Comparison of Catalyst Immobilization Techniques onto Filter Media for Airborne VOCs Decomposition

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Research Focus

Airborne pollutants:

Volatile organic compounds

Particulate matter

Other gases

- Environmental and health concerns (allergic reaction, headache, eye, nose and throat irritation)
- Precursors for PM

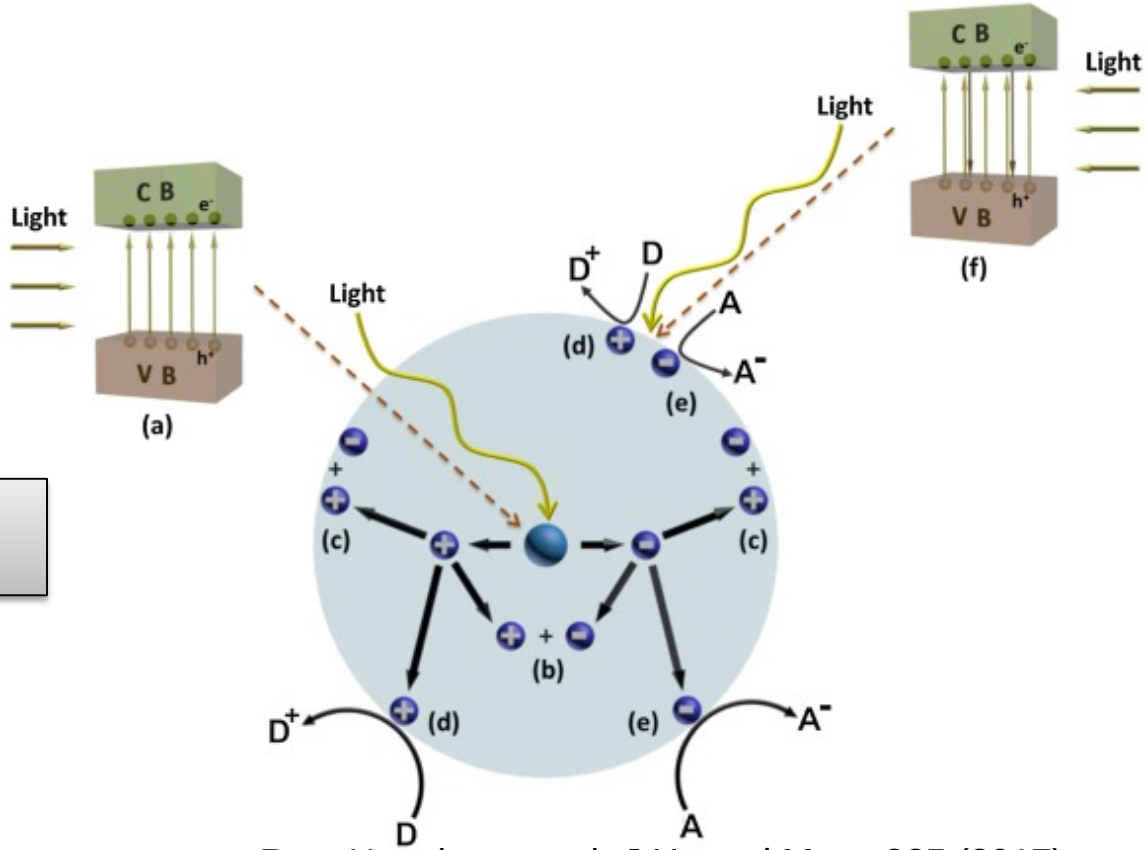
Source of VOCs:

- Natural emission by plants
- Industrial processes, combustion, waste treatment, …
- Cooking, carpets, desks, paintings, ceilings, tobacco smoke…

Photocatalysis

Titanium dioxide (TiO_2)

Oxidation: $h^+ + OH^- \rightarrow OH\cdot$
Reduction: $e^- + O_2 \rightarrow O_2^-$

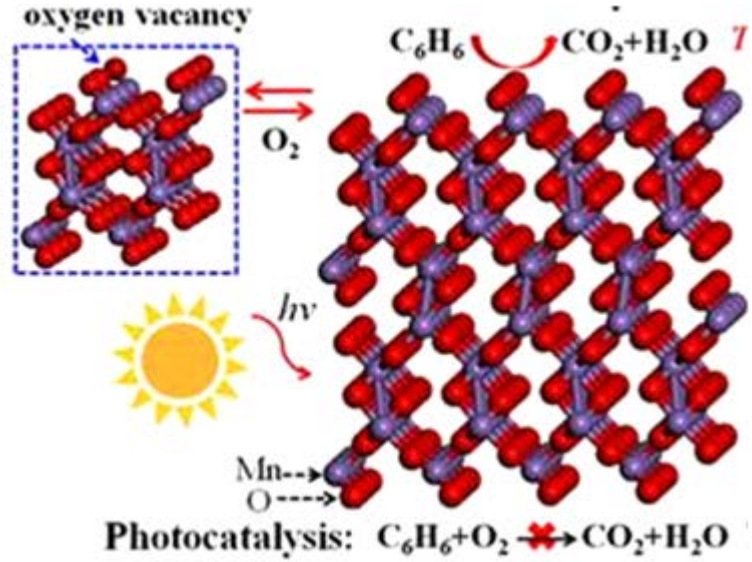


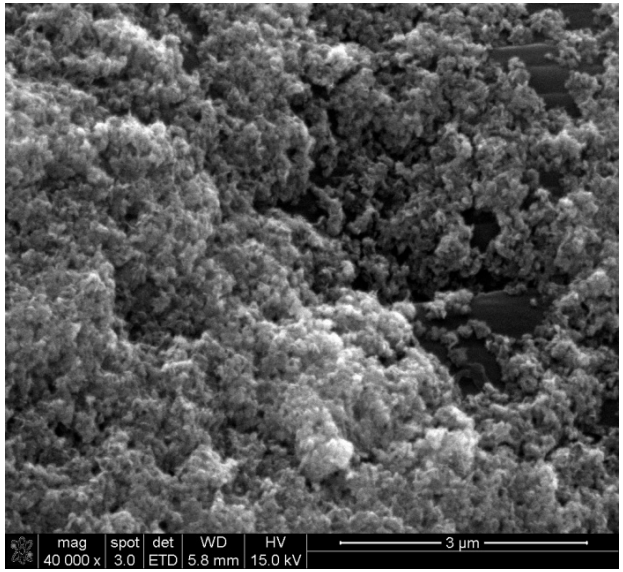
Ren, Hangjuan, et al, *J Hazard Mater* 325 (2017) 340-366.

Catalysis by Visible Light

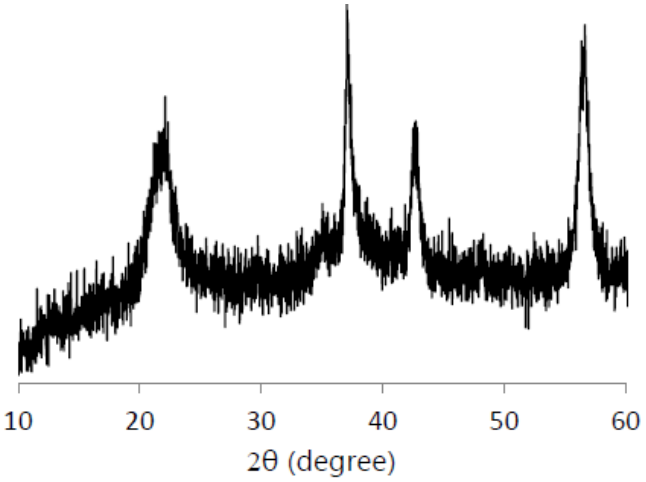
Manganese oxide (MnO_2)

A catalyst which can be activated by visible light





Ramsdellite MnO_2 – Synthesized with hydrothermal method, surface area 66.47 m^2/g (BET)



Immobilization of Catalysts

[1]Properties of support material:

Physical and chemical stability

Large surface area

Filter support materials:

Glass fibre filter F9 (LydAir®MG)

Nylon mesh (SEFAR NITEX 03-30/20)

[1]Immobilization techniques requirements:

Effective exposure to light
Stable and durable coating
Effective contact of catalyst and pollutant
Easy and energy efficient
Economical and suitable for large-scale application

[1]Han, Zhenan, et al, *Aerosol Air Qual. Res* 12 (2012) 1327-1335

Materials and Methods

Catalyst immobilization

1. Concentration of catalyst suspension: 5wt%
2. Sonification for ~ 30 min
3. Stirring
4. Coating of filter media

Spray method

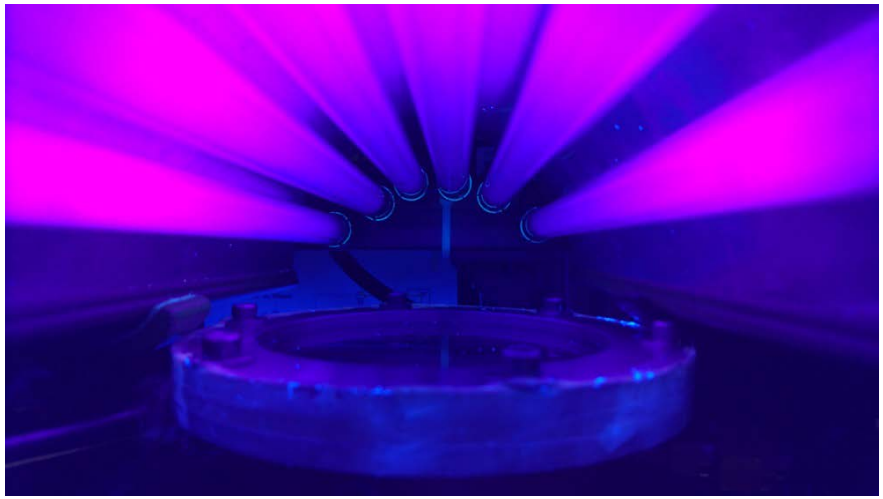
– Spraying distance ≈ 10 cm

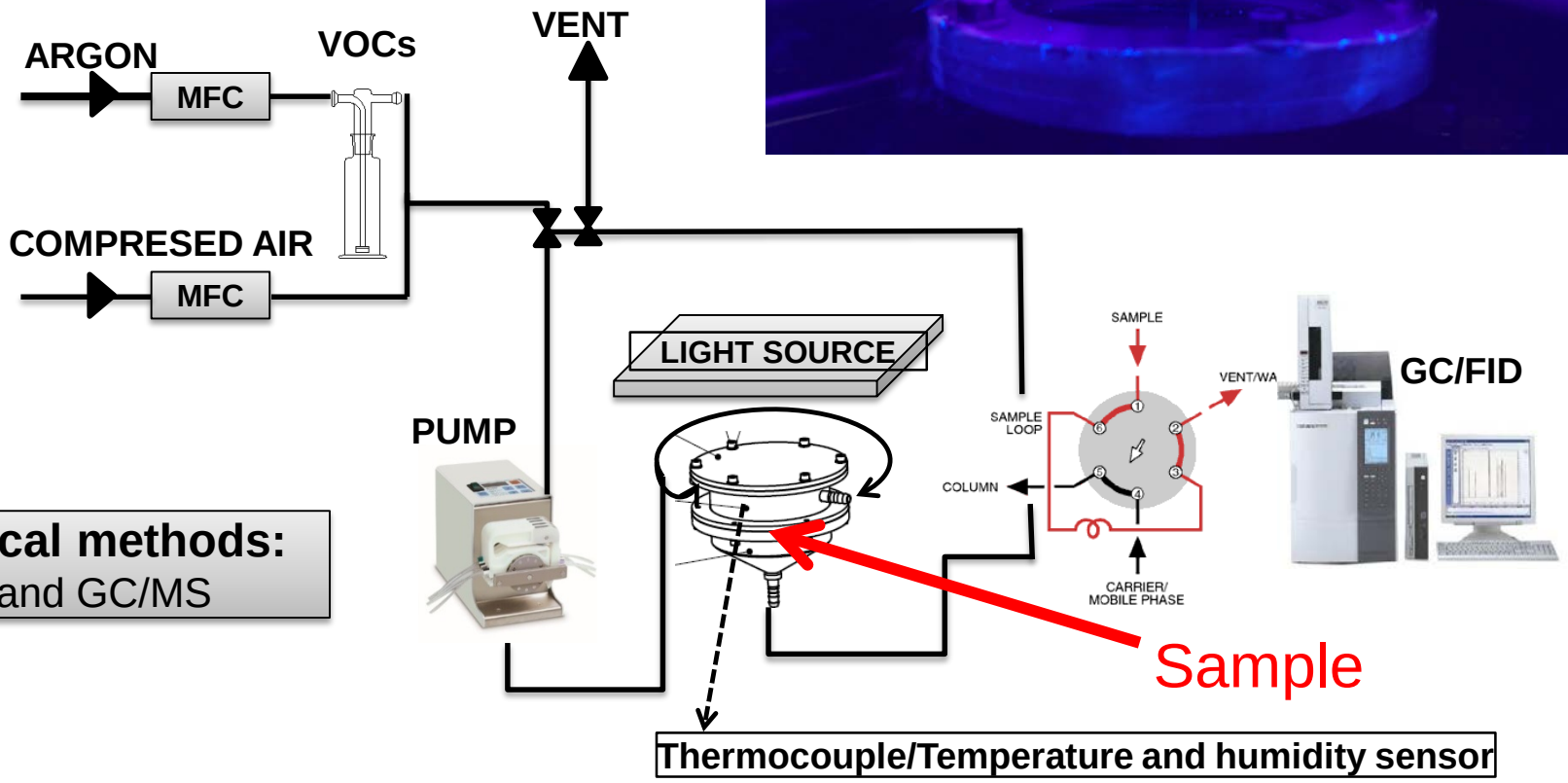
Dip-coating method

5. Drying in ambient condition (in fume hood) for 12 h

Experimental Setup

Reactor volume: **1.14 L**
Circulation flow rate: **24 mL/min**
Temperature: **22 °C**
Relative humidity: below **10 %**
VOC: **Toluene**/Hexane



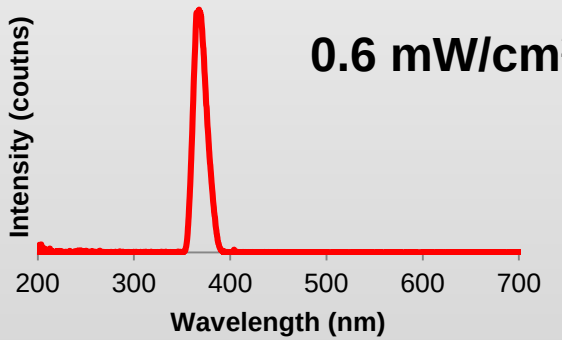


Analytical methods:
GC/FID and GC/MS

Light Intensity Measurement

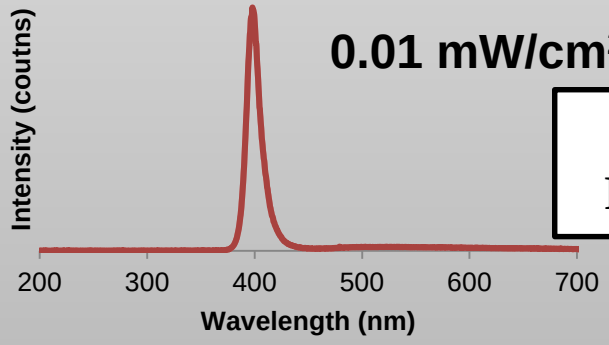
UV-A light source

BLB lamp 6x 8W



0.6 mW/cm²

ColorBright™ UV LED strip light

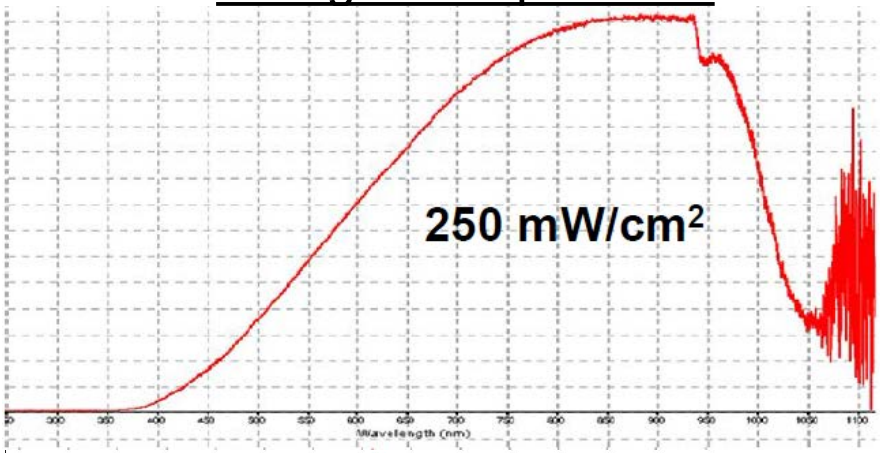


0.01 mW/cm²

NO REACTION

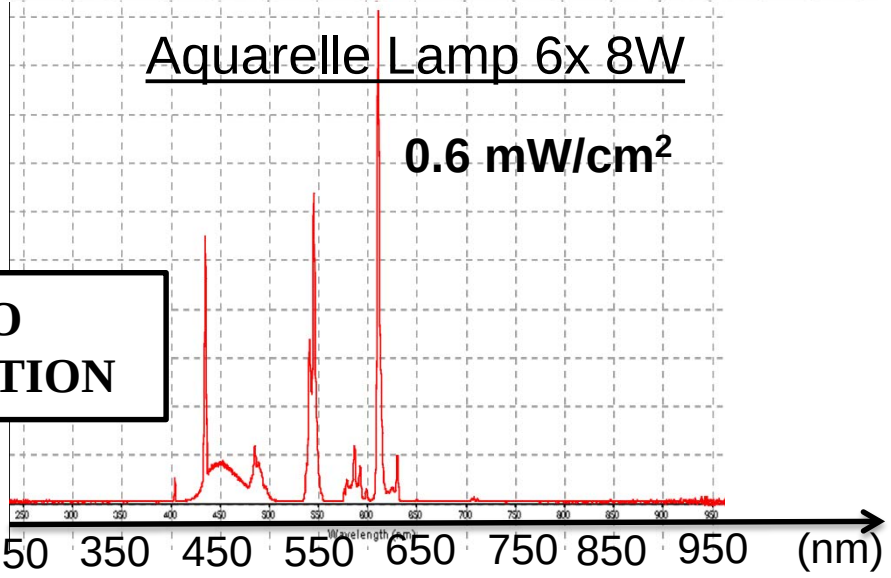
Visible light source

Halogen lamp 500W



250 mW/cm²

Aquarelle Lamp 6x 8W

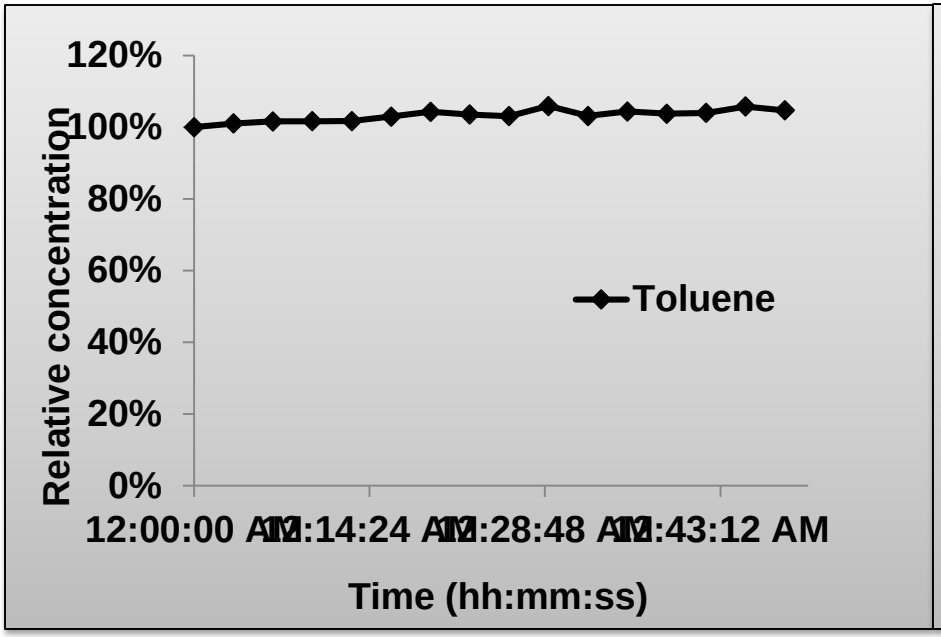


0.6 mW/cm²

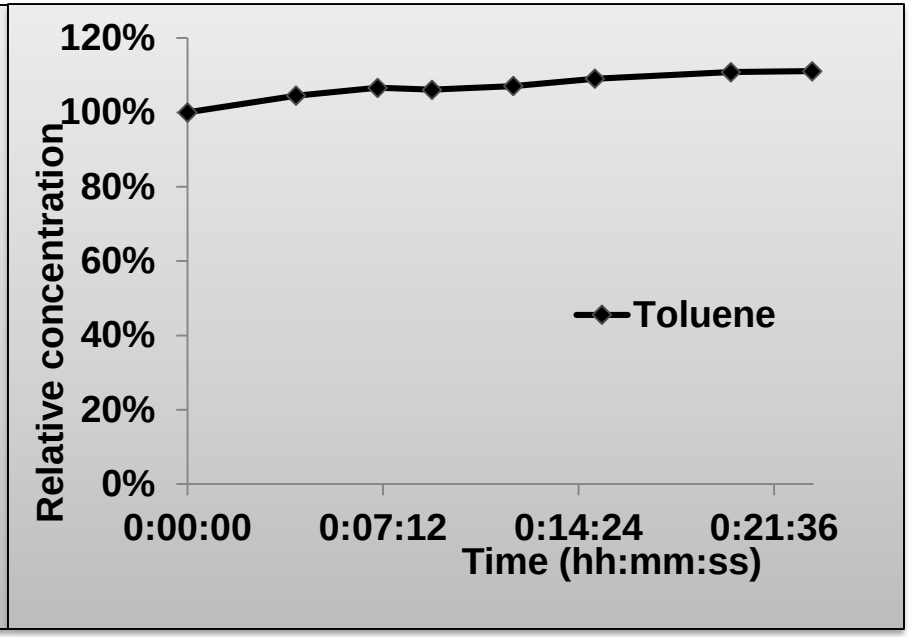
Catalysis Evaluation

Photolysis

Toluene + **BLB lamp**



Toluene + **Halogen lamp**

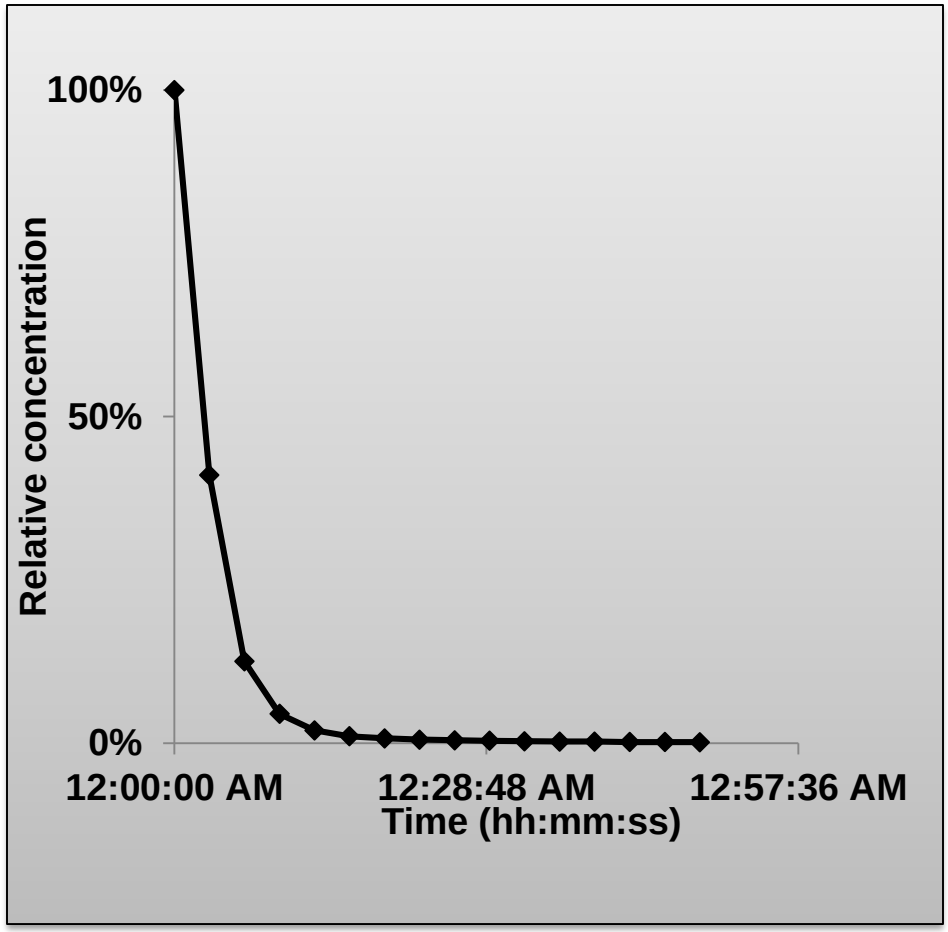


Adsorption

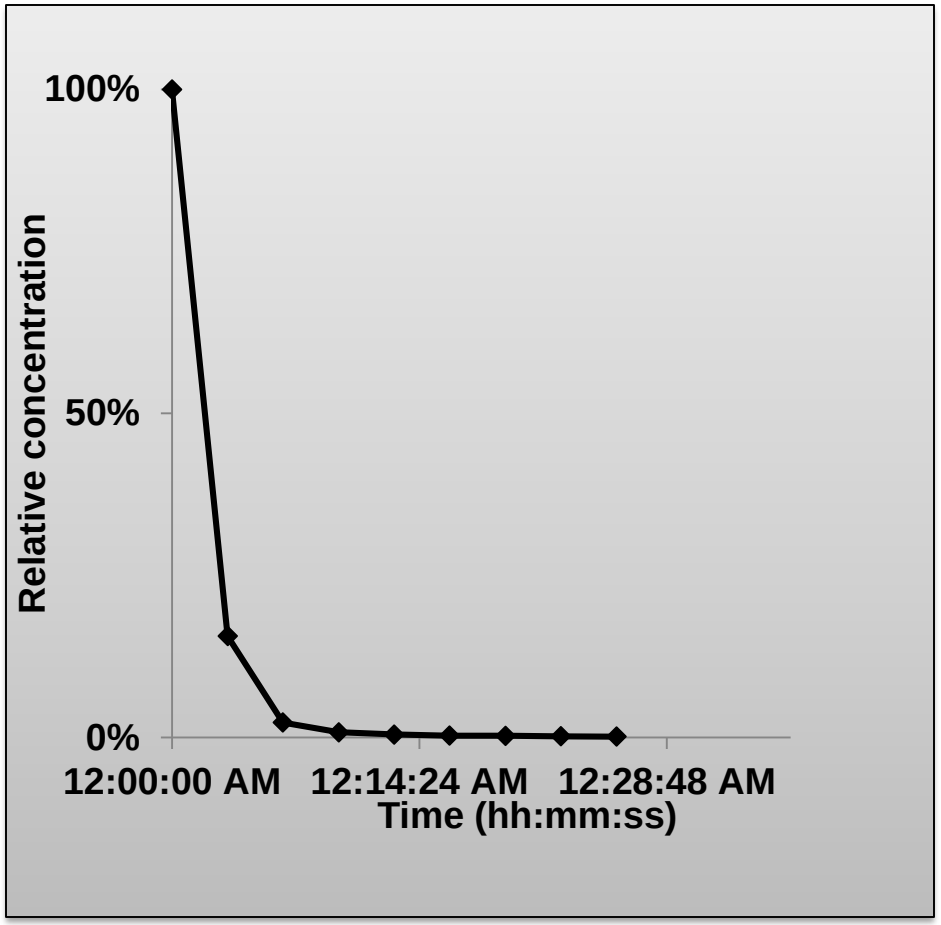
Data acquired after stable condition was reached.

Degradation of Toluene

MnO_2



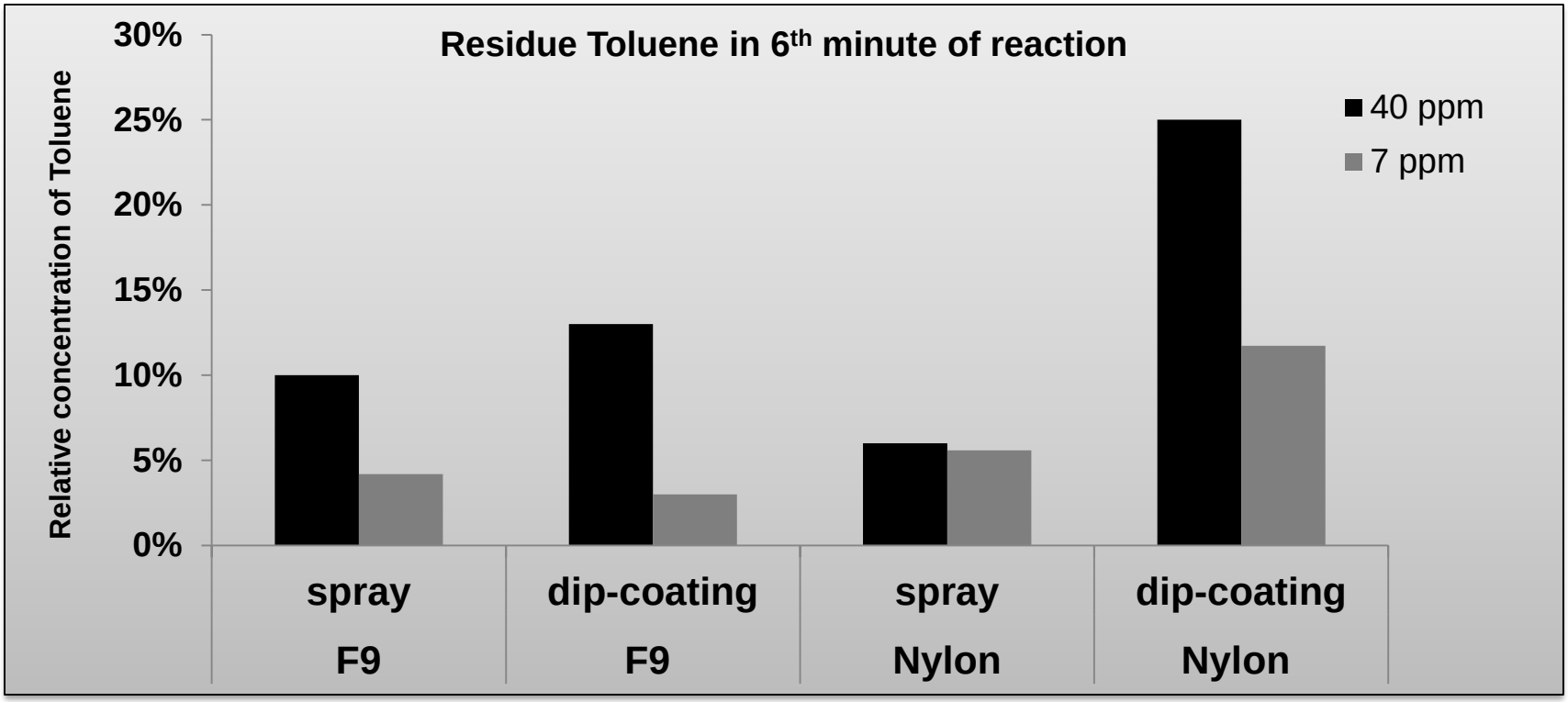
TiO_2



Photocatalysis MnO_2

Type of filter	Type of coating	MnO_2 load, w_{cat} (g)	Number of coating cycles
F9	spray	0.0984	6
F9	dip-coating	0.0957	2
Nylon	spray	0.1047	11
Nylon	dip-coating	0.0904	3

w_{cat}= 0.097 ± 0.01 g



SEM

Type of filter	Type of coating	MnO_2 load, m_{cat} (g)	Number of coating cycles	Degradation efficiency (%)
F9	**spray**	**0.0984**	**6**	**90**
F9	dip-coating	0.0957	2	87
Nylon	spray	0.1047	11	94
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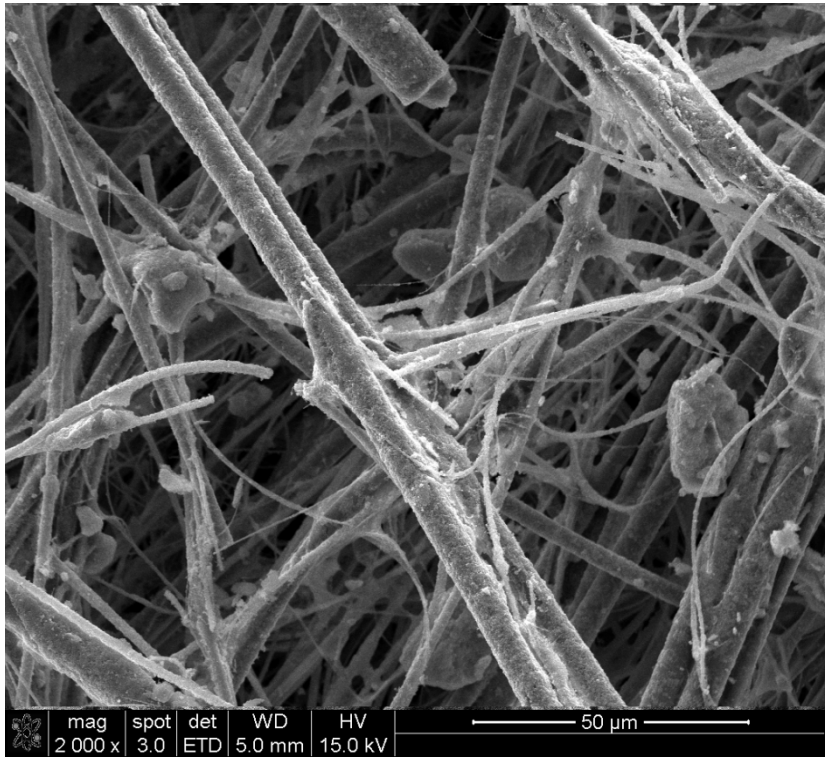

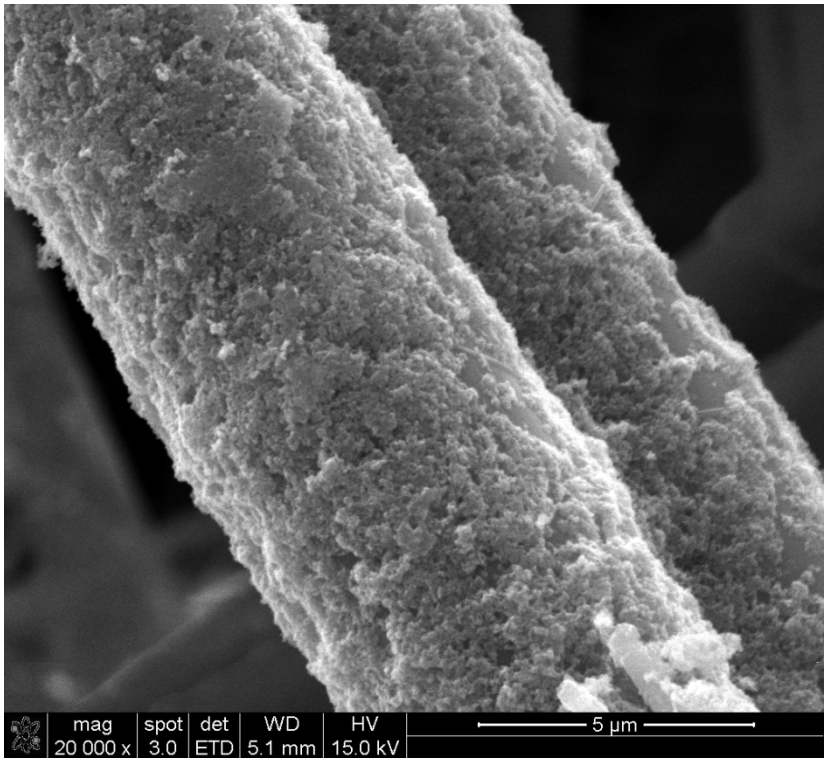

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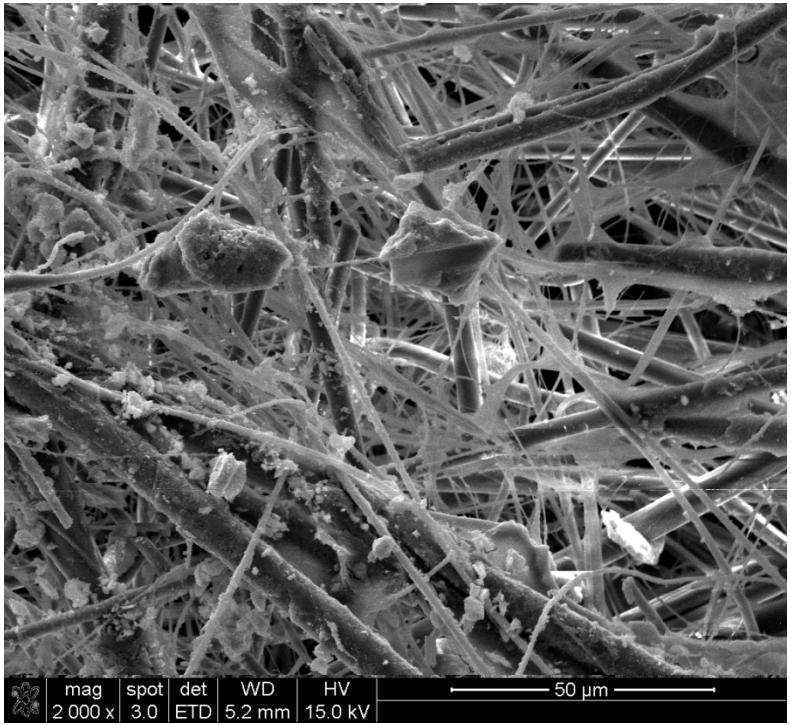

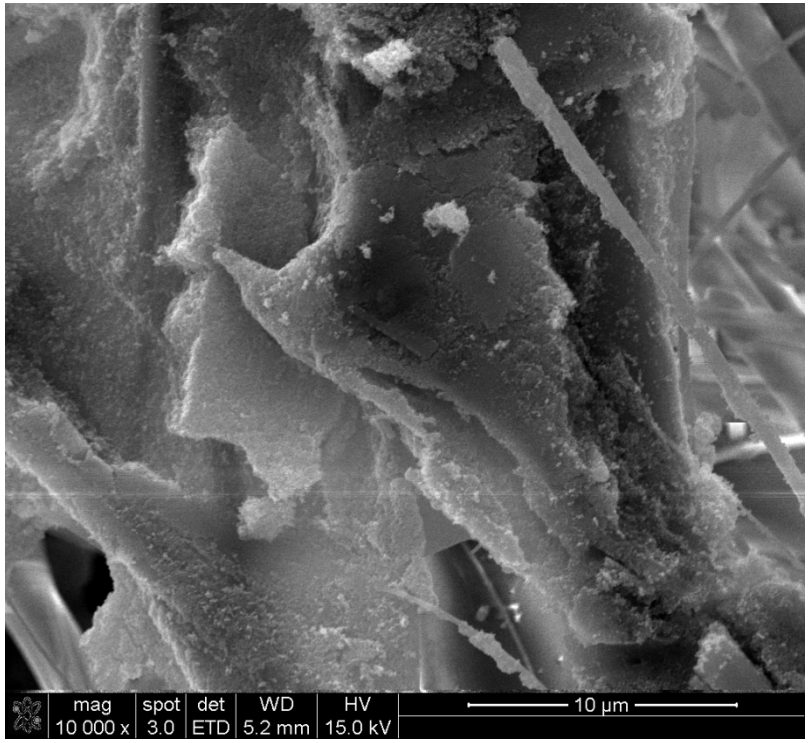

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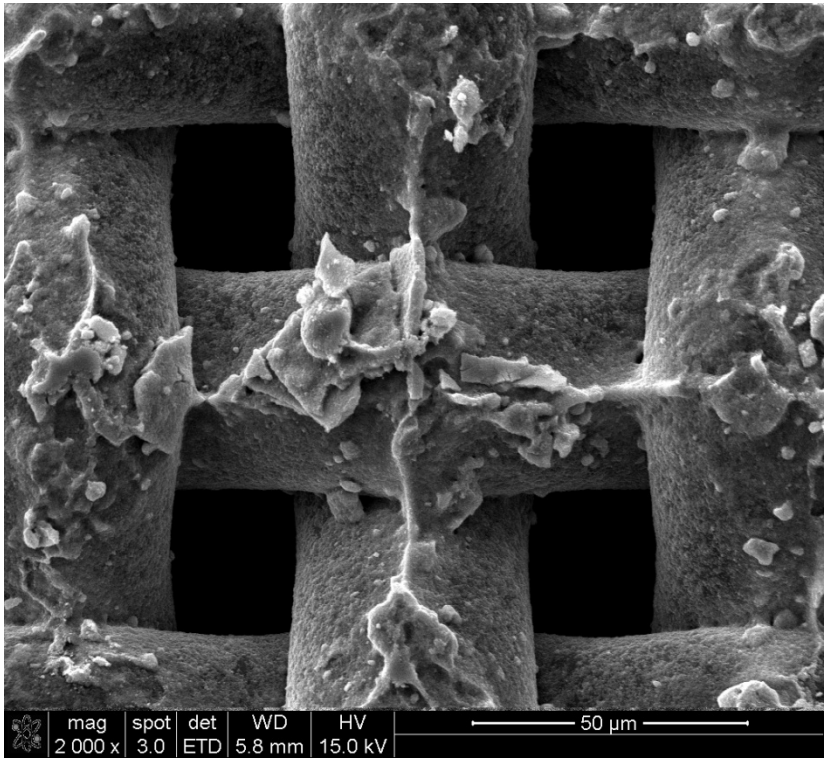

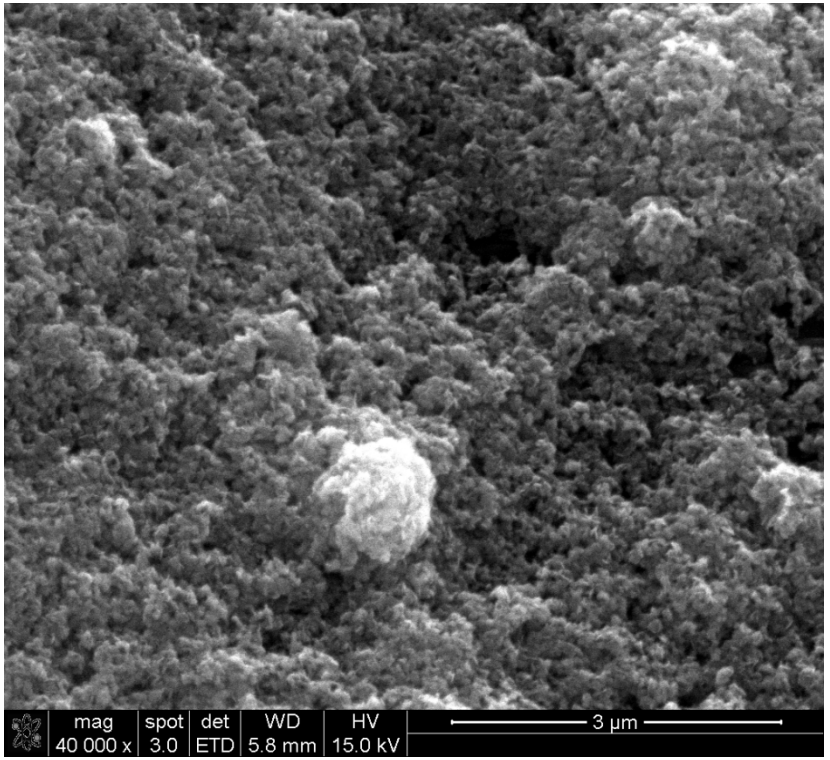

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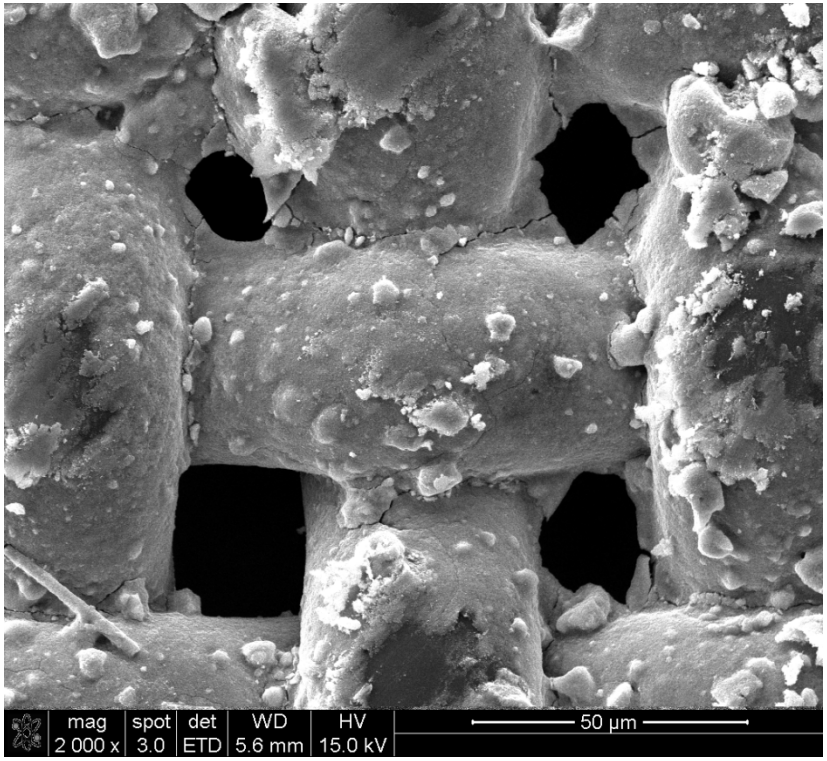
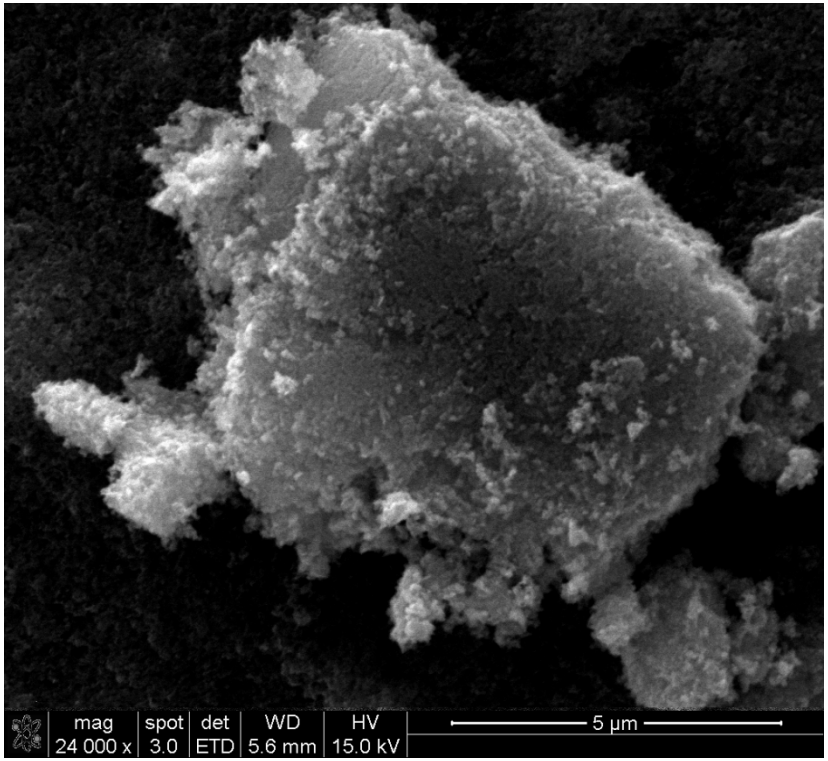
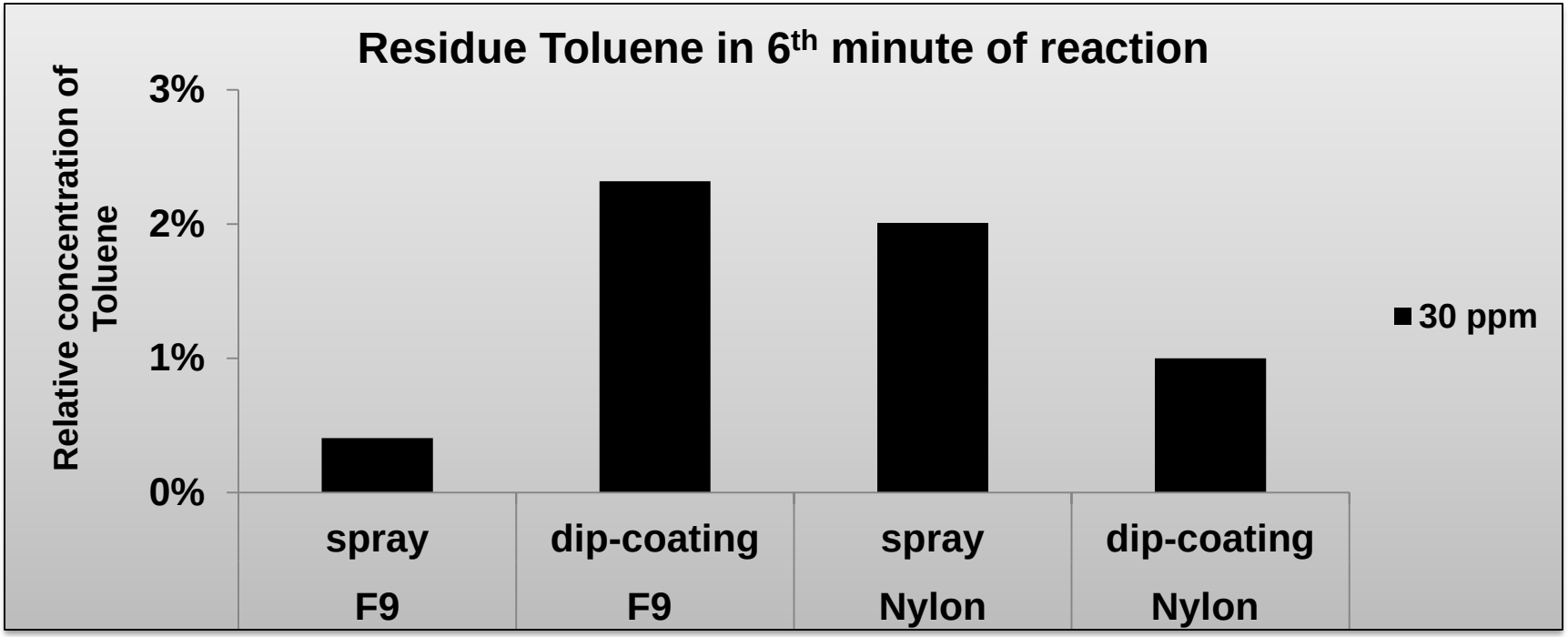




Photocatalysis TiO_2

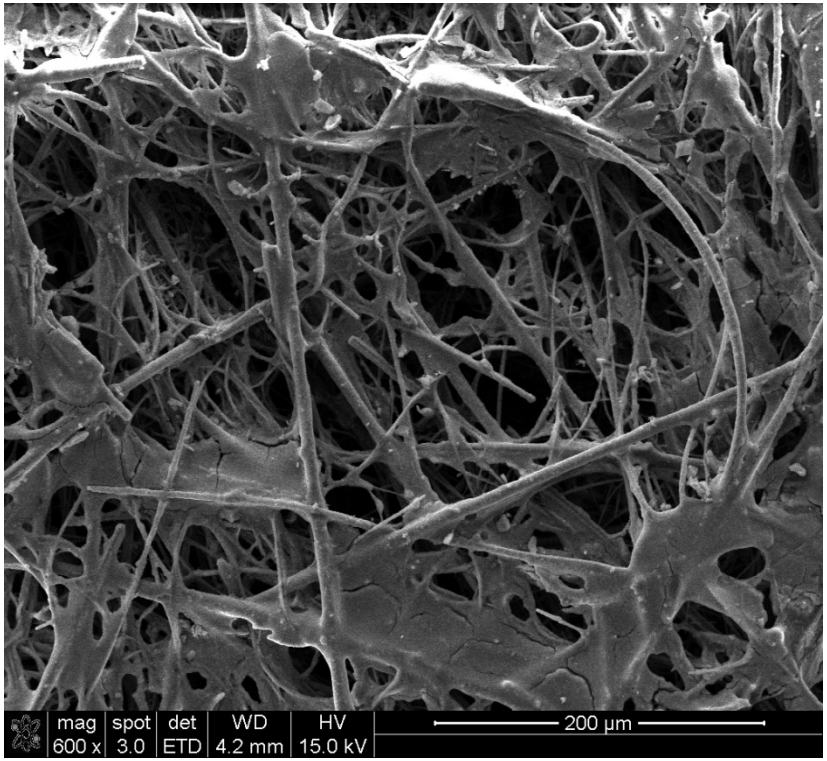
Type of filter	Type of coating	TiO_2 load, m_{cat} (g)	Number of coating cycles
F9	spray	0.1160	9
F9	dip-coating	0.1009	3
Nylon	spray	0.1000	4
Nylon	dip-coating	0.1612	1

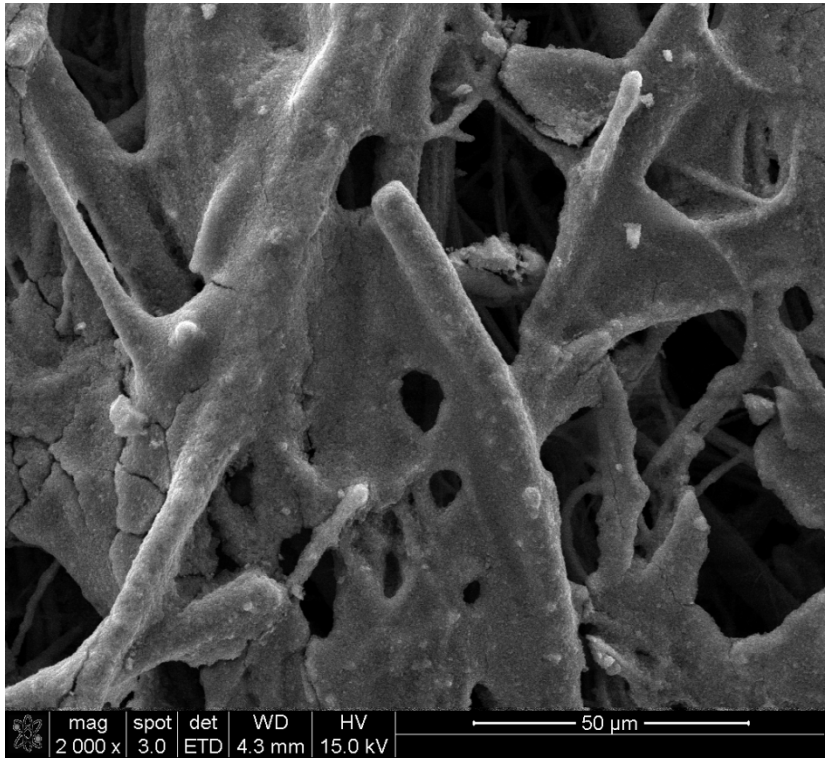
w_{cat}= 0.12 ± 0.03 g



SEM

Type of filter	Type of coating	TiO_2 load, m_{cat} (g)	Number of coating cycles	Degradation efficiency (%)
F9	**spray**	**0.1160**	**6**	**99.5**
F9	dip-coating	0.1009	2	97.5
Nylon	spray	0.1000	11	98
Nylon	dip-coating	0.1612	3	99





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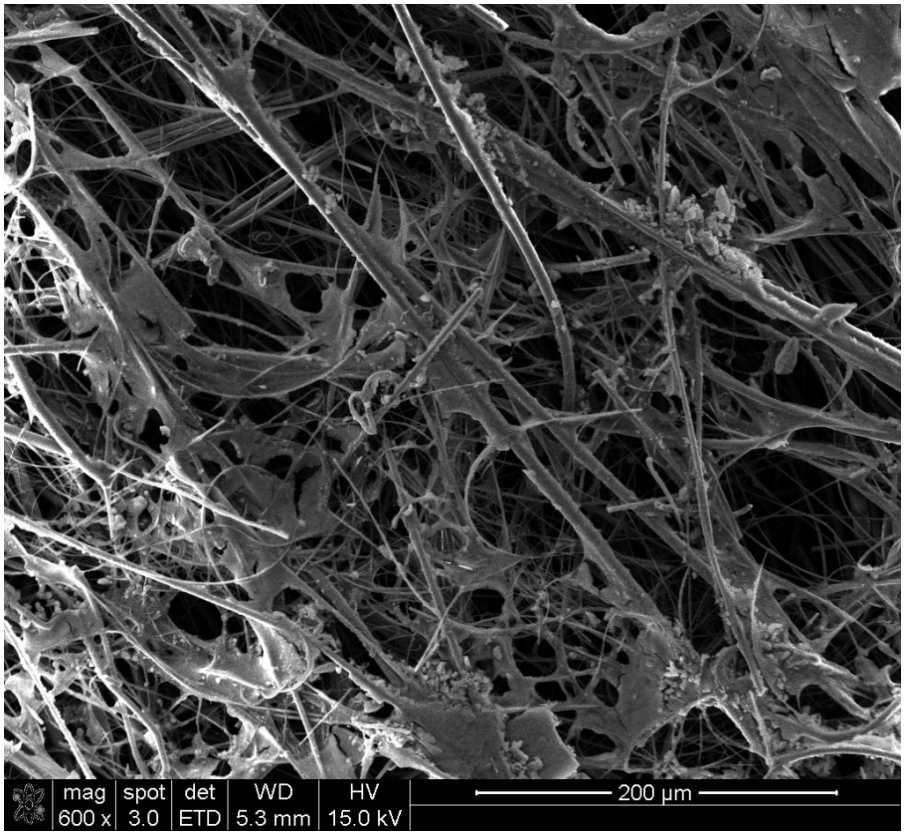

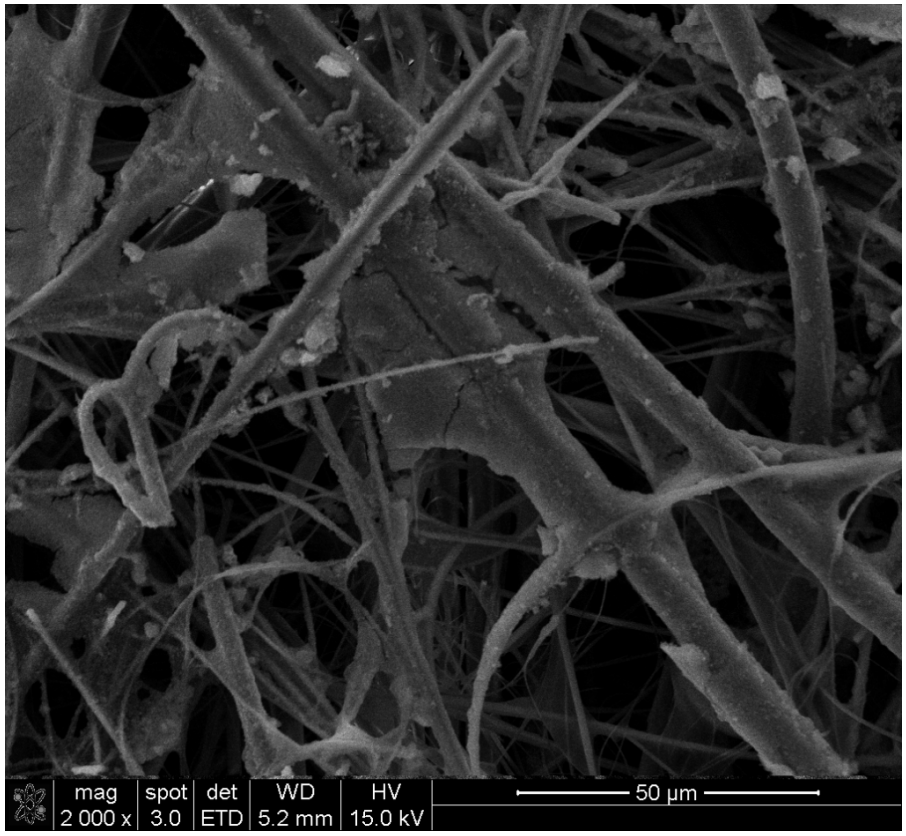

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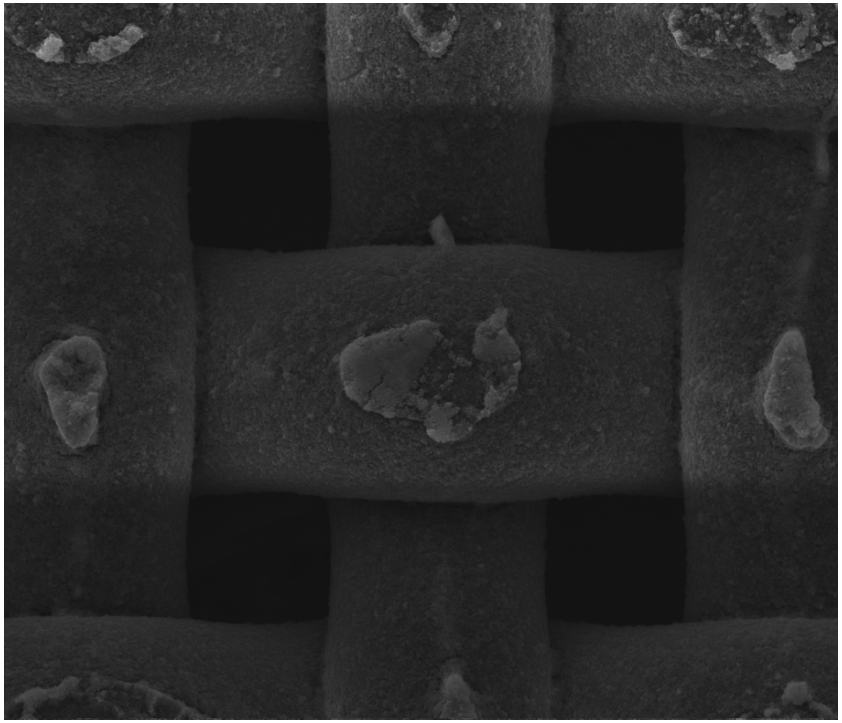

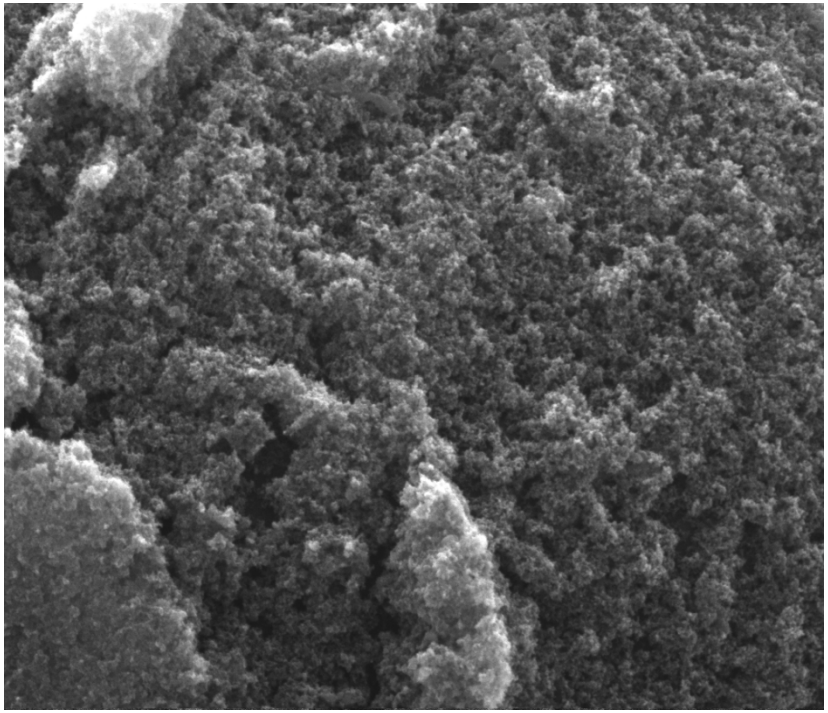

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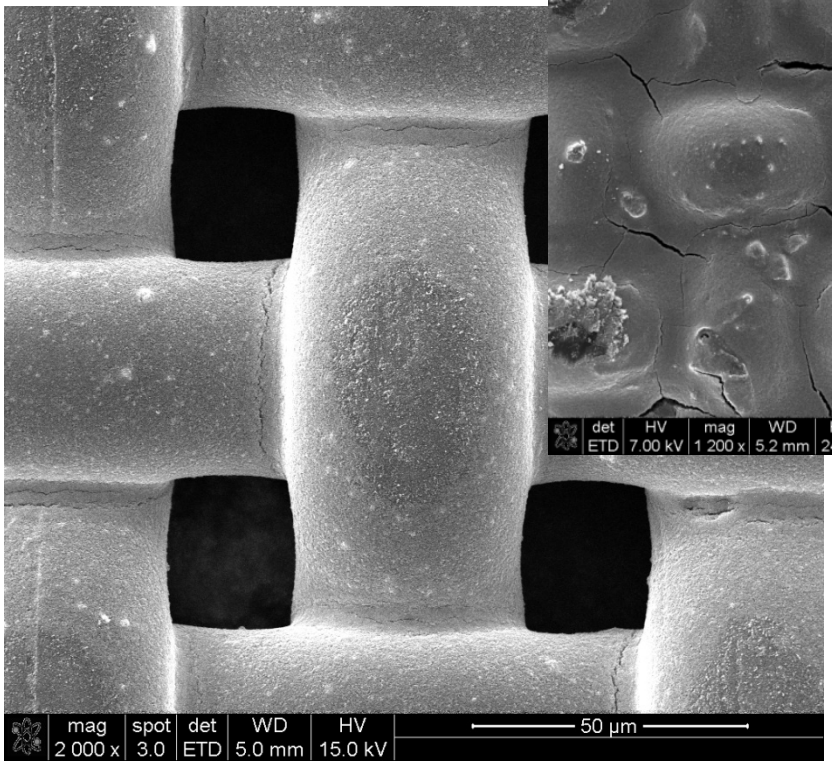
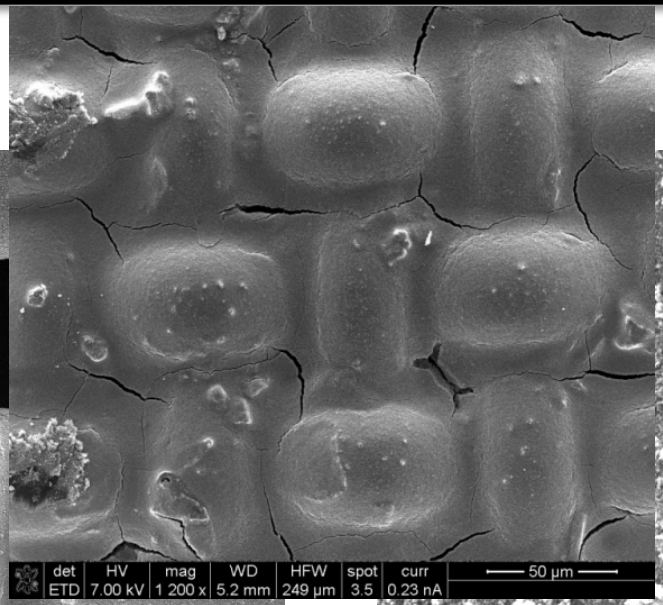
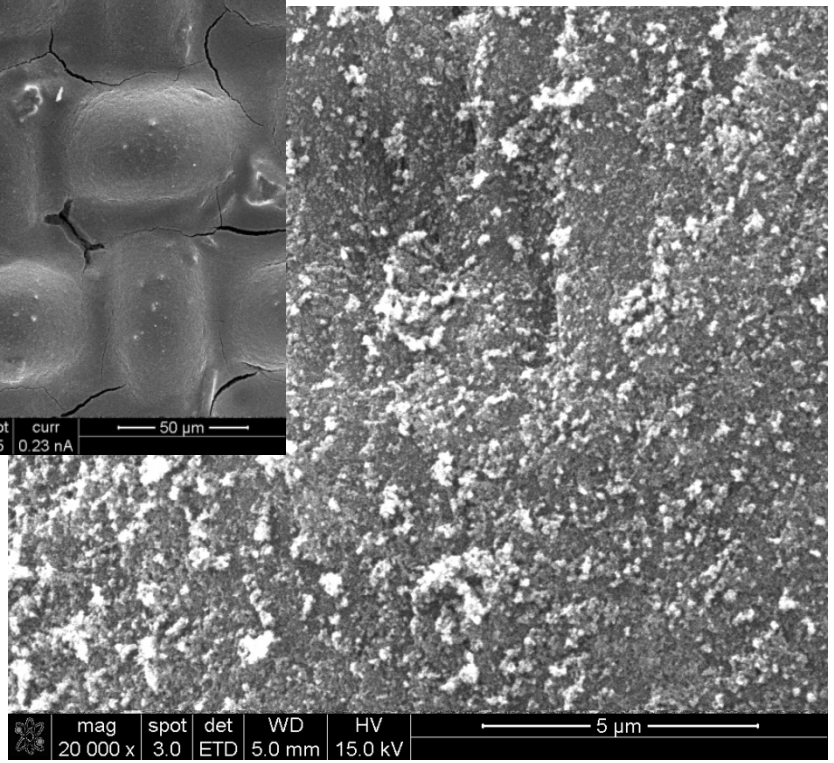
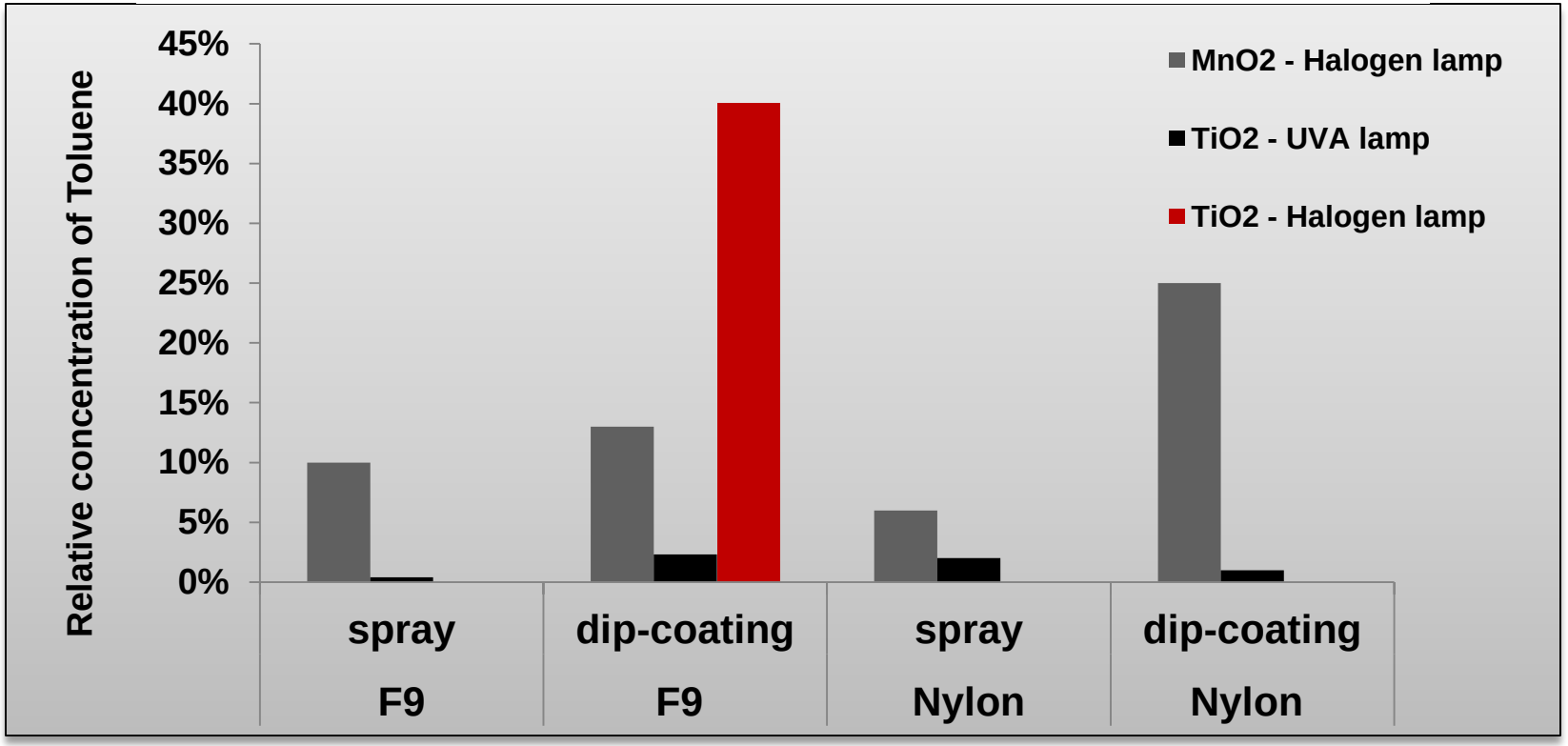






MnO_2 vs. TiO_2

	$C_{Toluene}$ (ppm)	W_{cat} (g)	Surface area (m^2/g)
MnO_2	40 ± 4	0.097 ± 0.01	66
TiO_2	30 ± 5	0.12 ± 0.03	35-65



Conclusion

Dip-coating method

Formation of agglomerates

Spray coating method

More uniform dispersion of catalyst

Less agglomerates

Better performance

TiO_2 more efficient under UV-light irradiance and less efficient under irradiance with halogen lamp than MnO_2