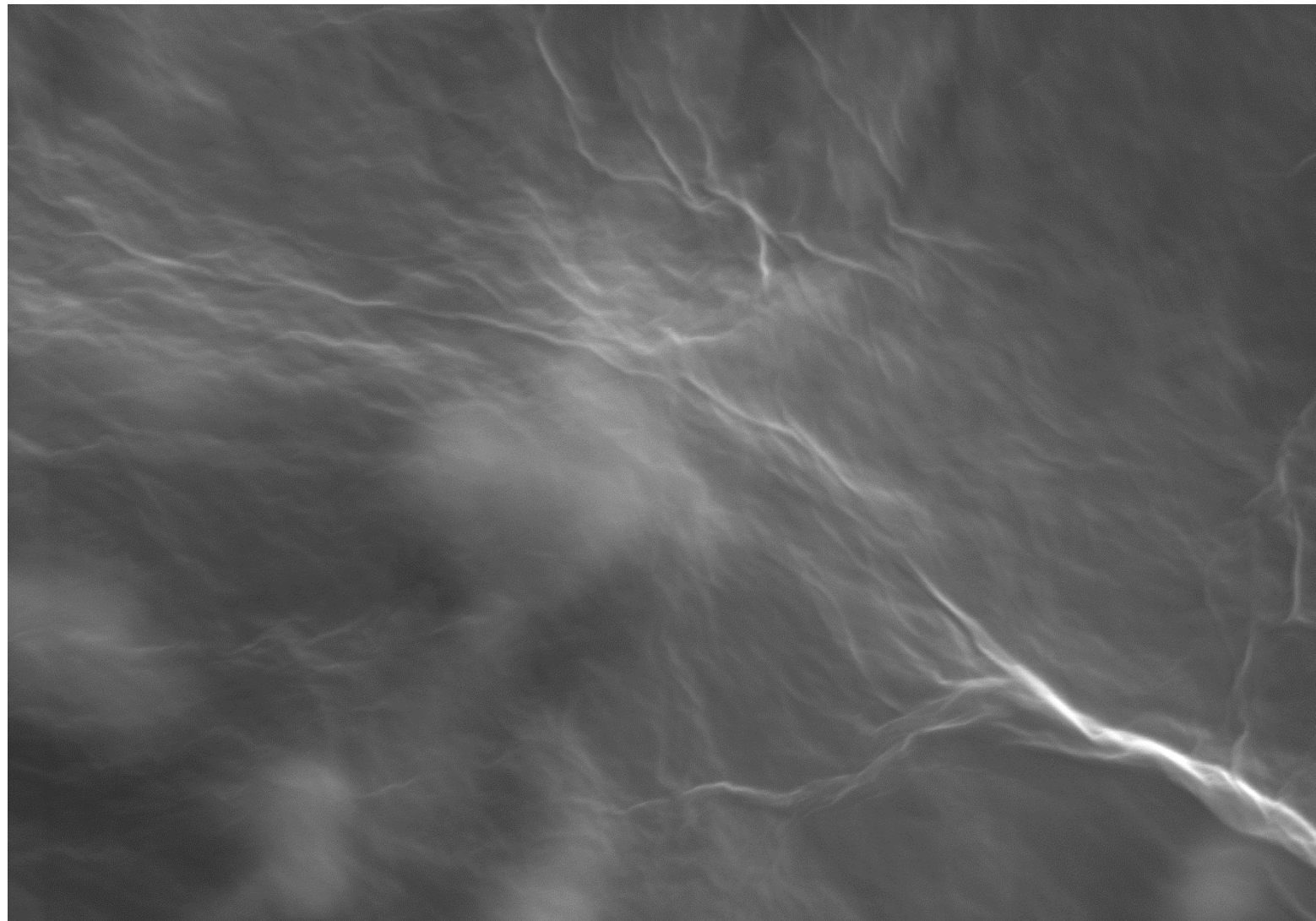
Copper oxide crystallites are not homogeneously distributed on the Cu grid, but concentrated at grid borders.

Introduction

Methods

Results

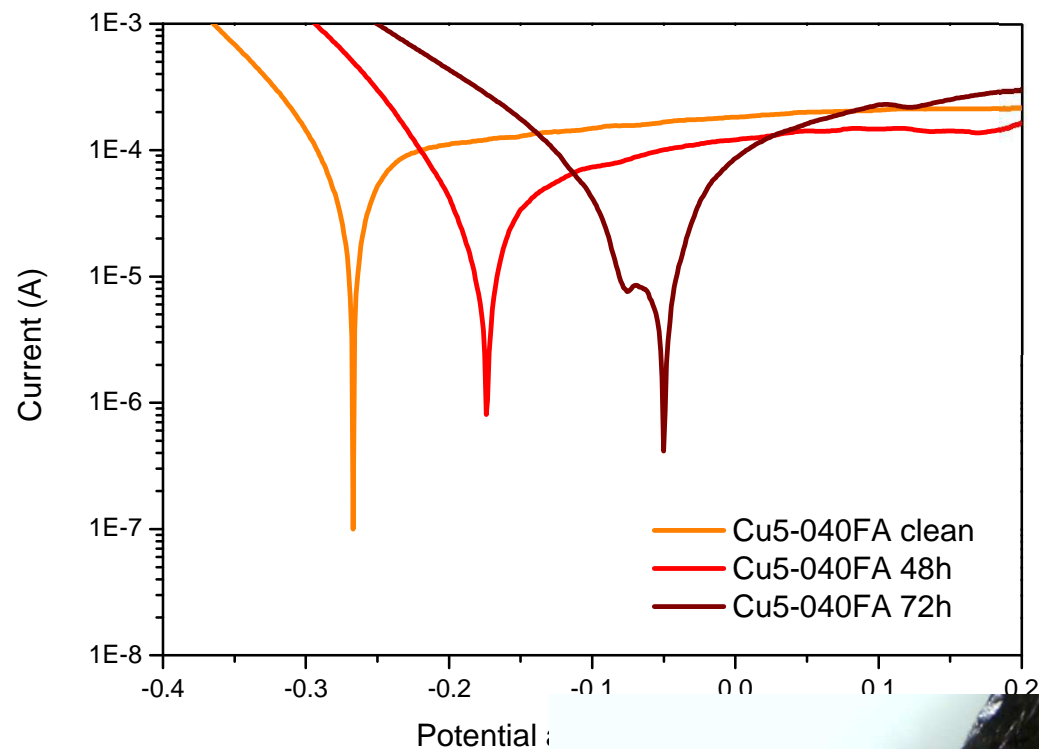
Conclusions



CIEMAT 15.0kV 15.1mm x20.0k SE

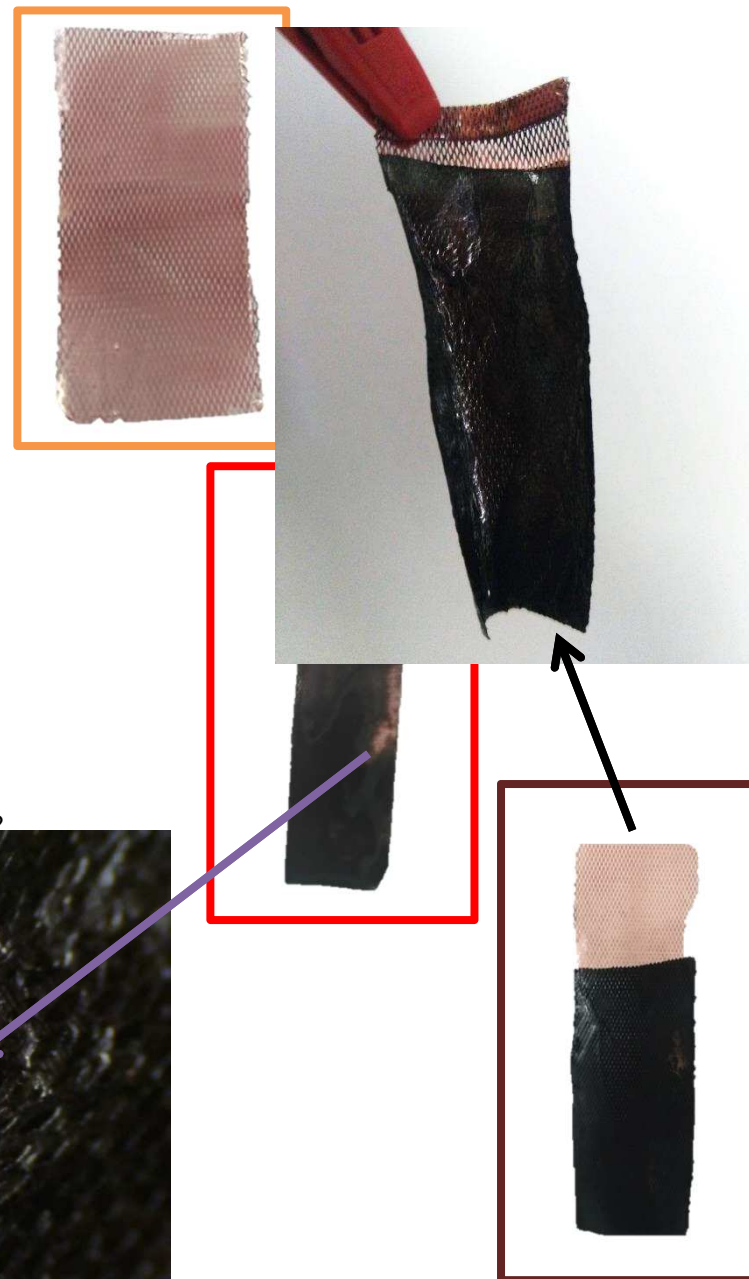
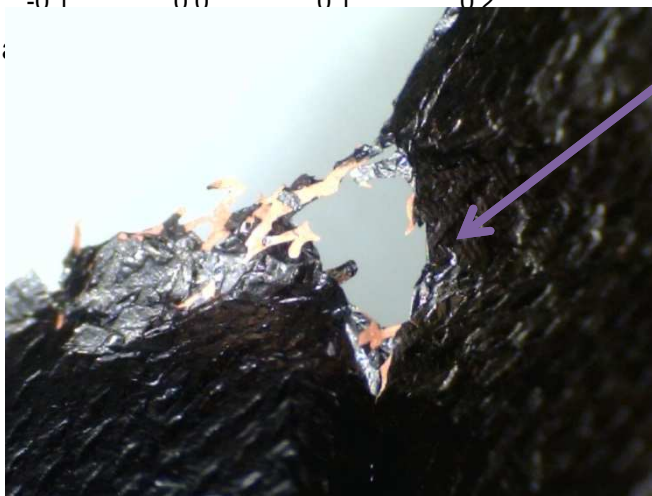
2.00um

## Tafel curves



### Conditions:

- Three electrode cell
- 0,5M  $H_2SO_4$
- 50 mV/s



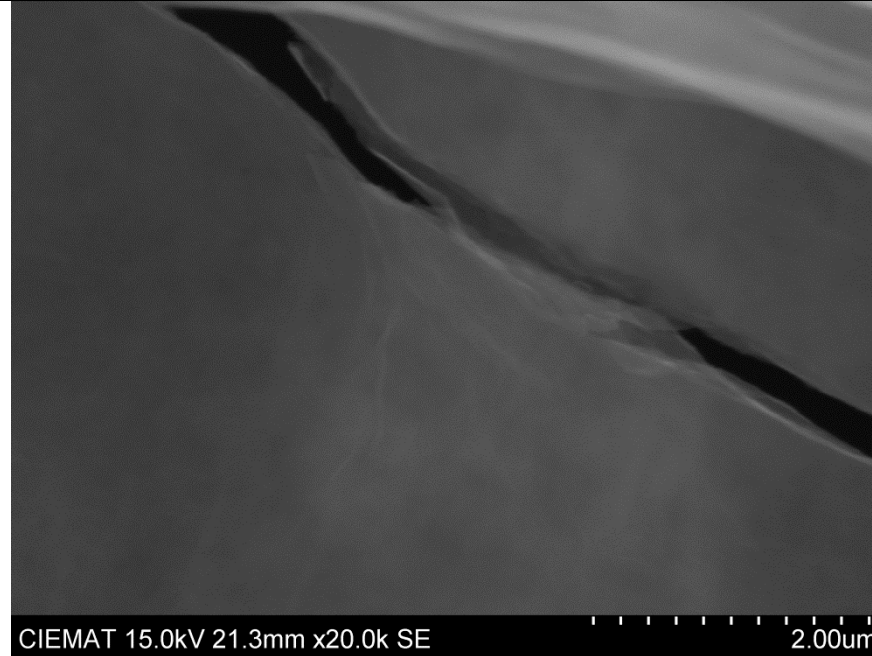
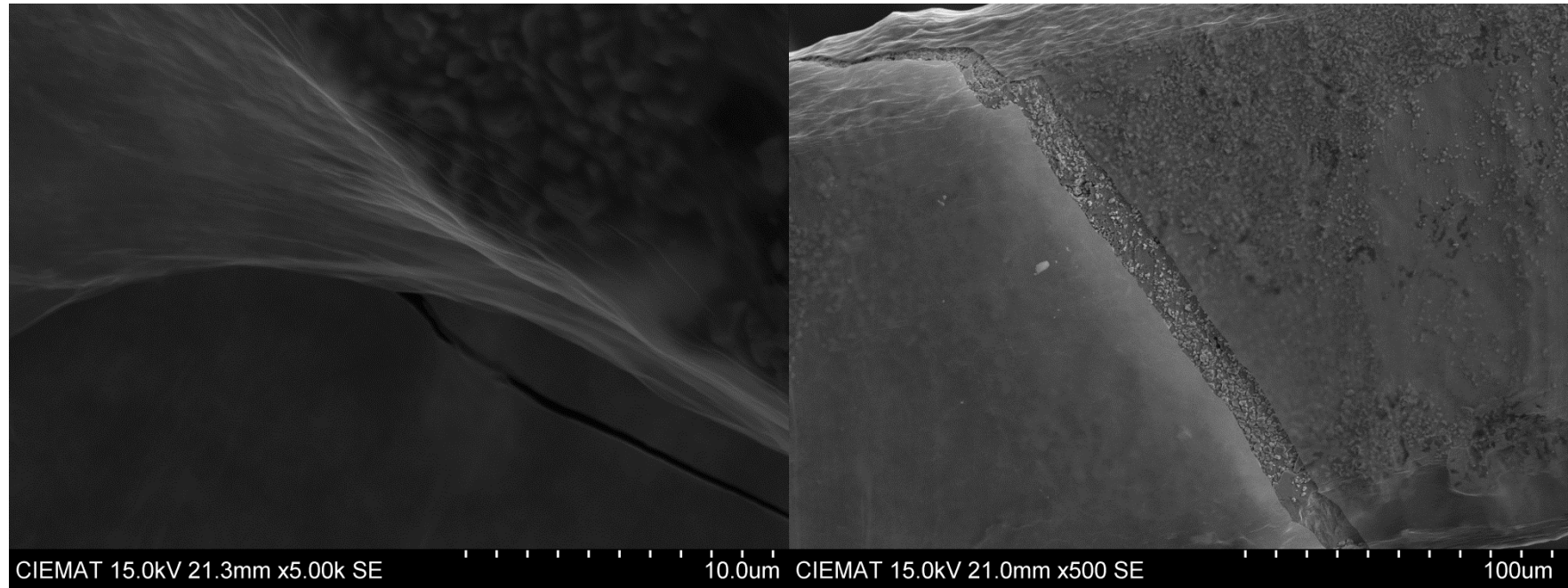


# Introduction

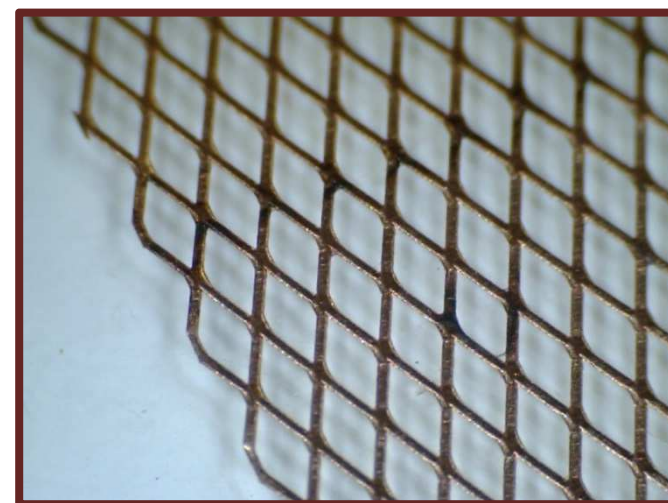
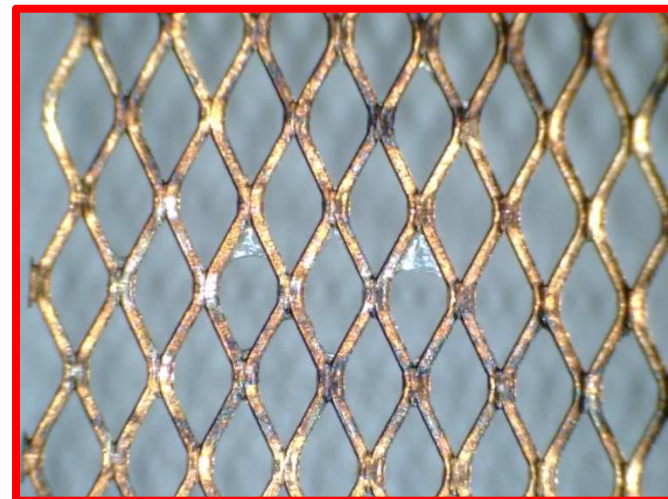
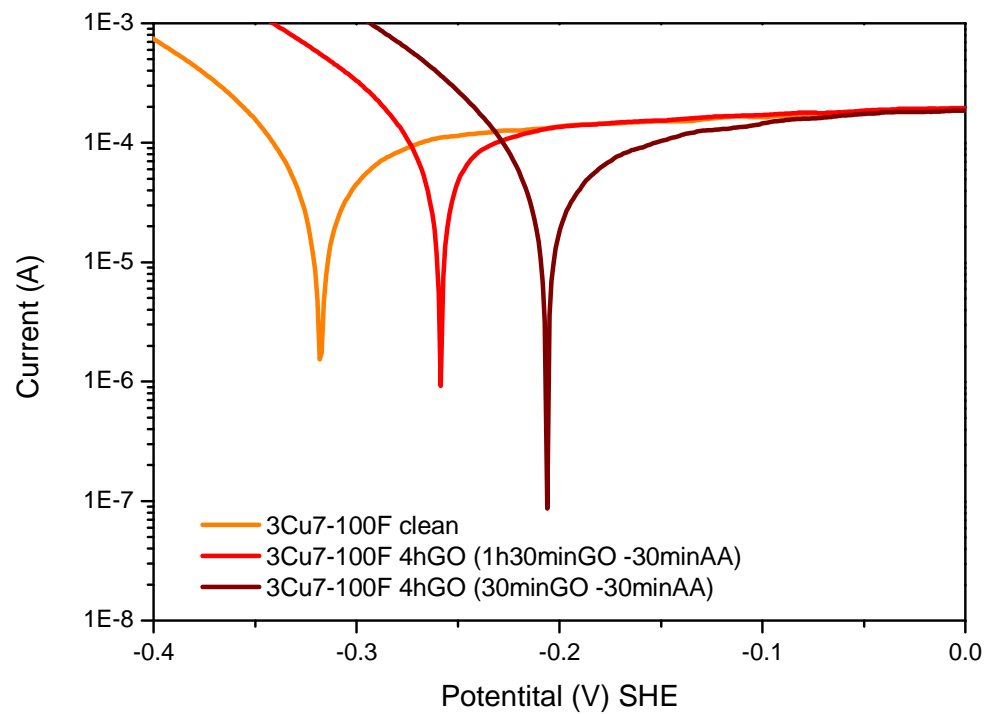
# Methods

# Results

# Conclusions

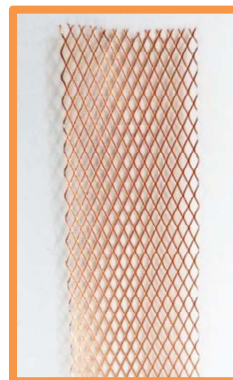


## Tafel curves



### Conditions:

- Three electrode cell
- 0,5M  $H_2SO_4$
- 50 mV/s



- Graphene films have been obtained by SARA-GO synthesis process with different thickness.
- Graphene films as corrosion protection for copper, has been demonstrated in fuel cells conditions but it requires long periods of synthesis to avoid defects in the coating.
- The use of AA to reduce r-GO coatings and copper oxides on the surface is another option to reduce defects on graphene films and better corrosion protection in less time.
- Graphene self-assembly has to be optimized by controlling the graphene layer formation and time of AA reduction in order to obtain better corrosion protection.

