Physical Properties of Gra-doped $ZnFe_2O_4$ thin films for solar cells application

PhD student: Fatma Ezzahra Dhif

Ca'Foscari University supervisors:

Alberto Vomiero

Elisa Moretti

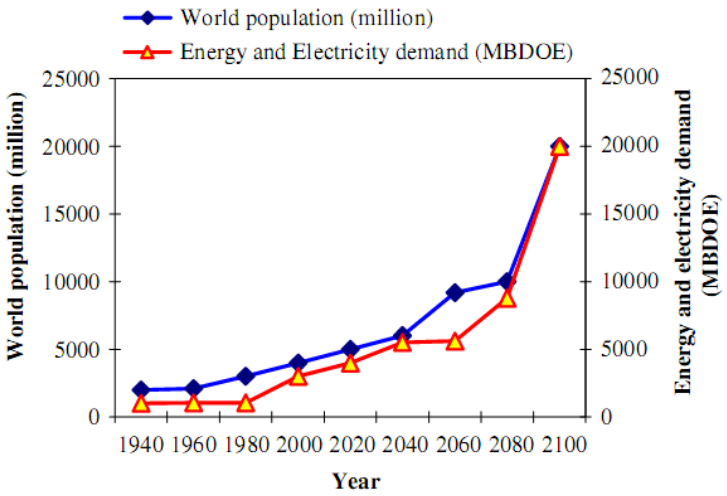
The University of Tunis El Manar

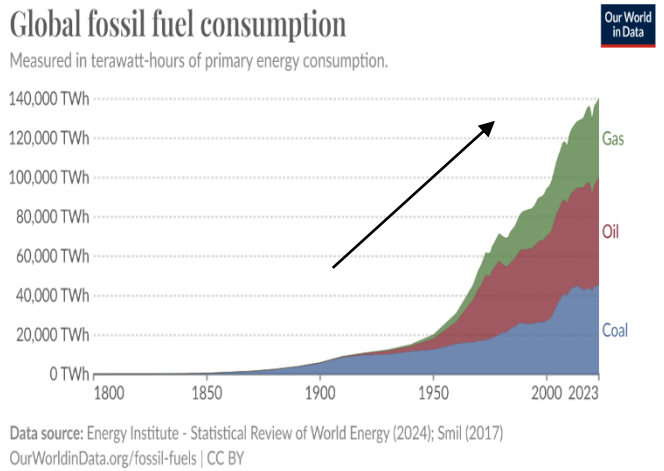
Supervisor:

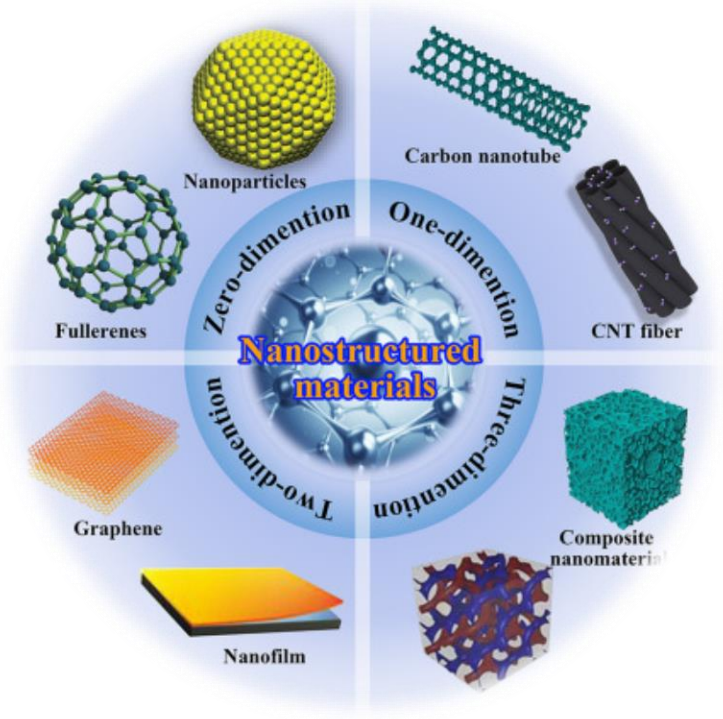
Neila Jebbari

Presentation outline:

- **Introduction**
- **Synthesis Process**
- **Results & Discussion**
- **Application**
- **Conclusion & Prespectives**

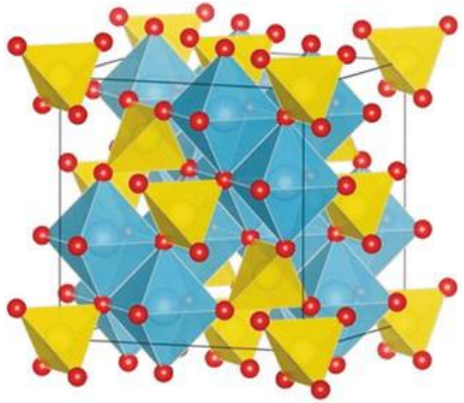

World population (million)
Energy and Electricity demand (MBDOE)
World population (million)
Energy and electricity demand (MBDOE)
25000
20000
15000
10000
5000
0
1940 1960 1980 2000 2020 2040 2060 2080 2100
Year


Global fossil fuel consumption
Measured in terawatt-hours of primary energy consumption.
Our World in Data
140,000 TWh
120,000 TWh
100,000 TWh
80,000 TWh
60,000 TWh
40,000 TWh
20,000 TWh
0 TWh
Gas
Oil
Coal
1800
1850
1900
1950
2000 2023
Data source: Energy Institute - Statistical Review of World Energy (2024); Smil (2017)
OurWorldinData.org/fossil-fuels | CC BY

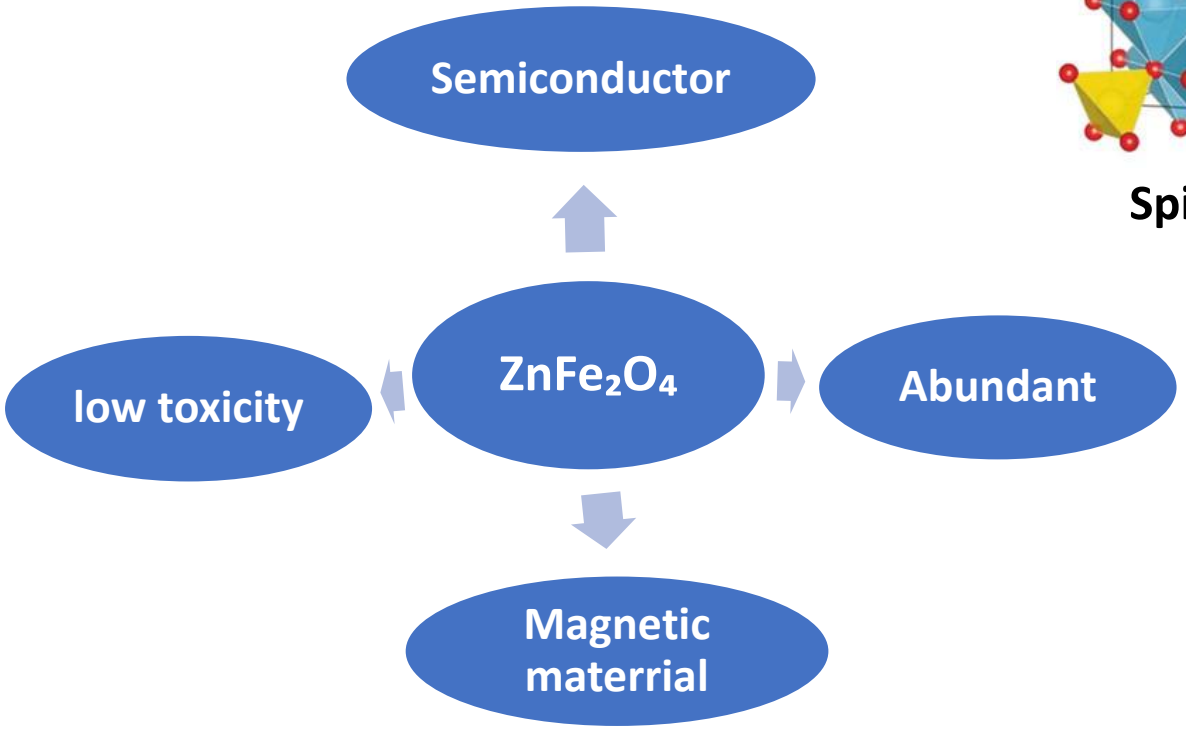


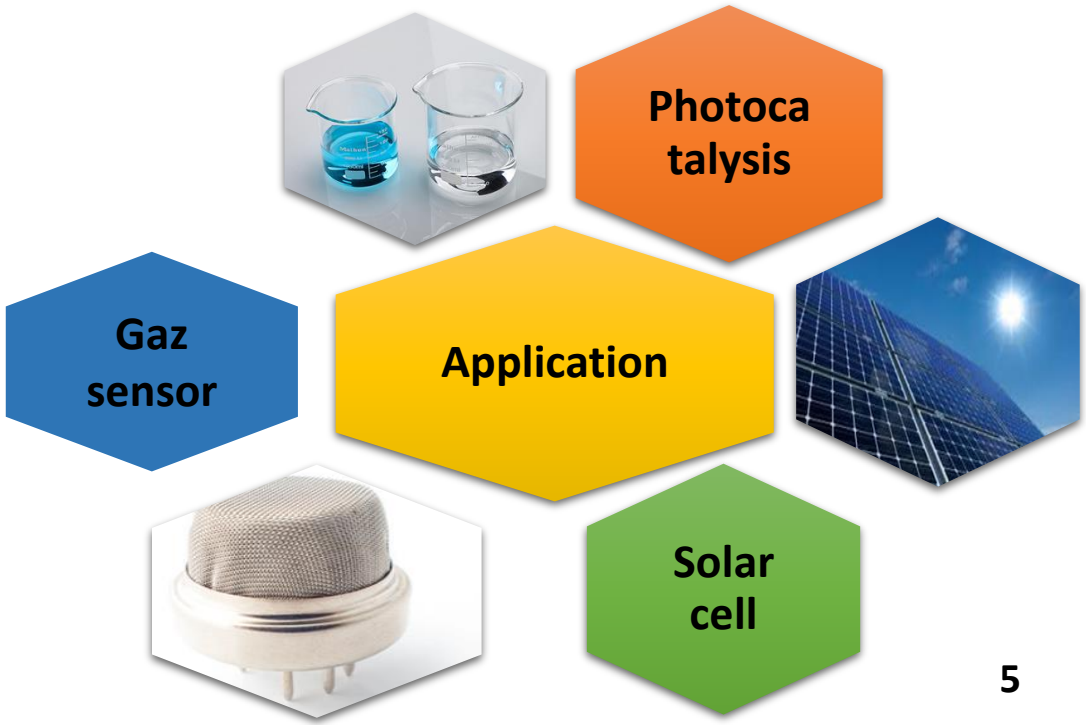
Green energy is the key solution to overcoming all these issues and fostering a cleaner, healthier environment for future generations

Advancing innovative materials is vital for maximizing the efficiency and effectiveness of renewable energy applications



Spinel structure





Pros

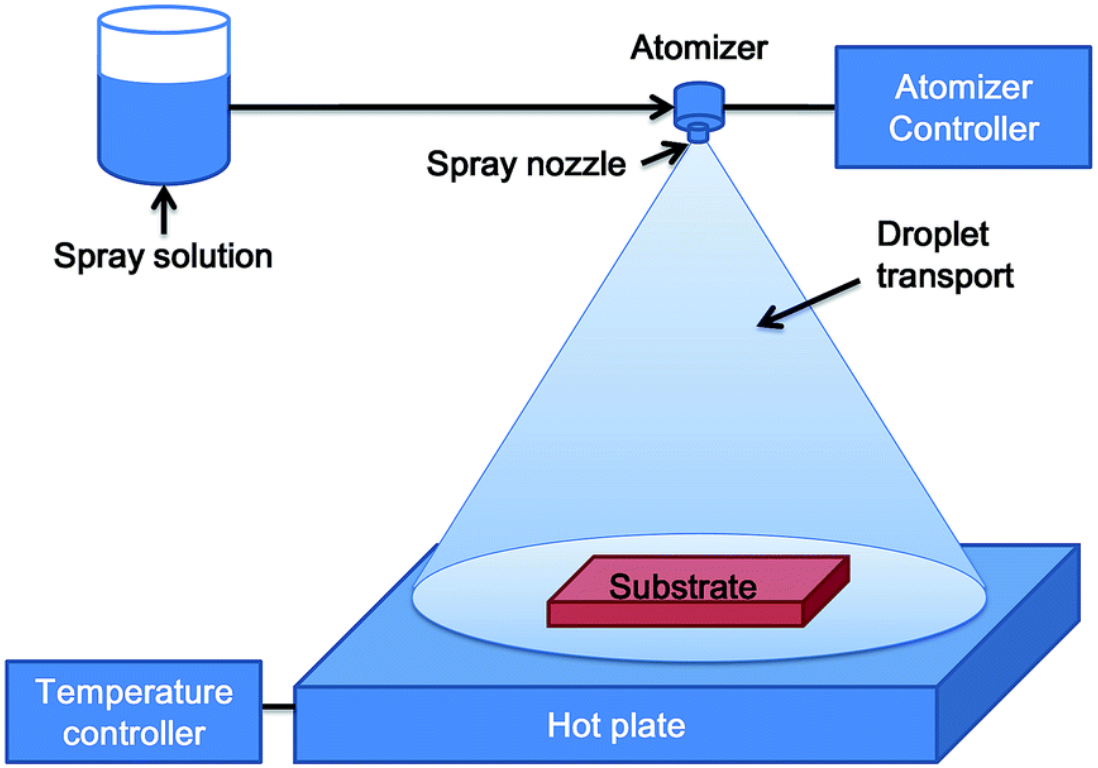
+ High physicochemical stability.
+ High Surface area and porosity.
+ Narrow band gap

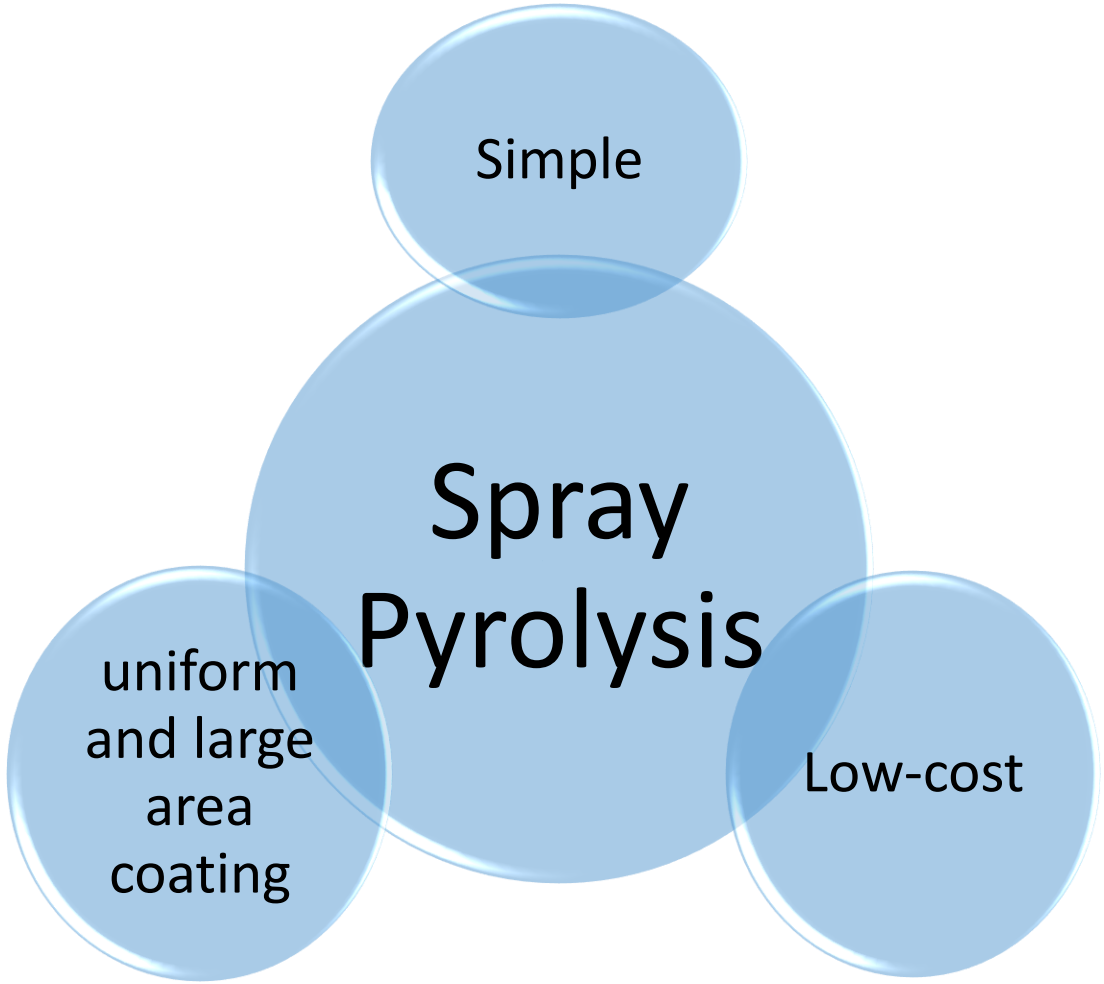
Cons

- Limited charge carier mobility.
- Light absorption limitations.

optimizing the performance of zinc ferrite thin films

Doping


Atomizer
Atomizer Controller
Spray nozzle
Spray solution
Droplet transport
Substrate
Temperature controller
Hot plate

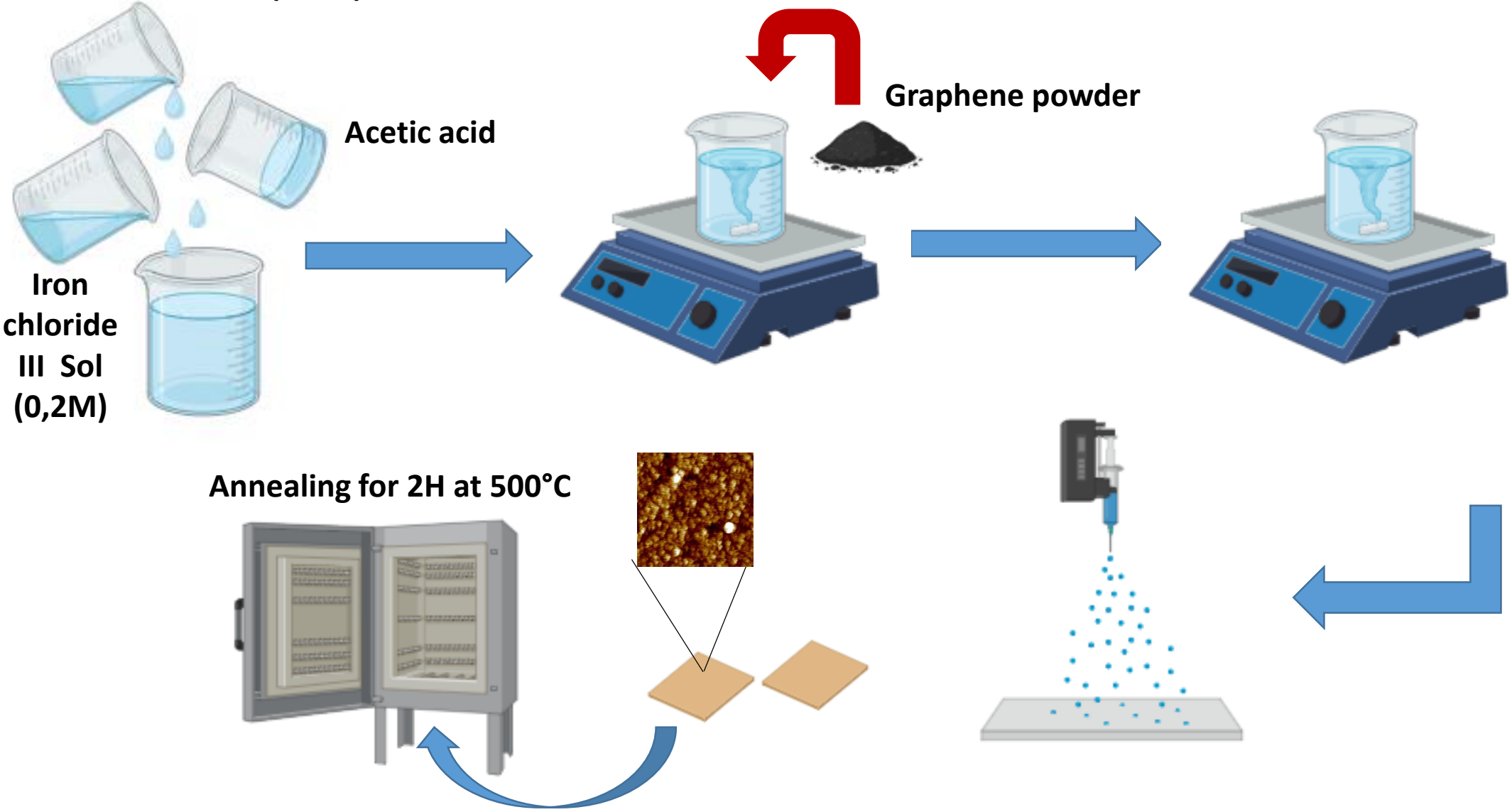

Simple
Spray Pyrolysis
uniform and large area coating
Low-cost

Zinc acetate Sol (0,1M)

Acetic acid

Iron chloride III Sol (0,2M)

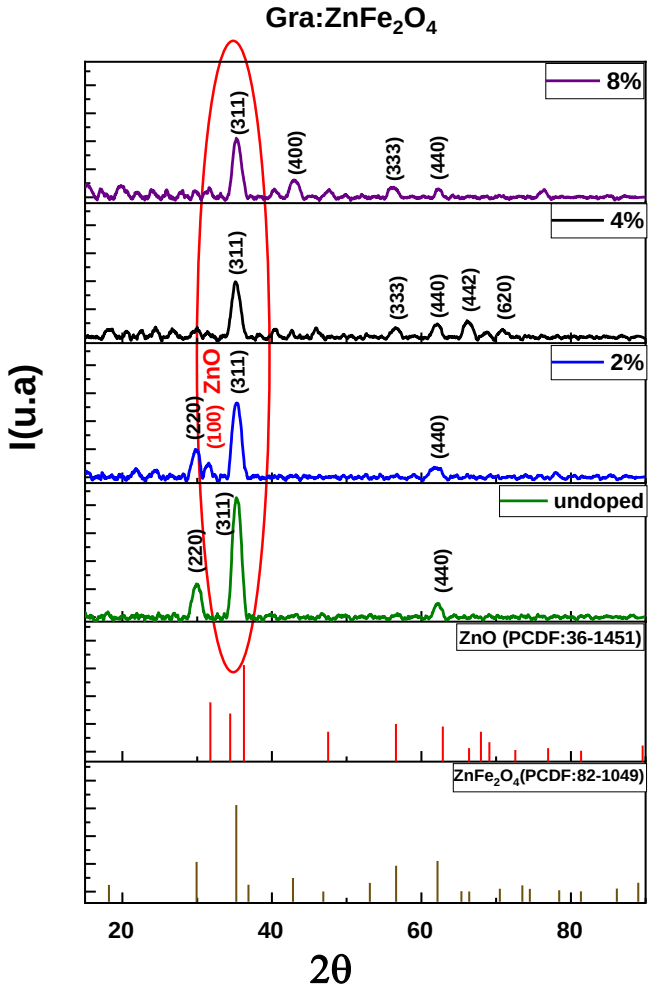
Graphene powder



Annealing for 2H at 500°C

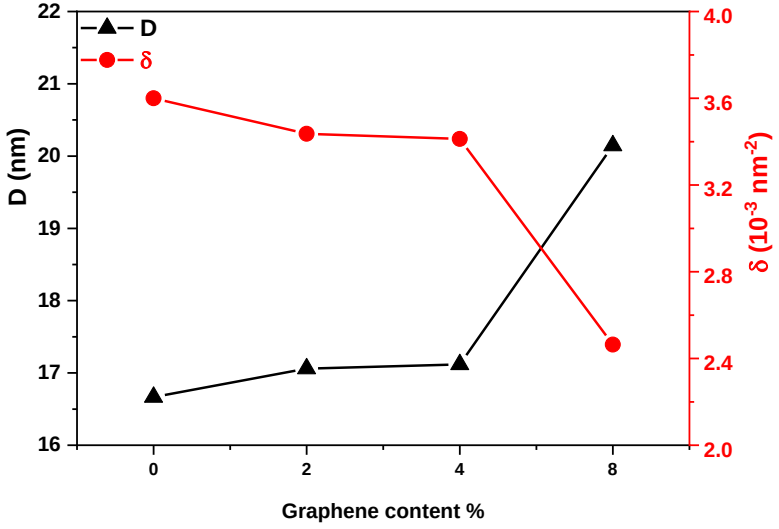
XRD analysis:

Decrease of the crystallinity of elaborated the thin films with the increase of the graphene amount.



The crystallites size (D) values are calculated using the Debye–Scherrer formula:

$$D = \frac{k\lambda}{\beta \cos\theta}$$



The graphene concentration ↑

The crystallites size (D) ↑

Morphological analysis: SEM:

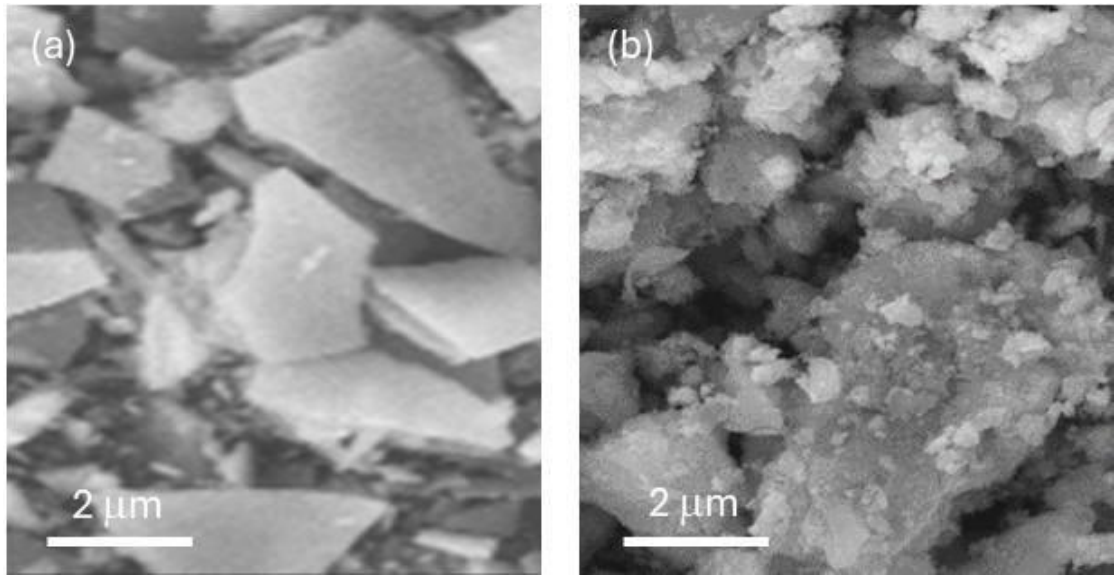
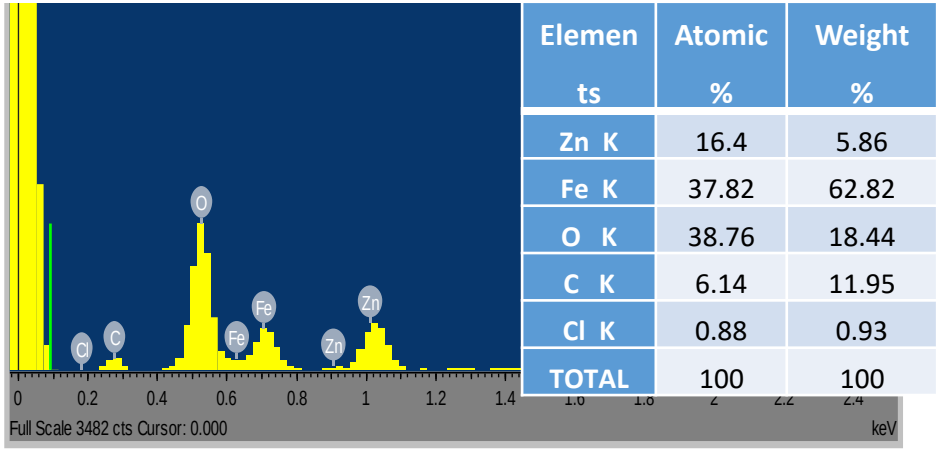


Figure : SEM images of a) undoped $ZnFe_2O_4$ and b) Graphene 8% doped $ZnFe_2O_4$ thin films .

Graphene doping has deteriorated the crystallinity of the $ZnFe_2O_4$ thin films which is **in good agreement with XRD results.**

EDX:

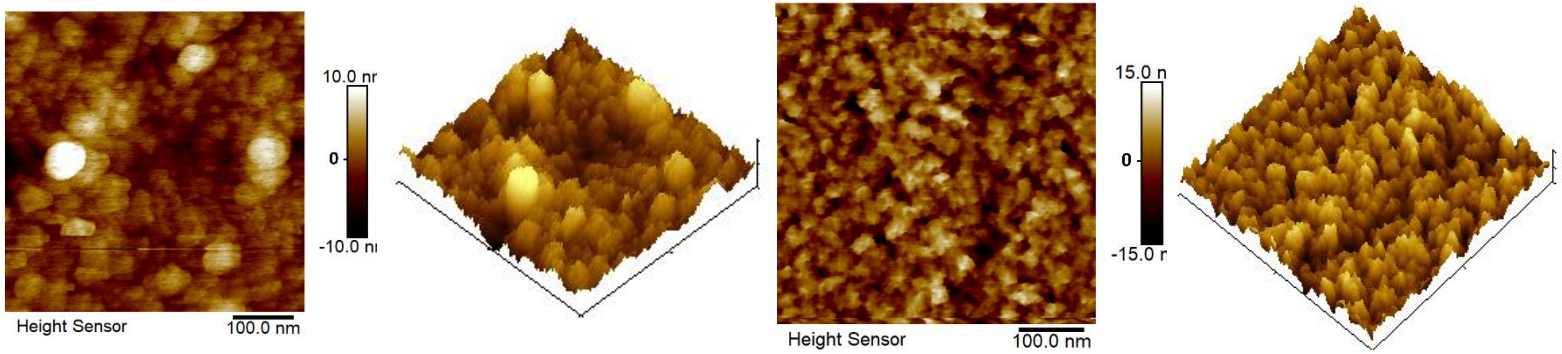


Elements	Atomic %	Weight %
Zn K	16.4	5.86
Fe K	37.82	62.82
O K	38.76	18.44
C K	6.14	11.95
Cl K	0.88	0.93
TOTAL	100	100

Figure : EDX analysis of 8% Gra:$ZnFe_2O_4$ thin films .

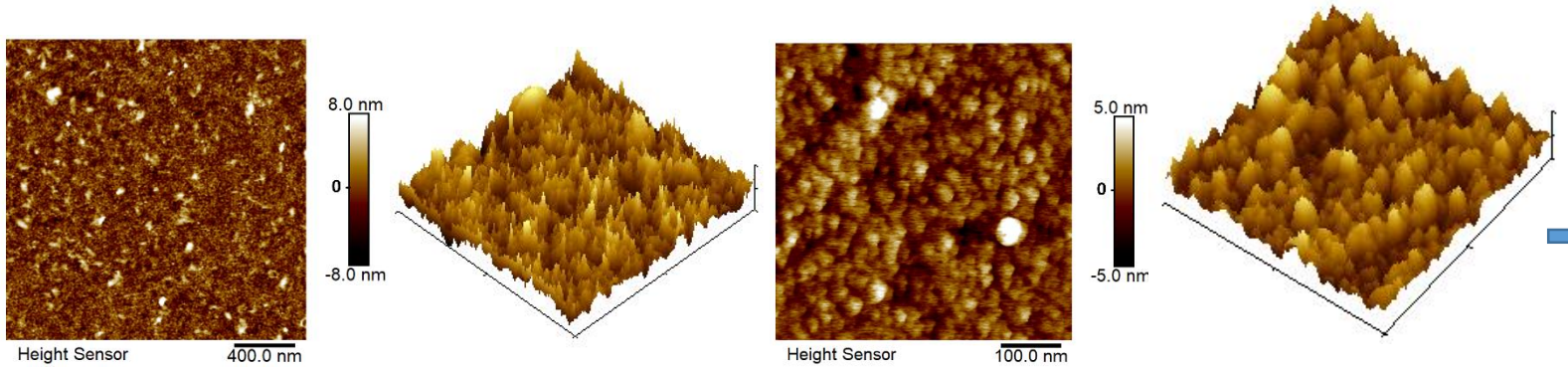
The presence of Zn, Fe, O and C as principal elements with the existence of some trace amount of Cl, coming from the iron precursor.

AFM:



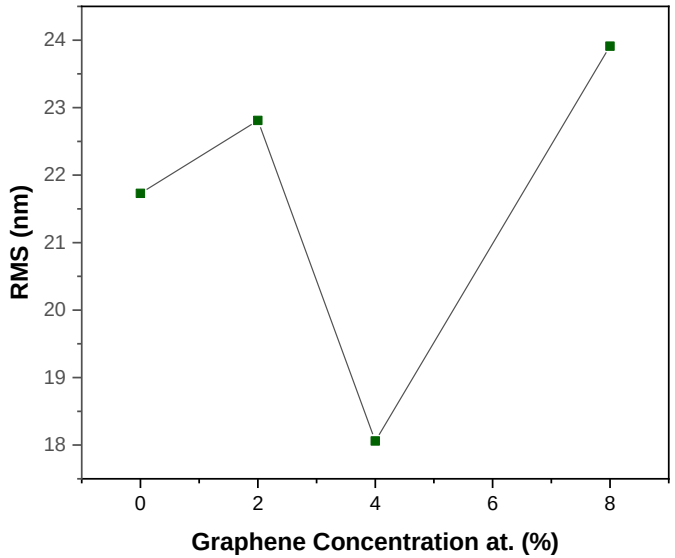
$ZnFe_2O_4$ undoped

2% Gra:$ZnFe_2O_4$



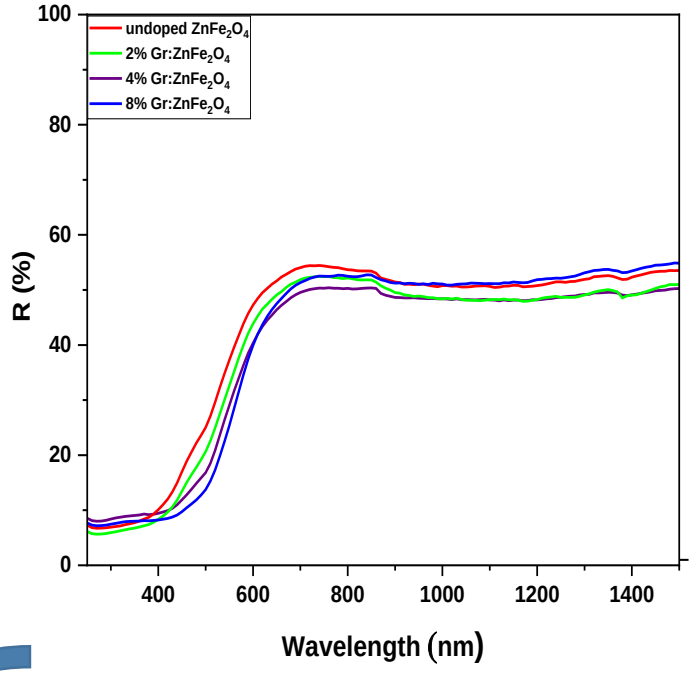
4% Gra:$ZnFe_2O_4$

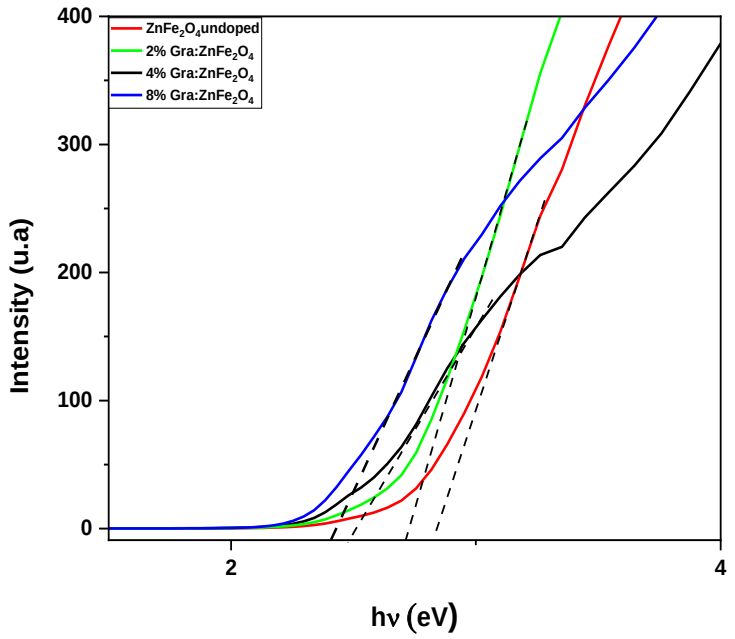
8% Gra:$ZnFe_2O_4$



→ The graphene doping changes the surface morphology, making it smoother snd more structured

Optical analysis:





Sample	Eg (eV)
$ZnFe_2O_4$ undoped	2.76
$ZnFe_2O_4$:Gra 2%	2.69
$ZnFe_2O_4$:Gra 4%	2.48
$ZnFe_2O_4$:Gra 8%	2.40

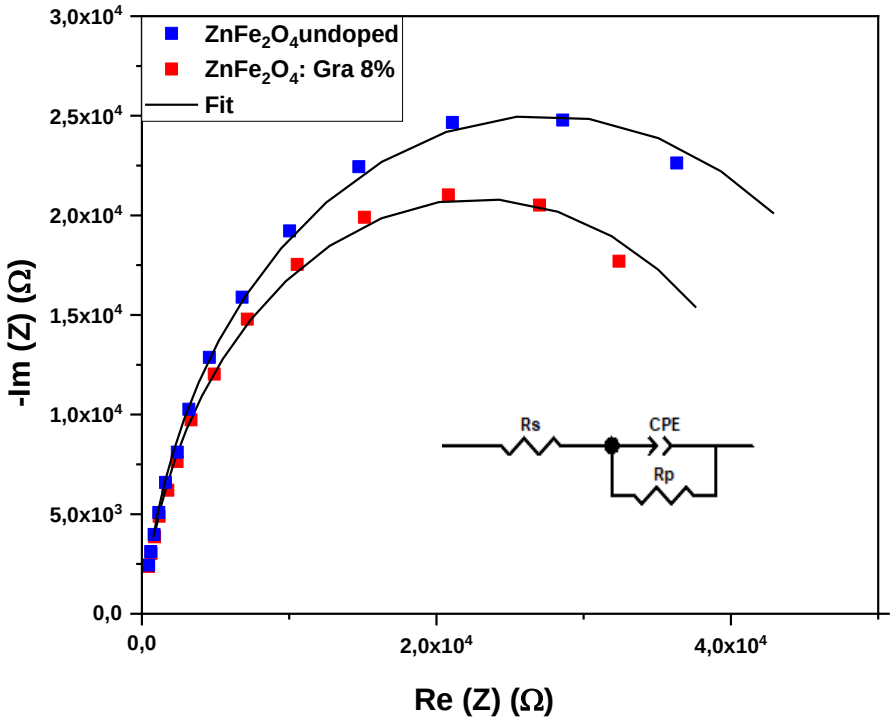
The graphene amount ↑ **The gap Energy** ↓

The undoped $ZnFe_2O_4$ presents the highest reflectance, while the 4% Gra:$ZnFe_2O_4$ showed the lowest reflectance.

Graphene doping increase the absorbance of the zinc ferrite.

The Graphene doping contribute to the formation of intermediate energy levels within the band gap of zinc ferrite, facilitating electron transitions and reducing the overall band gap energy.

Electrochemical impedance spectroscopy analysis (EIS):



Electrical parameters	Rs (Ω)	Rp (kΩ)	CPE-T (F)	CPE-P (F)
$ZnFe_2O_4$ undoped	187.1	54.23	9.089E-11	0.94866
8% Gra: $ZnFe_2O_4$	175.2	45.35	9.778E-11	0.94595

8% Gra: $ZnFe_2O_4$ present a small Rp=54,35 kΩ than the undoped $ZnFe_2O_4$ Rp=54,23 kΩ.

The graphene doping **increase the electrical conductivity.**

Solar Cell simulation using SILVACO Atlas software

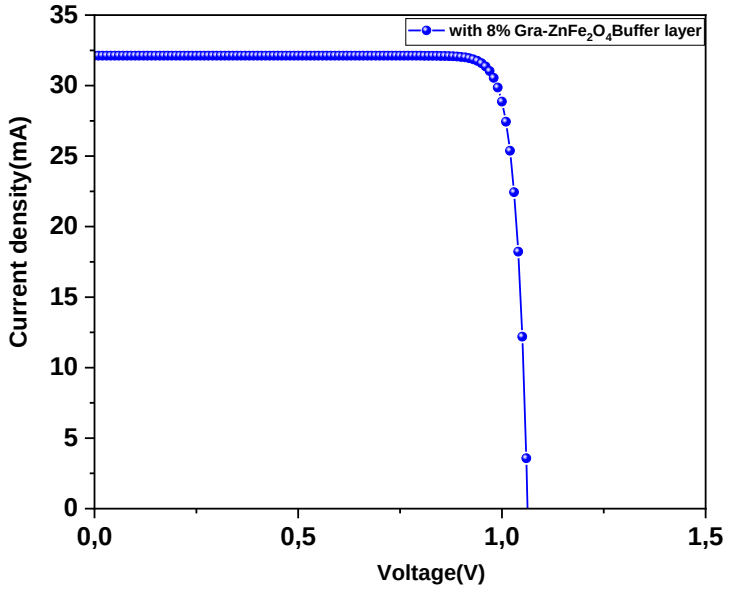
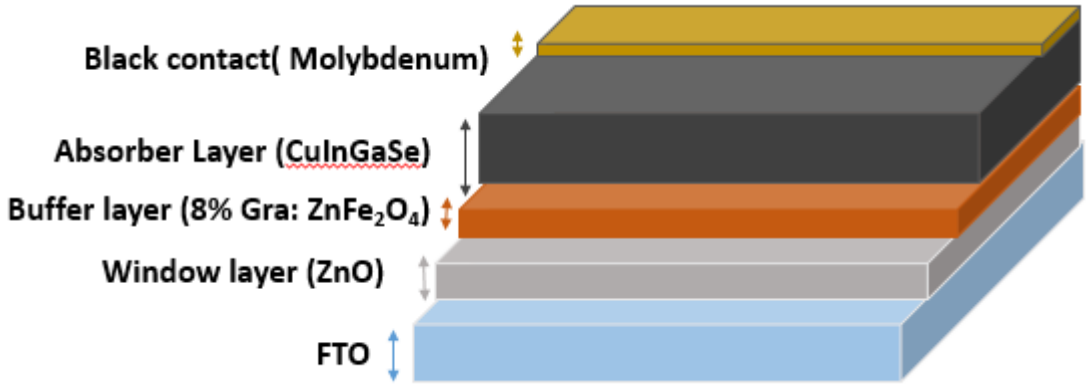


Figure: J-V Characteristic of the solar cell FTO/ZnO/$ZnFe_2O_4$/CuInGaSe.



Solar cell structure

Vos=1,06V

Jsc=32,12mA/cm²

FF=88,8%

η=30.7%.

Conclusion

Thin films of $ZnFe_2O_4$ with different concentrations of graphene are successfully deposited on a glass substrate by a simple and inexpensive technique: spray pyrolysis.

The XRD analysis reveals that graphene doping in $ZnFe_2O_4$ deteriorates the crystallinity of the zinc ferrite structure.

The optical analysis demonstrates that graphene doping enhance the optical absorbance which could be advantageous for applications such as photodegradation.

Prespectives

Comparative analysis between the simulated solar cell and the experimental solar cell using graphene doped zinc ferrite as a buffer layer.

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Thank You
For Your Attention

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Research Group

LPMC Laboratoire de Physique de la Matière Condensée