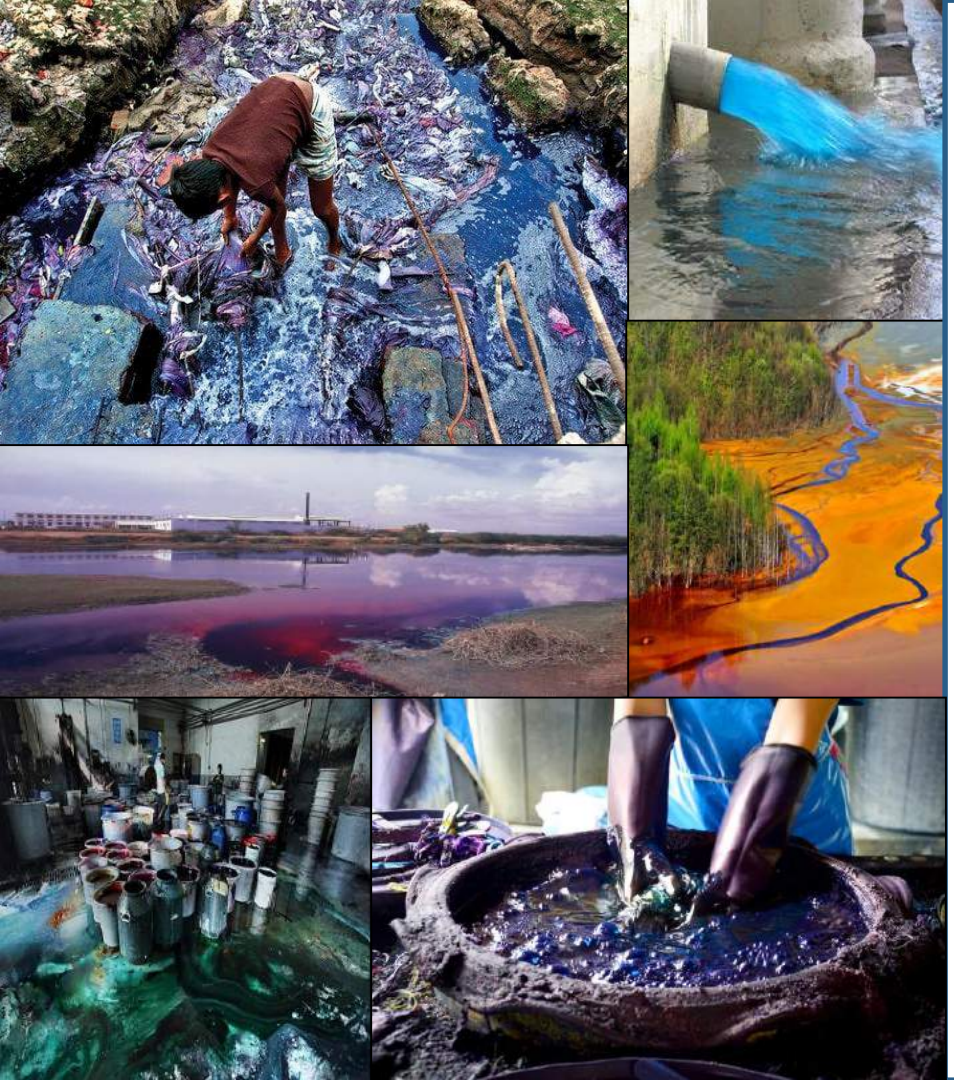


APPLICATIONS OF GRAPHENE OXIDE IN WASTEWATER TREATMENT

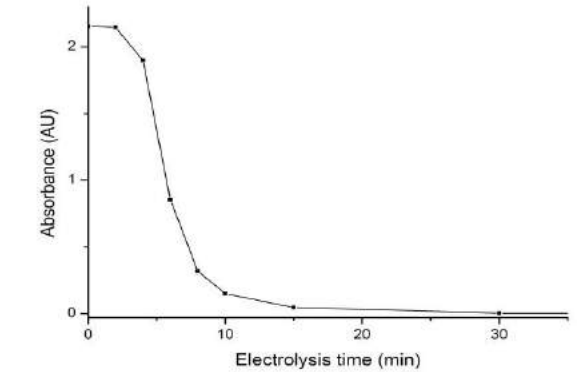
Dominika BEHUNOVÁ[1], George GALLIOS[2], Miroslava VÁCLAVÍKOVÁ[1]

[1]Institute of Geotechnics SAS, Watsonova 45, 040 01 Košice, Slovakia
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“The clothing industry is the second largest polluter in the world!” Textile industries consume large volumes of water and chemicals for wet processing of textiles.

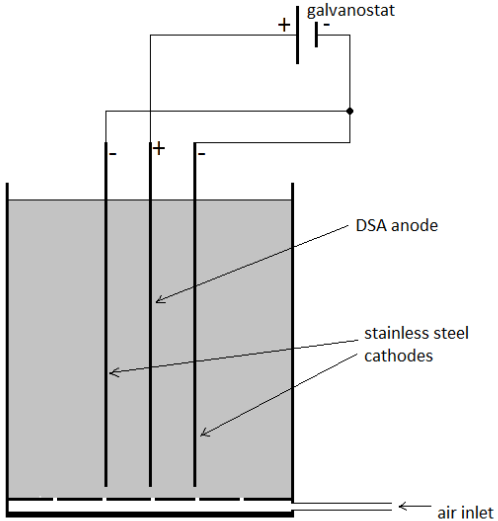
Electrochemical oxidation technique –DSA or BDD anode (Marie Curie Programme FP7-People-2013-WaSClean)

New research →electrophoretic deposition of stainless steel (SS) electrode by graphene oxide (GO).



Absorbance of the solution at 597 nm during electrolysis







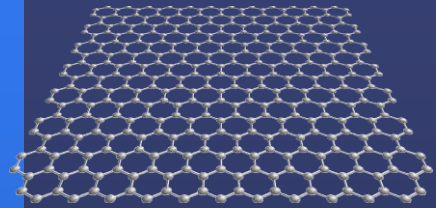
INTRODUCTION

→ Graphene

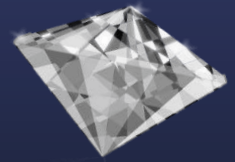
Content	Unit	Values
C-C bond length in single-layer graphene	nm	0.142
Specific surface area	m^2/g	~2630
Electron mobility (at room temp.)	$cm^2/(V·s)$	~2.5×10^5
Young's modulus	TPa	~1
Thermal conductivity	W/(m·K)	~5.1×10^3

- **a single-atomic layered material of sp2 bonded carbon atoms in honeycomb crystal lattice,**
- Andre K. Geim and Konstantin S. Novoselov, **Nobel price in physics** 2010,
- superior properties such as **large surface area** (2600 m^2g^{-1}), mechanical stability, tunable optical, thermal and excellent electrical properties (electron mobility 250 000 $cm^2V^{-1}s^{-1}$).





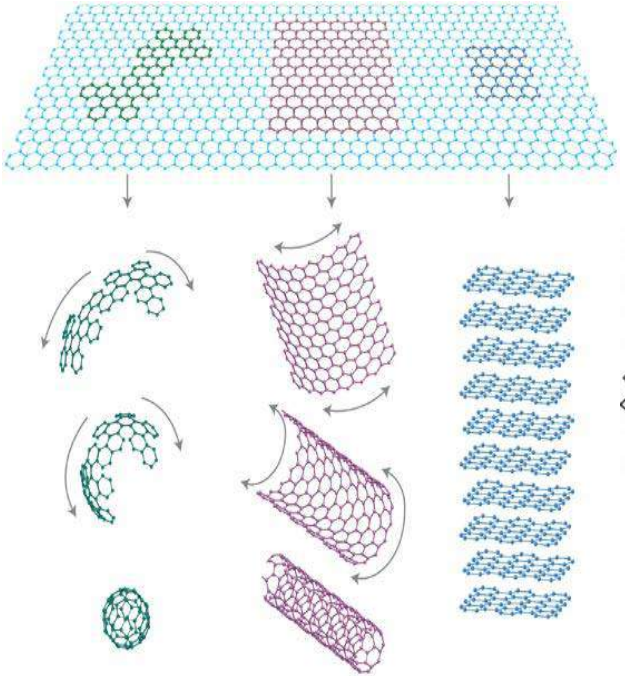
2D

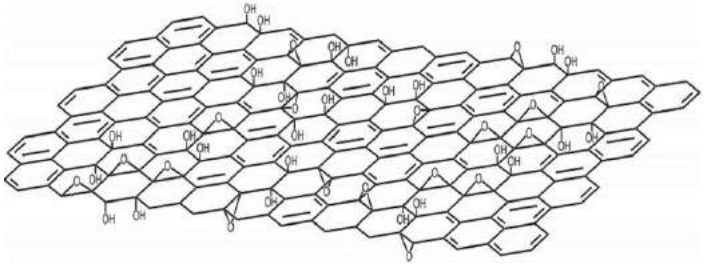




Structure

- **Graphene**
- **Graphene oxide**





GO is the functionalized graphene containing oxygen chemical groups, including epoxide and hydroxyl in the planes and carbonyl and carboxyl groups at the edges (GO, 2017).

It is a basic building block for graphitic materials. It can be wrapped up into fullerenes, rolled into nanotubes or stacked into graphite (Geim a kol., 2007).

Graphene production techniques

Mechanical exfoliation

Chemical vapor deposition (CVD)

Chemical synthesis



Synthesis GO

Brodie – Staudenmaier – Hofmann – Hummers-Offeman

Brodie first demonstrated the synthesis of GO by adding a portion of **potassium chlorate** to a slurry of graphite in **fuming nitric acid**.

60°C (Brodie, 1859).

$KClO_3$, HNO_3

Staudenmaier improved on this protocol by using **concentrated sulfuric acid** as well as **fuming nitric acid** and adding the **chlorate** in multiple aliquots over the course of the reaction.
(Staudenmaier a kol., 1898).

H_2SO_4, HNO_3,ClO^{3-}

Hofmann used combination with **concentrated nitric acid** and **potassium chlorate**.
(Hofmann, 1928).

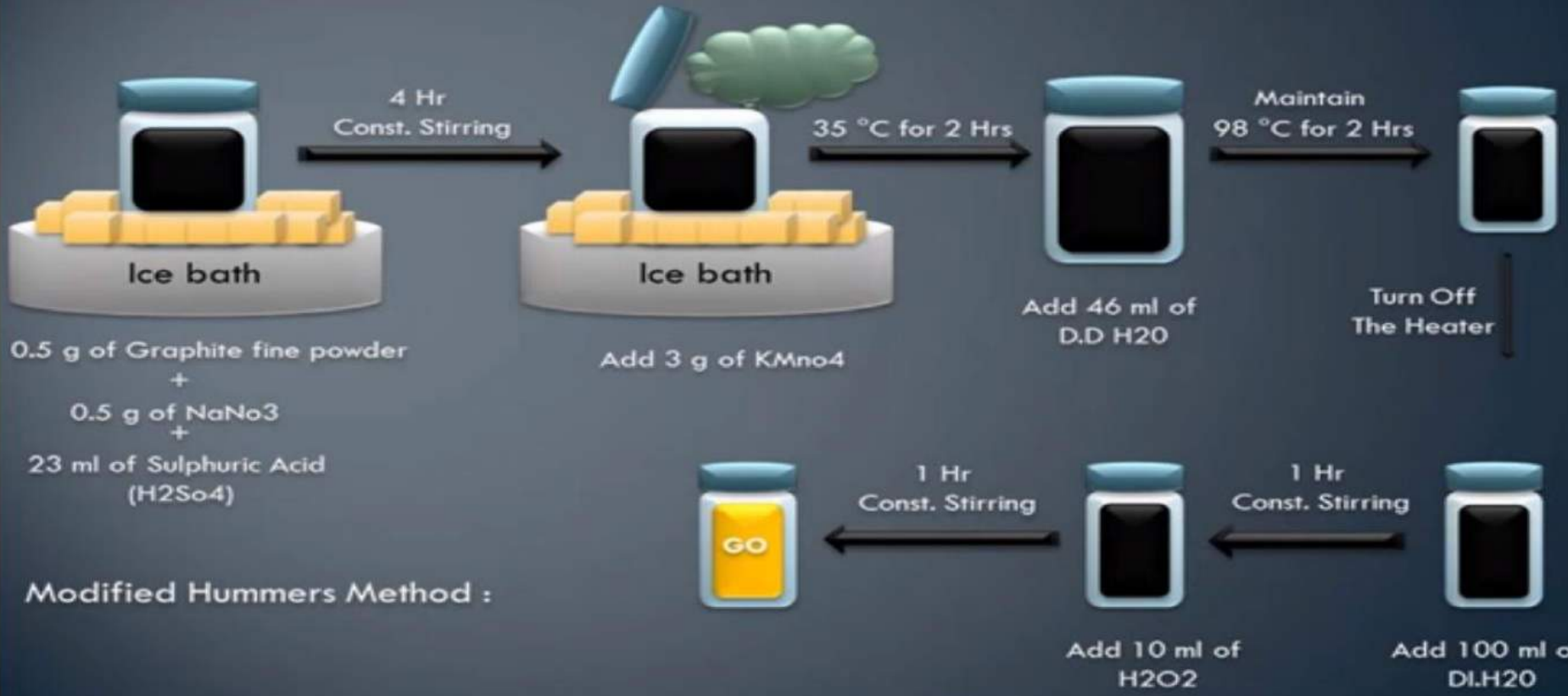
HNO_3,$KClO_3$

In 1958, Hummers reported the method most commonly used today: the graphite is oxidized by treatment with **potassium permanganate** and **sodium nitrate** in **concentrated sulfuric acid**.
(Hummers a kol., 1958).

$KMnO_4$, $NaNO_3$, H_2SO_4



Synthesis of Graphene Oxide :

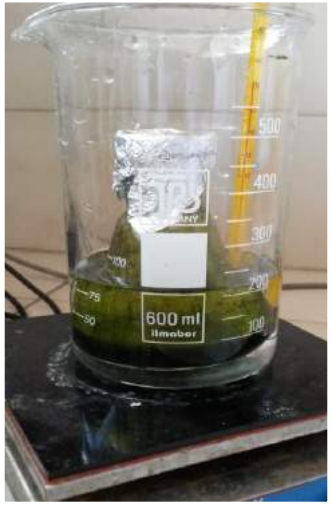


Modified Hummers Method :

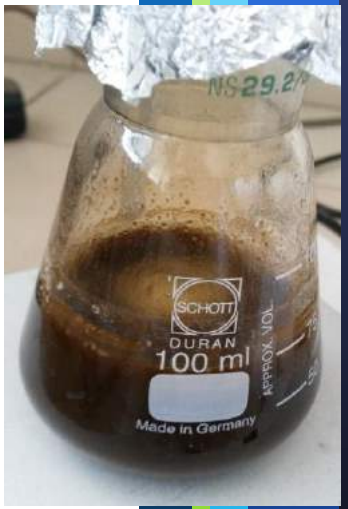
Modified Hummers method

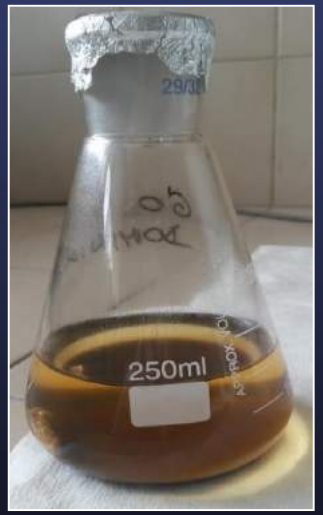
Stirring → Oxidation → Heating → GO



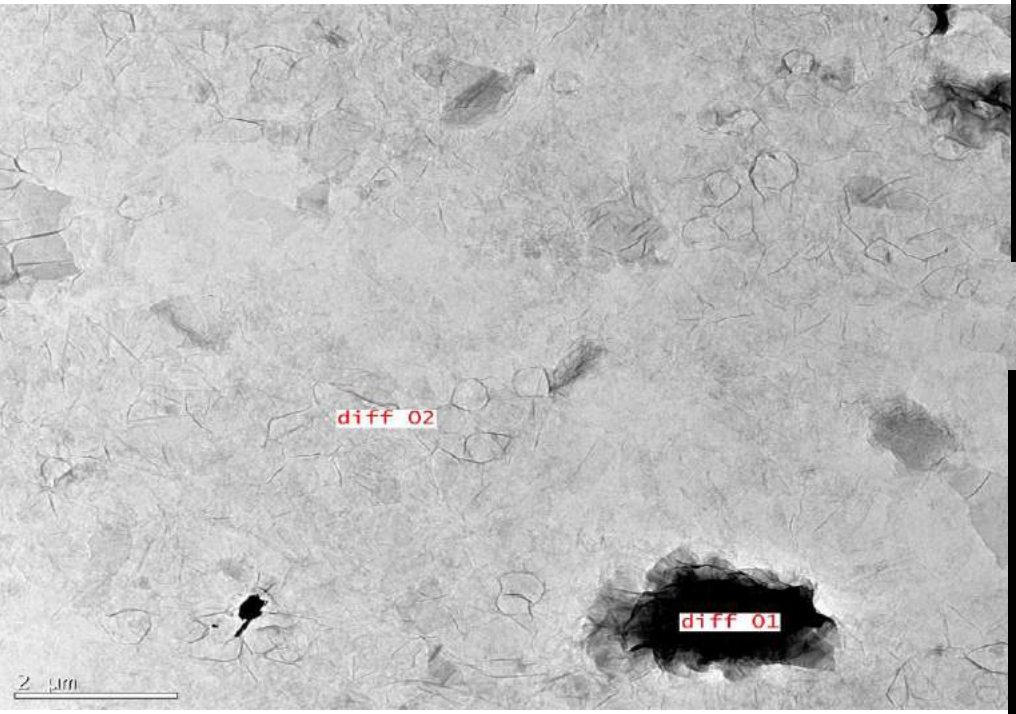




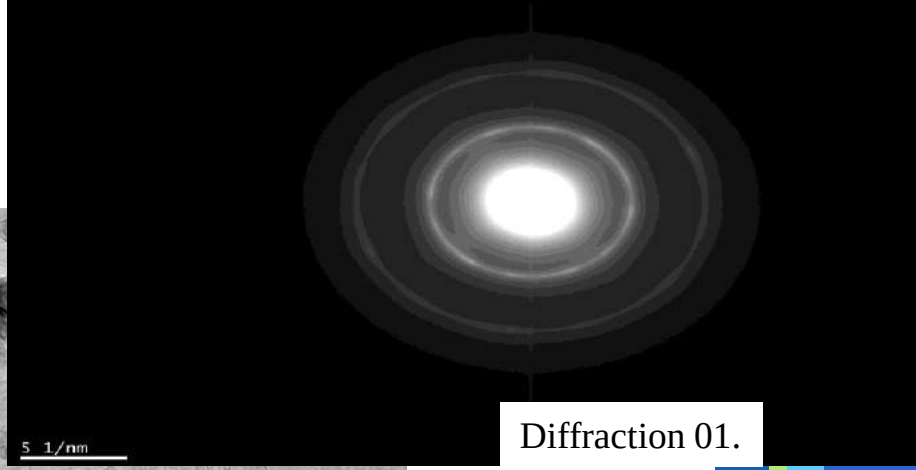




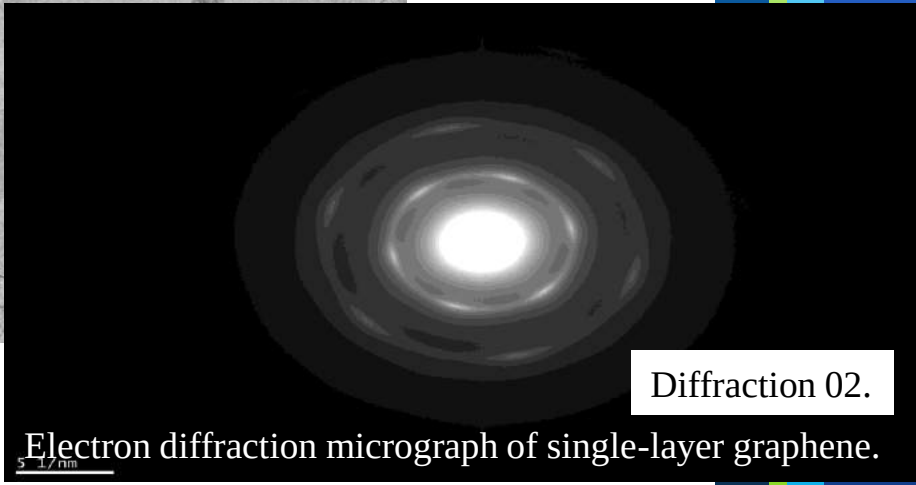
graphite powder, H_2SO_4, $NaNO_3$, $KMnO_4$, H_2O_2



TEM of graphene (Hummers method)



Diffraction 01.



Diffraction 02.

Electron diffraction micrograph of single-layer graphene.

Improved Method by Marcano et al.

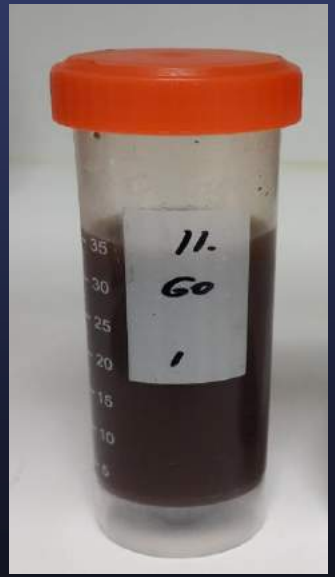
- eco-friendly method without using $NaNO_3$,
- increasing the amount of $KMnO_4$, and performing the reaction in a 9:1 ratio the mixture of H_2SO_4/H_3PO_4 improves the efficiency of the oxidation process.

Oxidation → Stirring and heating → H_2O_2 → GO

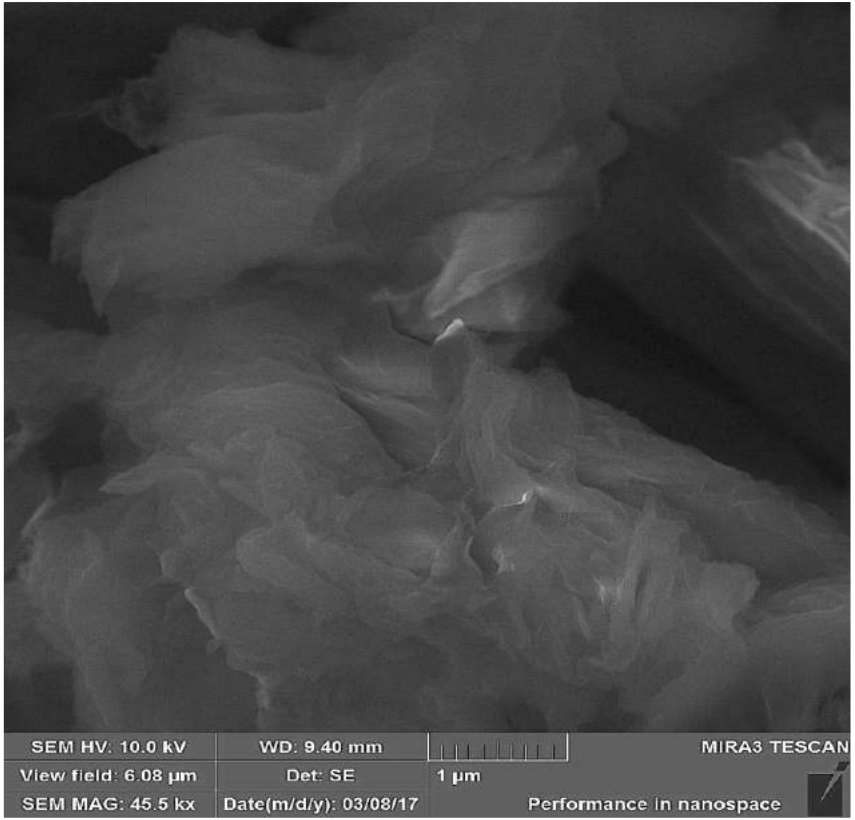




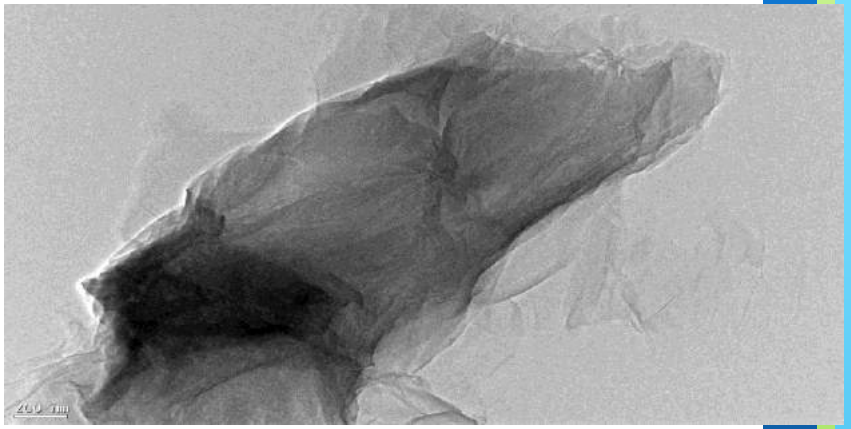




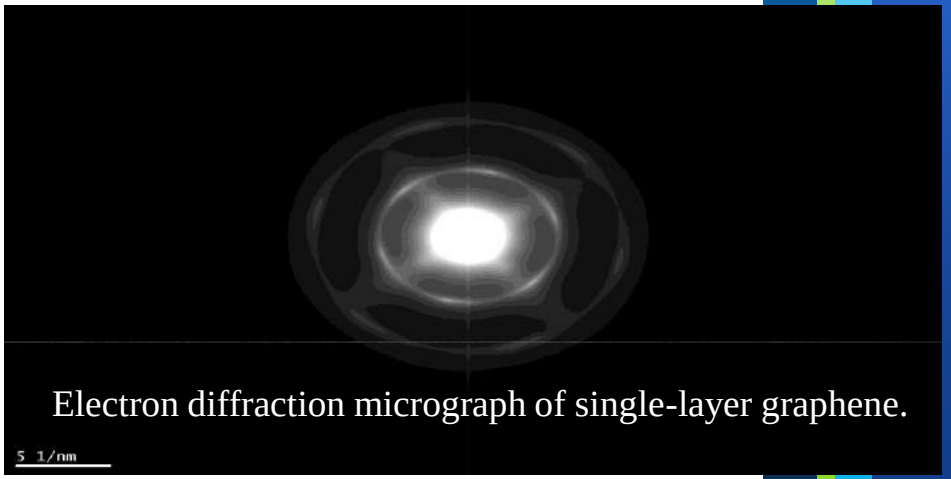
graphite powder, $KMnO_4$, H_2SO_4/H_3PO_4,H_2O_2



SEM of GO

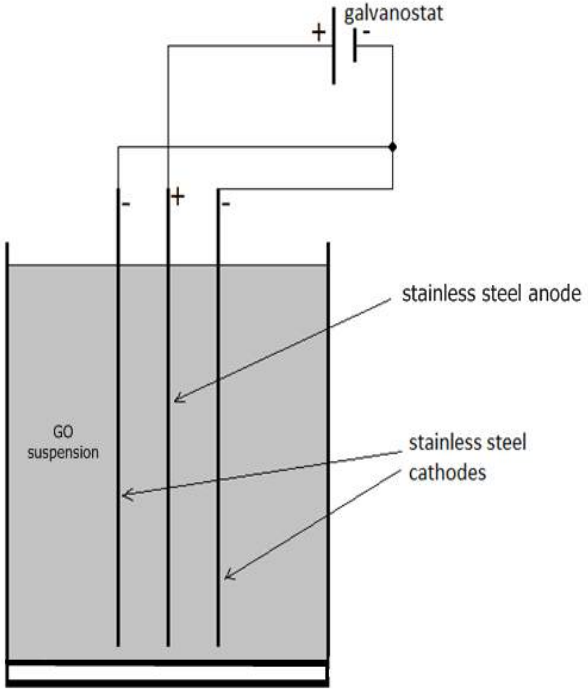


TEM of GO



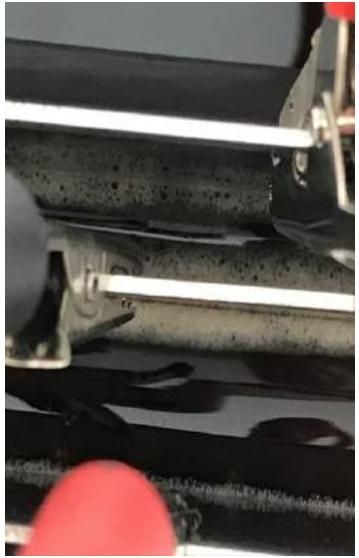
Electron diffraction micrograph of single-layer graphene.

Electrophoretic deposition (EPD)



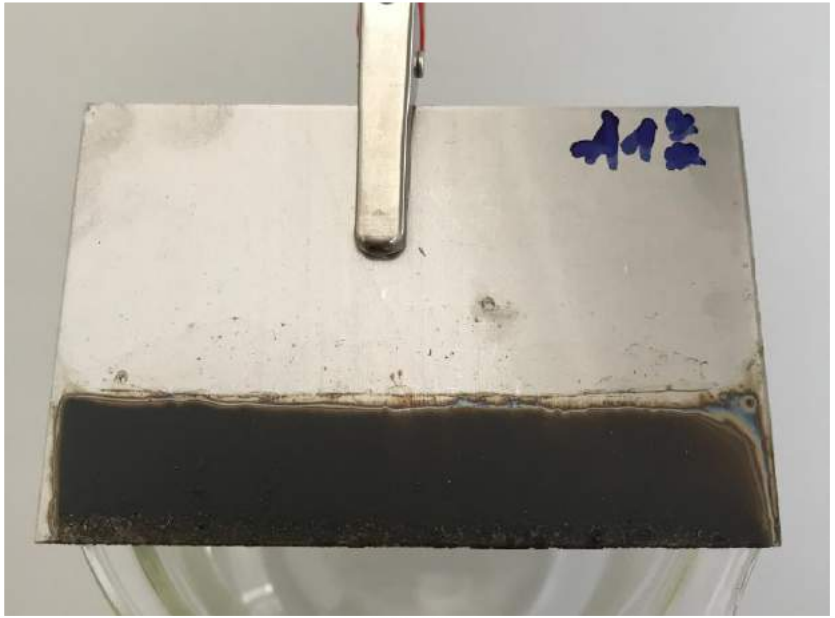






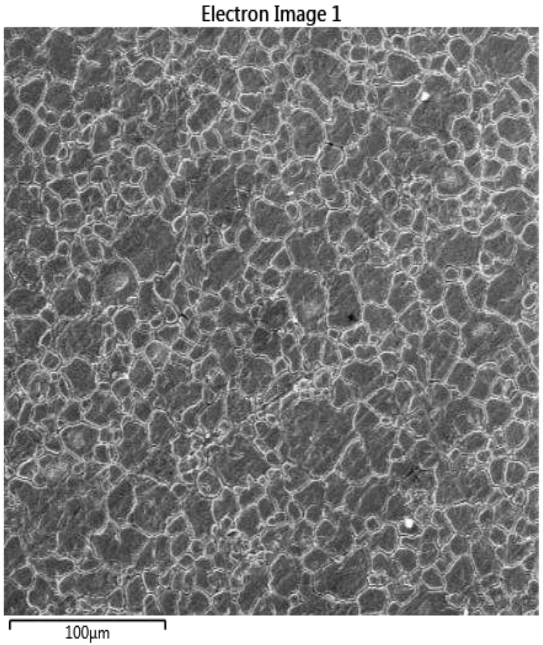


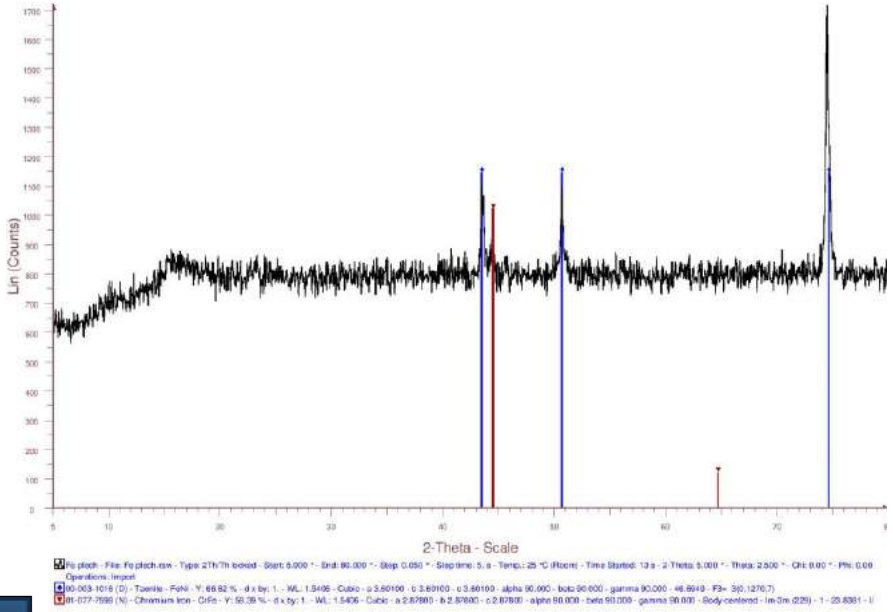
(a)



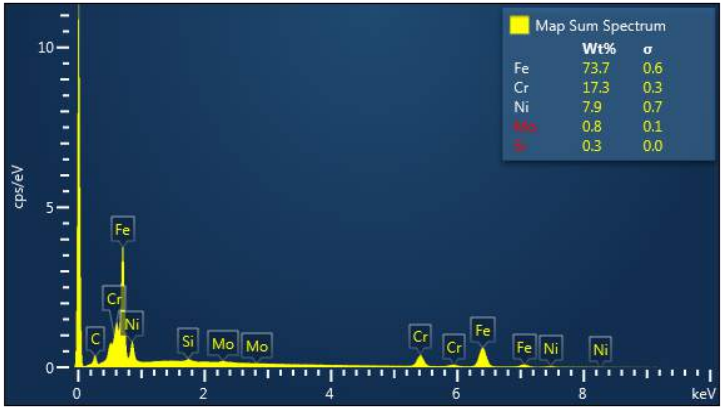
(b)

Images of (a) stainless steel surface before deposition and (b) GO-deposited on stainless steel

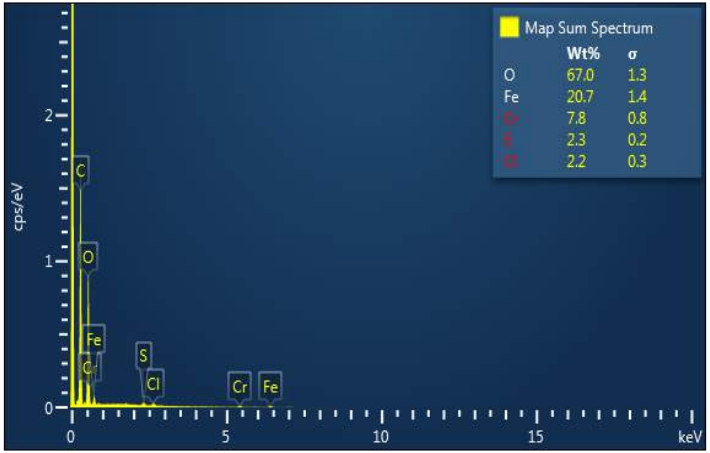




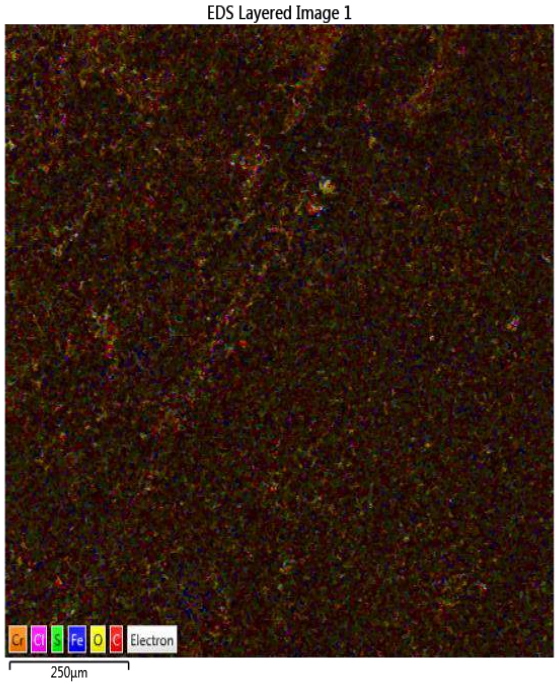
X-ray diffraction pattern of the SS.



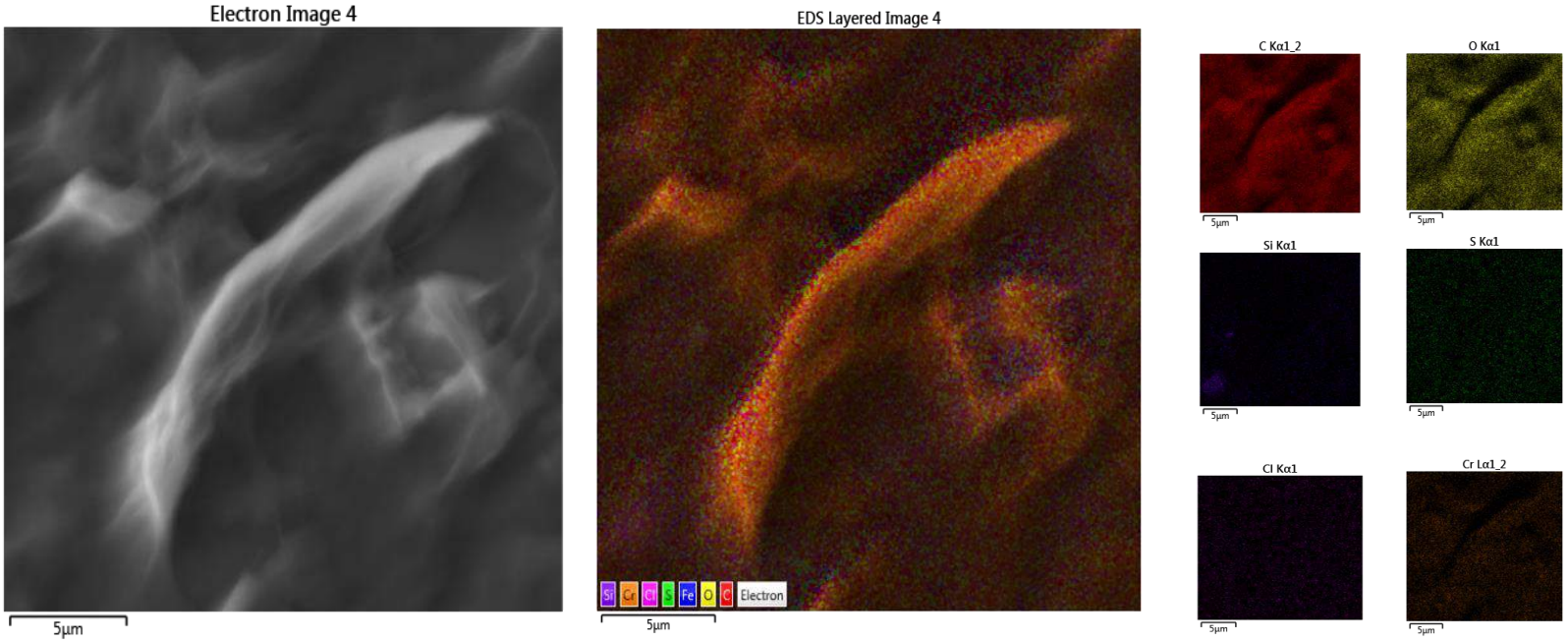
EDS of stainless steel without GO







GO-deposited on stainless steel



EDS images of GO-deposited on stainless steel electrode

NEXT: Assessment of performance of electrodes in water treatment technologies.

CONCLUSION

- **Graphene** has a unique atom-thick 2-dimensional structure, excellent **electronic, mechanical, optical and thermal properties**.

- GO will be employed for the electroplating/surface covering of the stainless steel electrode.

- In the polluted water, various **GO** composites display **strong affinity for the adsorption of heavy metal ion and organic contaminants** (PAHs, organic dyes, for instance methylene blue) but also function as efficient chemical and photo catalysts in converting the toxic organic contaminants in to the harmless products.

Thanks!

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