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Tuning Semiconductor Properties of Electrospun Iron Oxide Nanofibers

Marko Robić[1], Mira Ristić[1], Marijan Marciuš[1], Stjepko Krehula[1], Svetozar Musić[1]

[1]Division of Materials Chemistry, Ruđer Bošković Institute, Zagreb, Croatia

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Croatian Science Foundation

Introduction to iron oxides

pigments

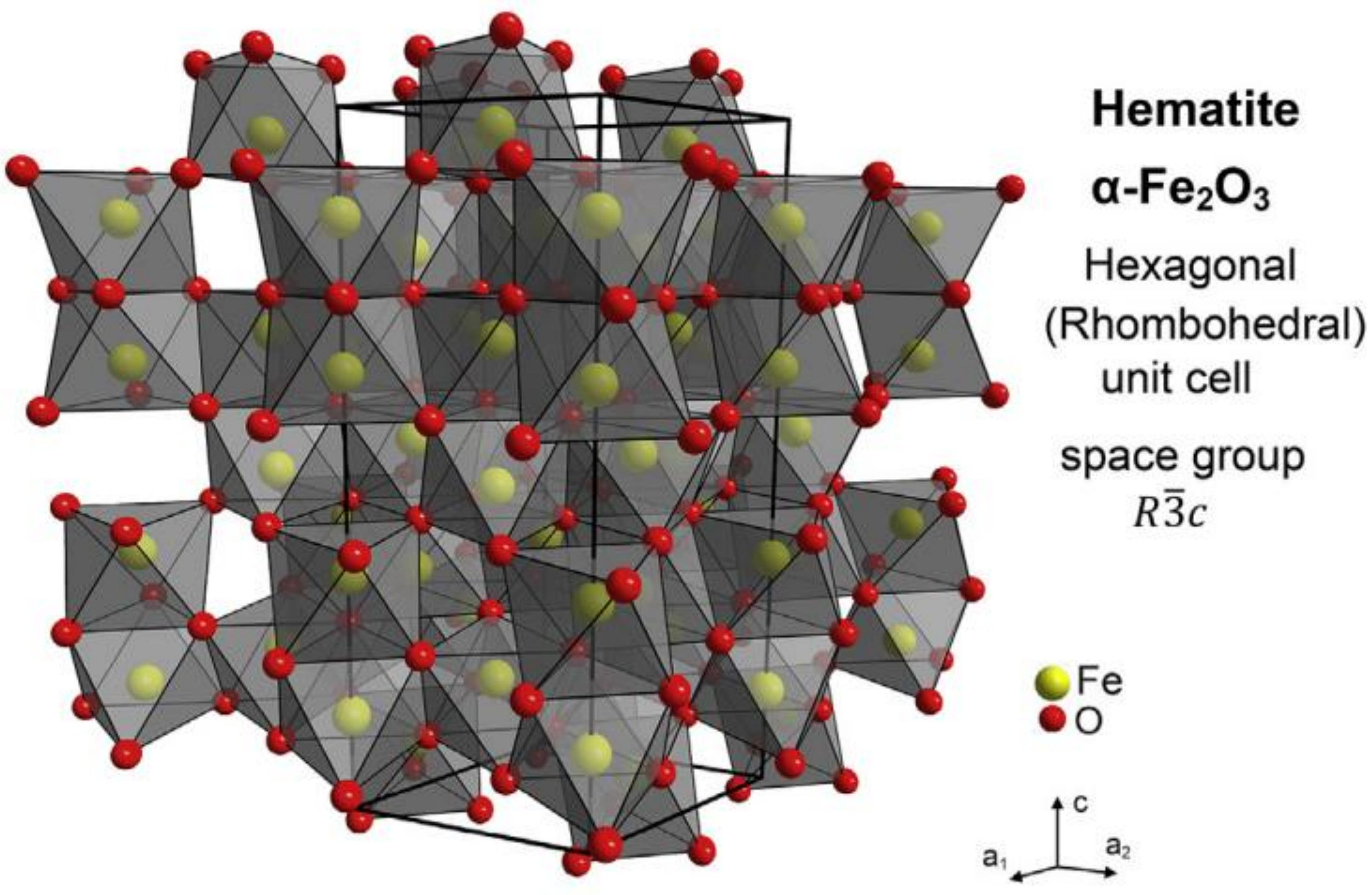
other — Applications — industry

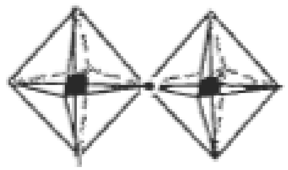
waste water treatmant

Goethite	α-FeOOH
Akaganeite	β-FeOOH
Lepidocrocite	γ-FeOOH
Feroxyhyte	δ-FeOOH
Bernalite	$Fe(OH)_3 \cdot n\ H_2O$
Ferrihydrite	$5Fe_2O_3 \cdot 9H_2O^*$
$Fe(OH)_2$	
High pressure FeOOH	
Hematite	α-Fe_2O_3
Maghemite	γ-Fe_2O_3
Wüstite	FeO
β-Fe_2O_3	
ε-Fe_2O_3	
Magnetite	Fe_3O_4
Green rusts	
Jarosite	$KFe_3(SO_4)_2(OH)_6$
Schwertmannite	$Fe_8O_8(OH)_6(SO_4) \cdot n\ H_2O$

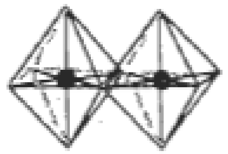
Cornell R. M., Schwertmann U., The iron oxides, structure, properties, reactions, Occurrences and uses, Wiley-VCH, 2nd edition, 2003.
*Ristić M. et al, J. Mol. Struct., **834–836** (2007) 454–460

Introduction to iron oxides

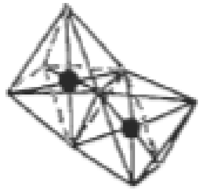




Octahedra sharing corners



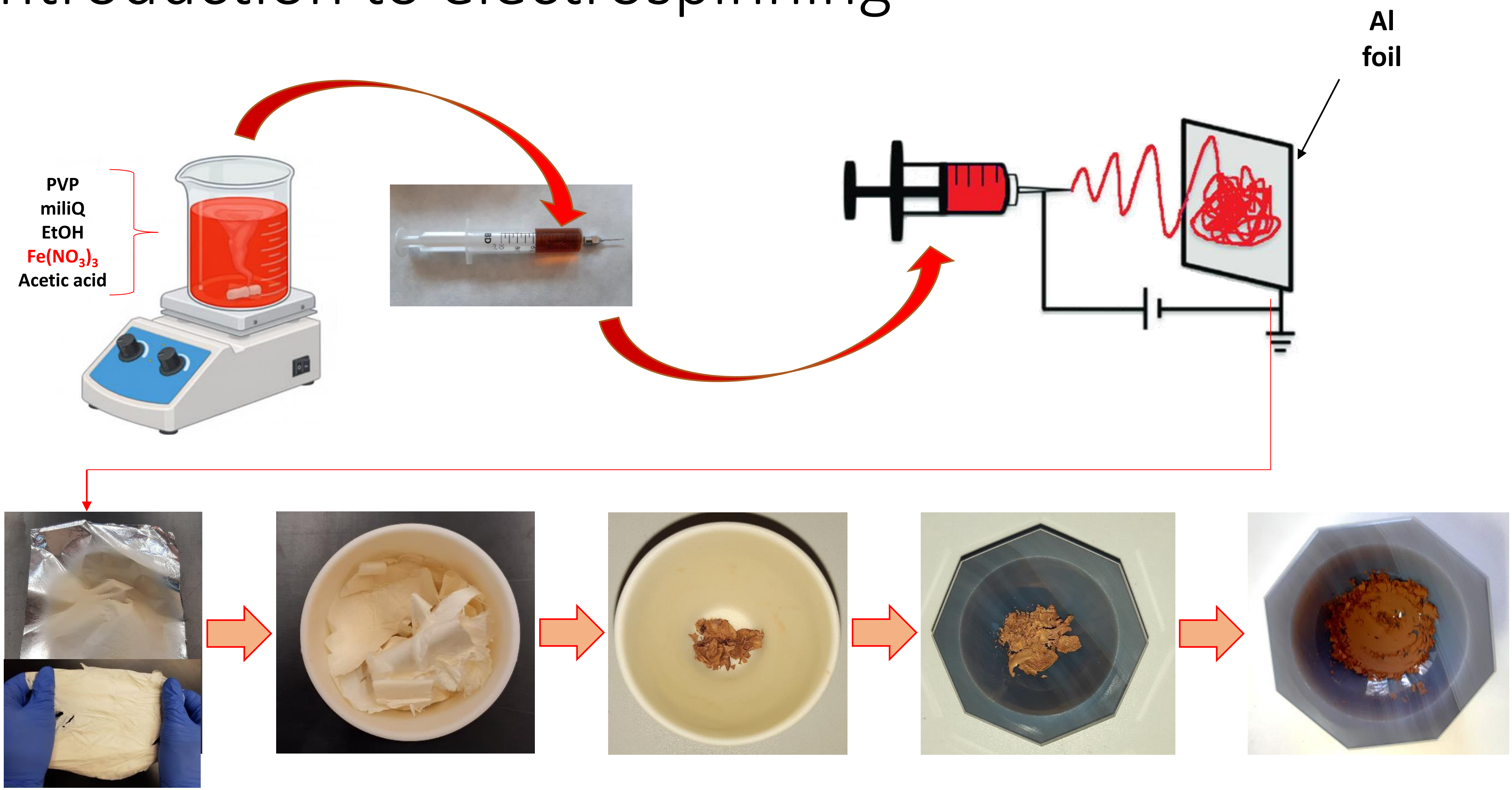
Octahedra sharing edges



Octahedra sharing faces

Stjepko Krehula et al., Synthesis and properties of indium-doped hematite, J. Alloys Compd. **695** (2017) 1900-19007

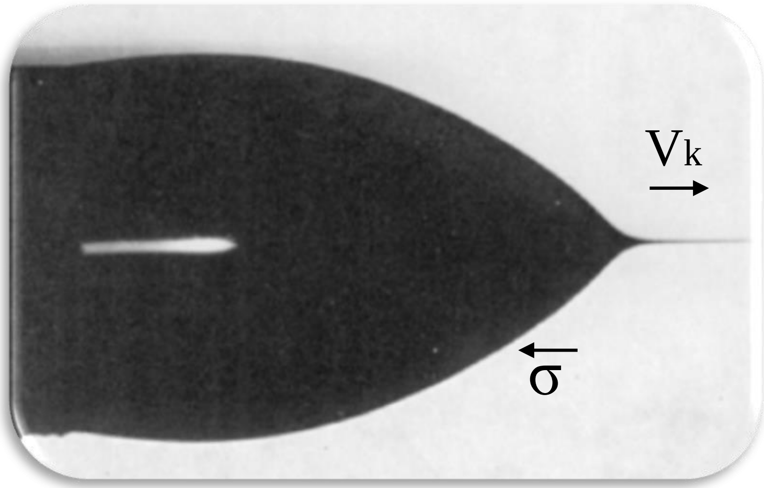
Introduction to electrospinning



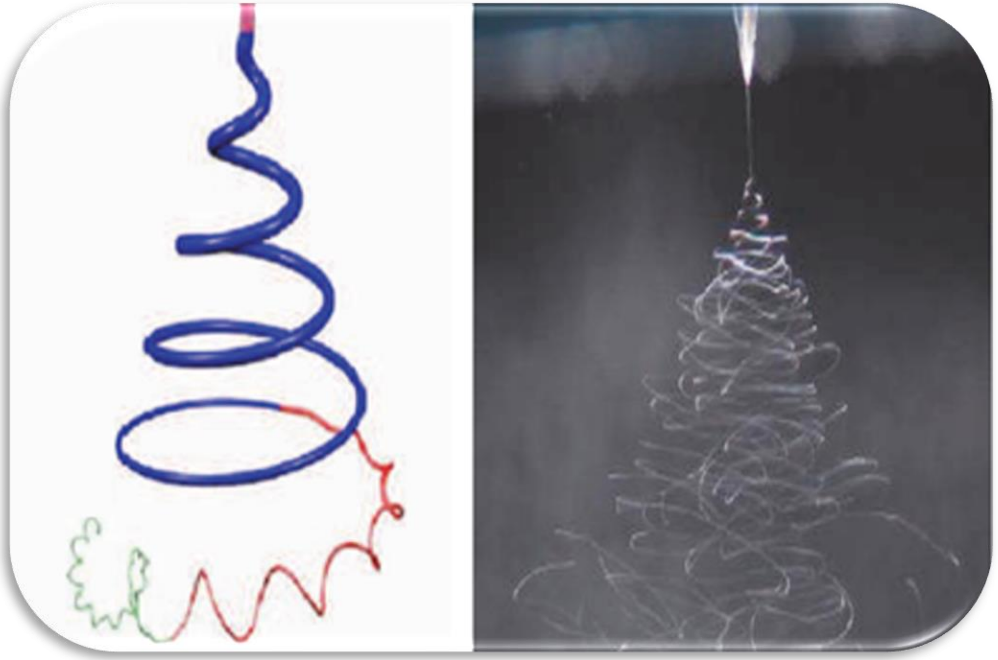
Electrospinning

Taylor conus

$V_k > \sigma$



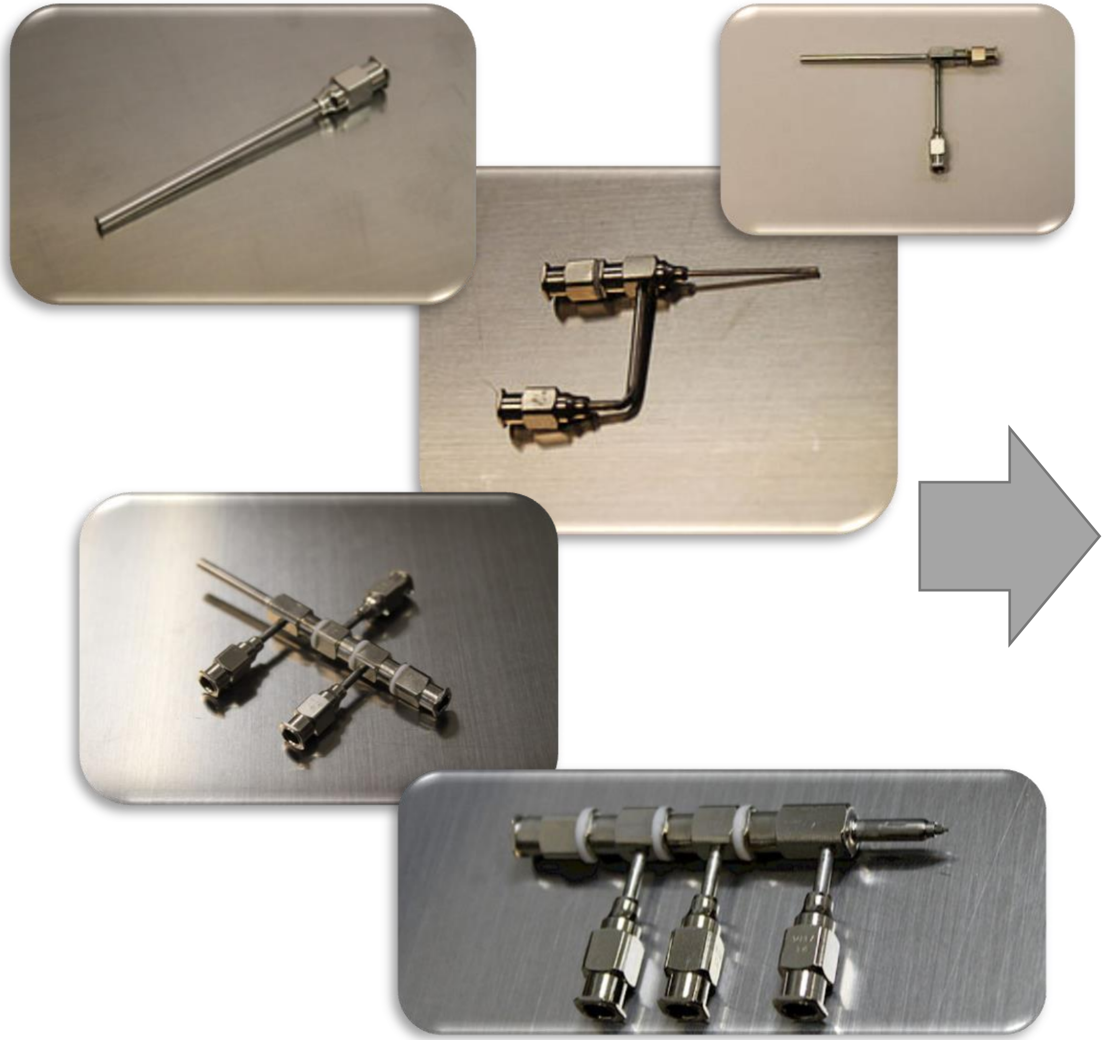
Electrospinning jet

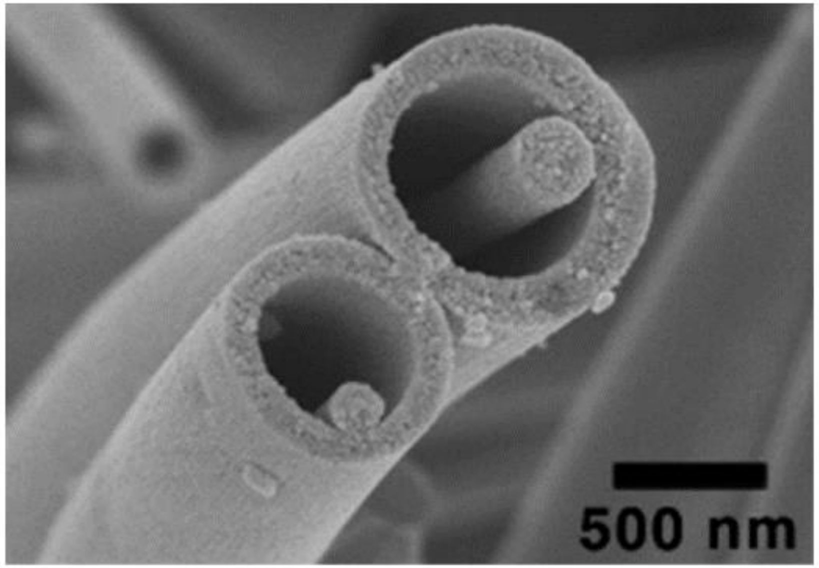


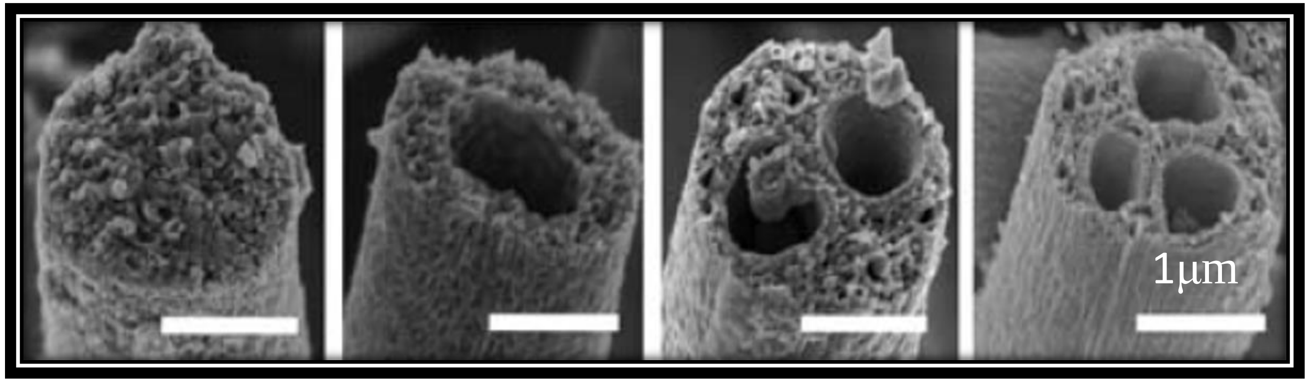
G. Taylor, Electrically driven jets, Proc. Roy. Soc. Lond. A. **313** (1969) 453-475

S. Petrík, Industrial Production Technology for Nanofibers, *ELMARCO s.r.o, Czech Republic*

Introduction to electrospinning

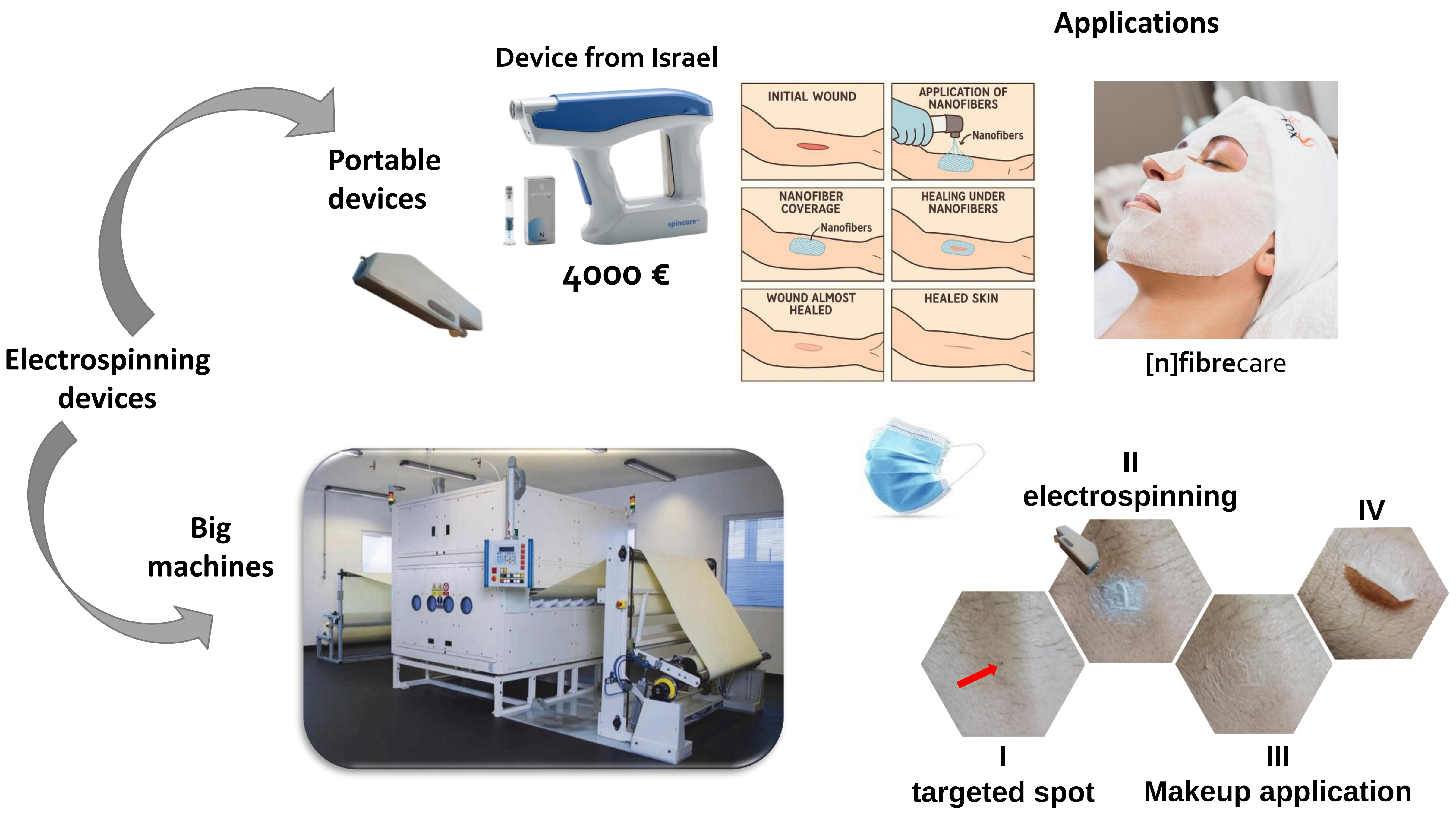


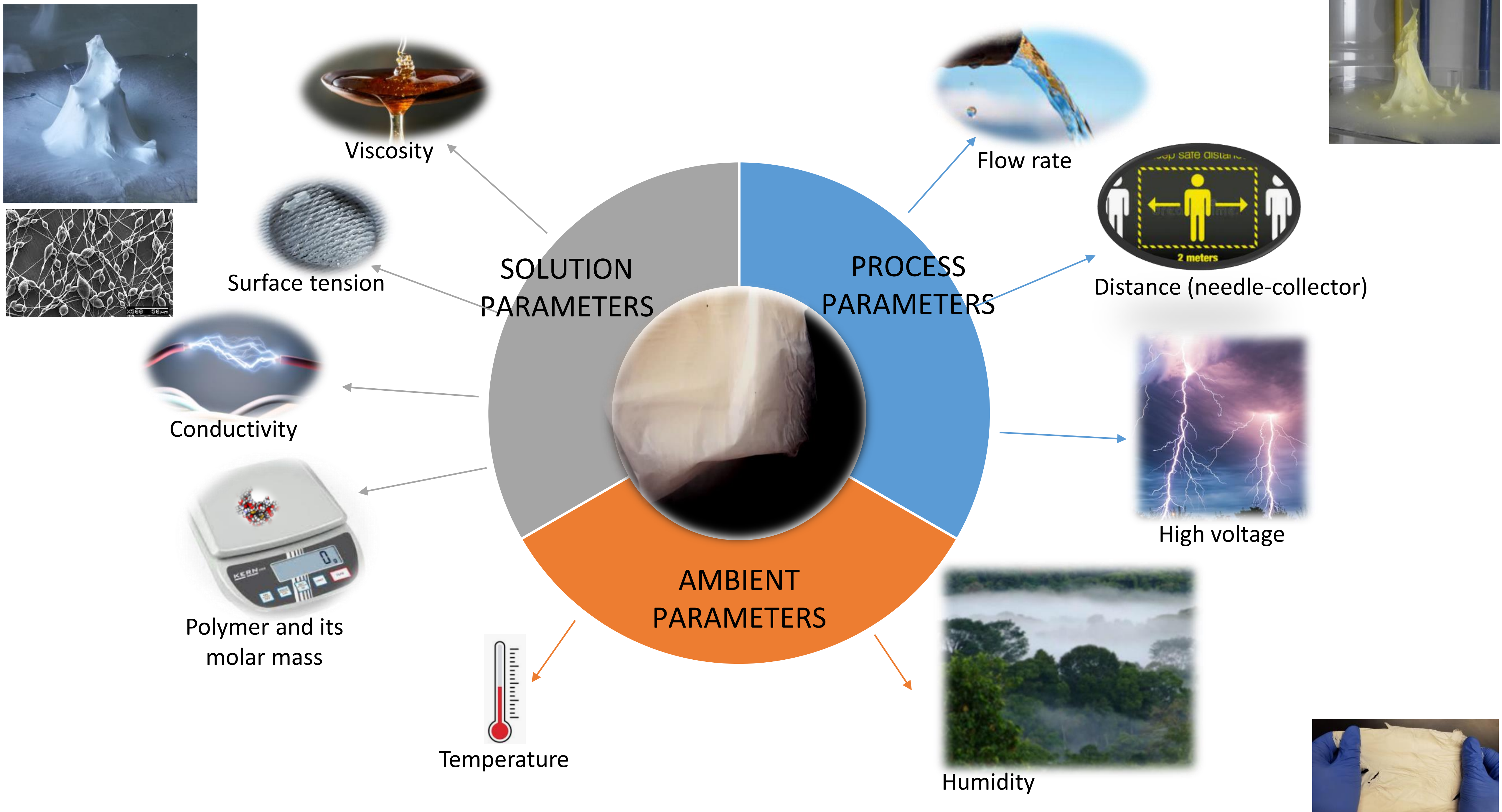




S. Homaeigohar, Y. Davoudpour, Y. Habibi and M. Elbahri, The Electrospun Ceramic Hollow Nanofibers, Nanomaterials **7** (2017) 383.

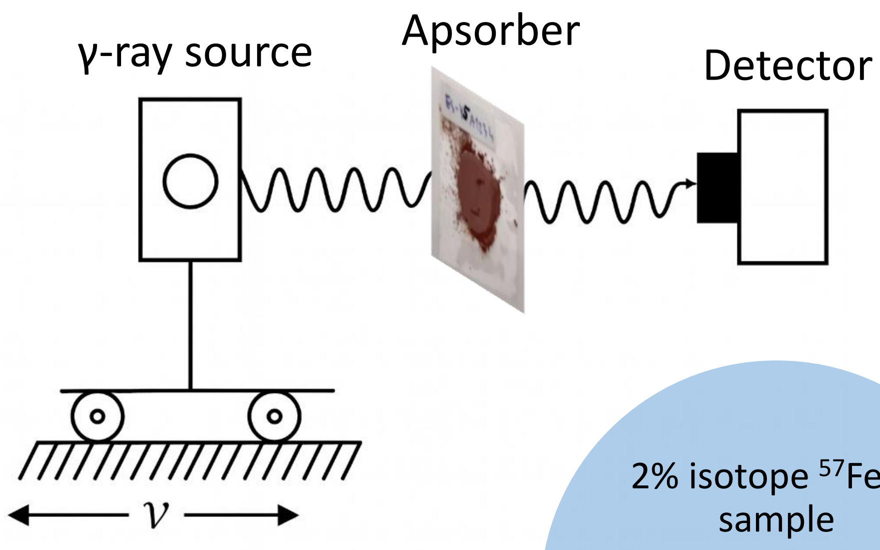
https://www.flickr.com/photos/51015268@N07/sets/72157633621380043/ (last-acces time 27.9.2025.)


Applications
Device from Israel
Portable
devices
spincare
4000 €
INITIAL WOUND
APPLICATION OF
NANOFIBERS
Nanofibers
NANOFIBER
COVERAGE
Nanofibers
HEALING UNDER
NANOFIBERS
WOUND ALMOST
HEALED
HEALED SKIN
[n]fibrecare
Electrospinning
devices
Big
machines
II
electrospinning
IV
I
targeted spot
III
Makeup application



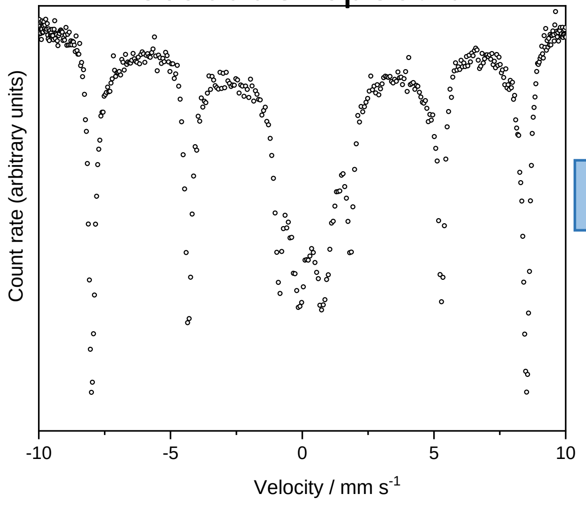
Bhardwaj N., Kundu S.C., *Biotechnol. Adv.*, **28** (2010) 325-347

Mössbauer spectroscopy

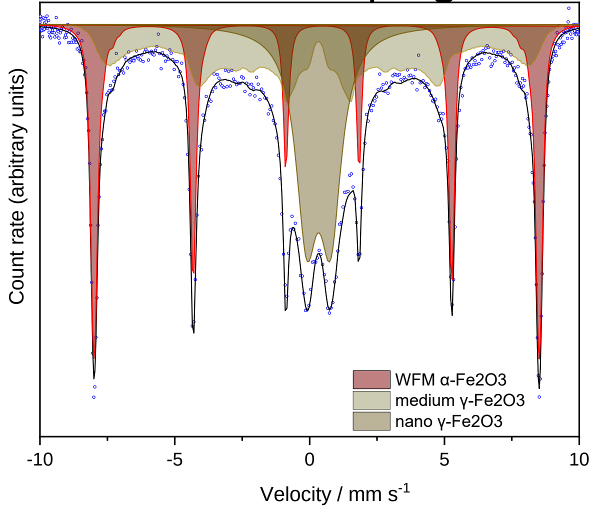


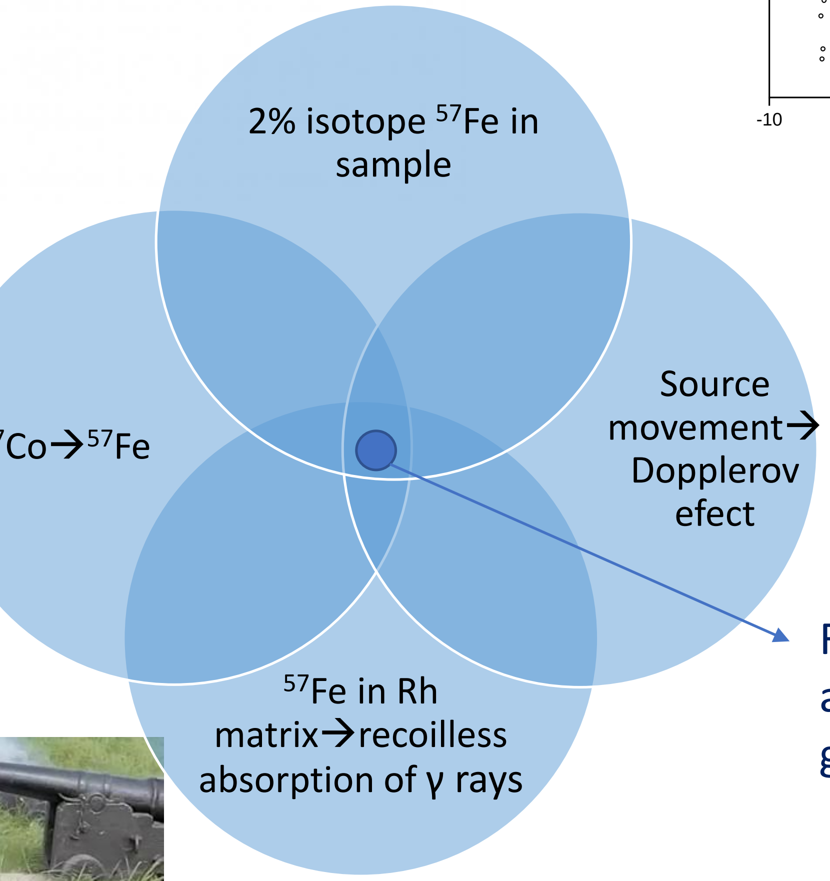
Electromechanical device

Mössbauer spectrum



MossWinn program





Resonant apsorption of gamma rays

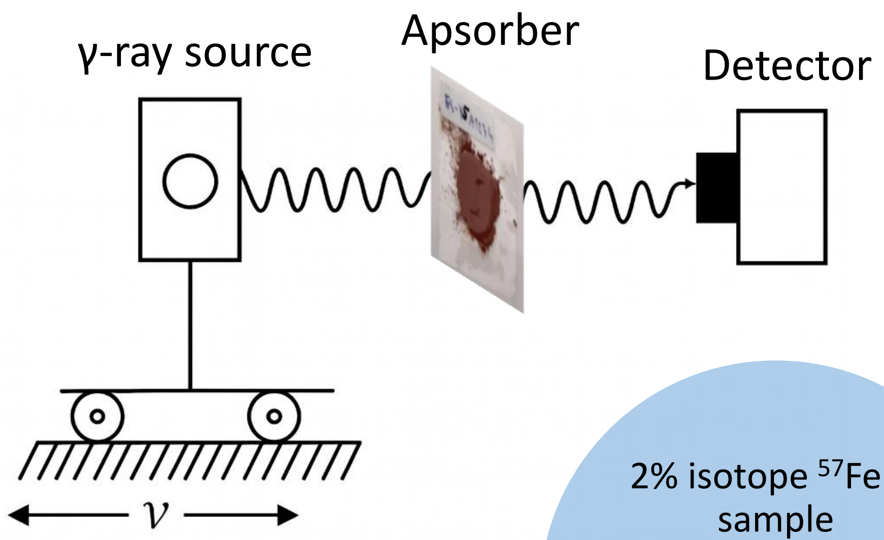
recoil

Rudolf Mössbauer

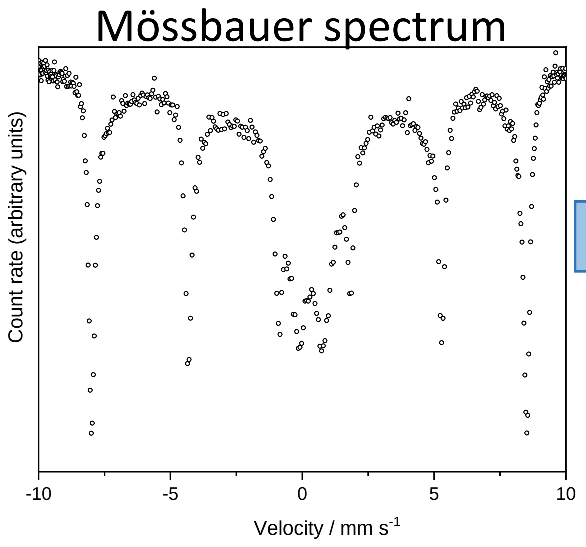
Discovery: 1957

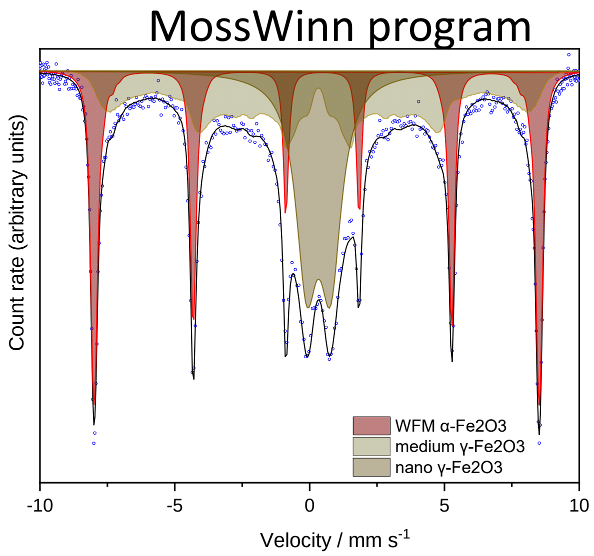
Nobel prize: 1961

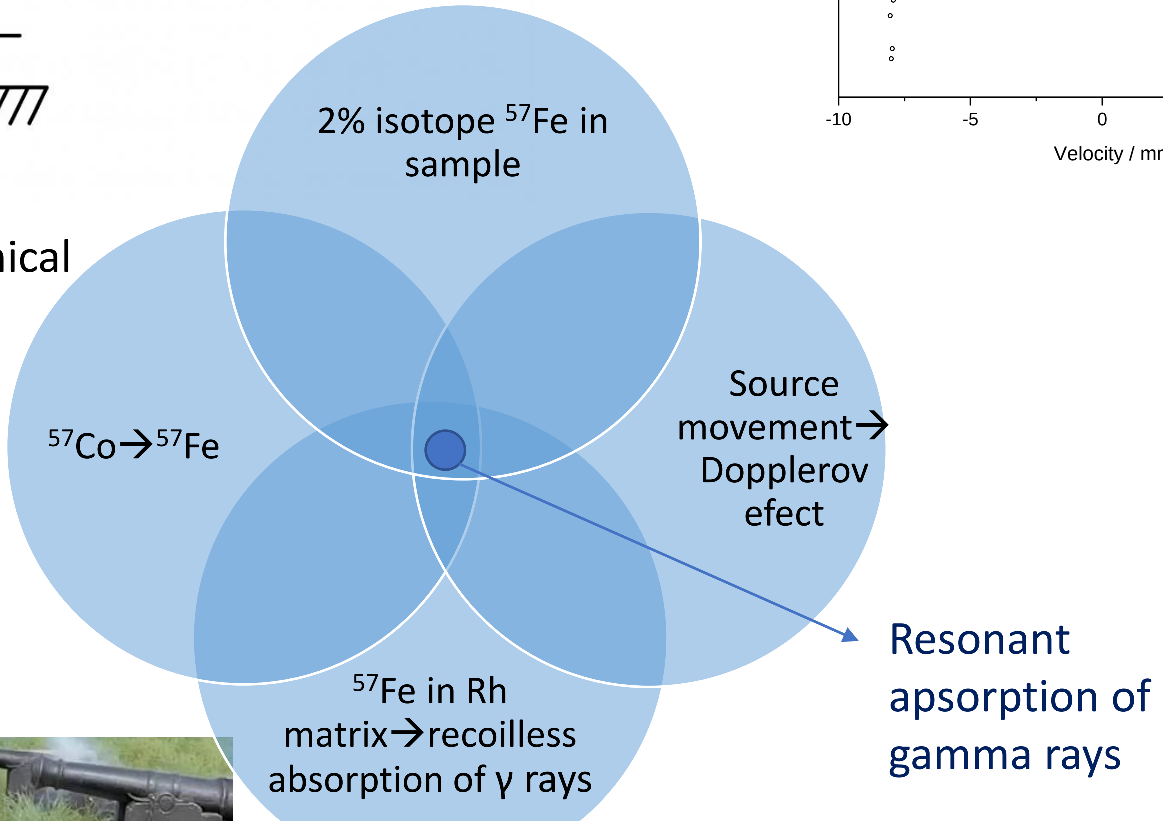
Mössbauer spectroscopy



Electromechanical device





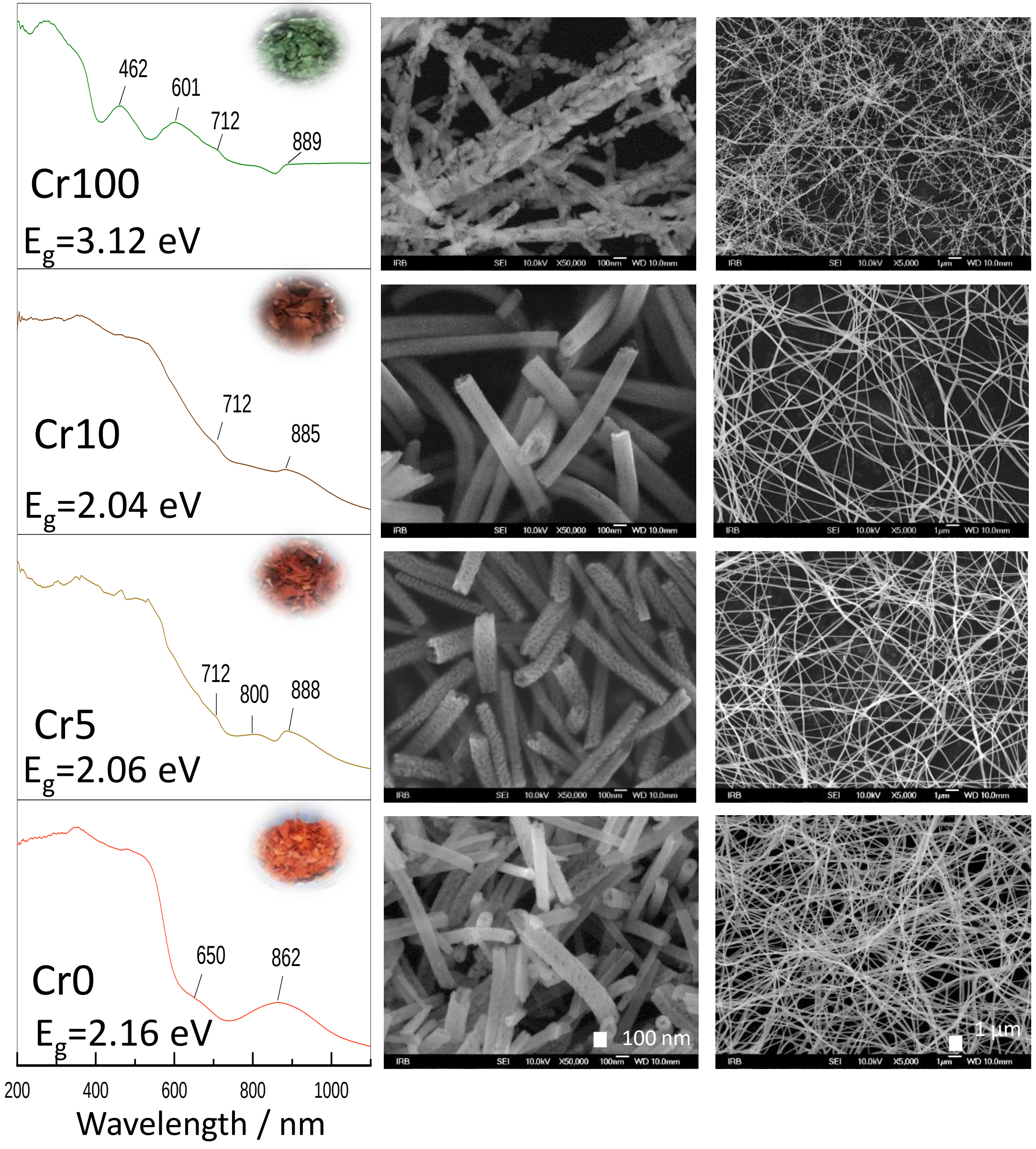


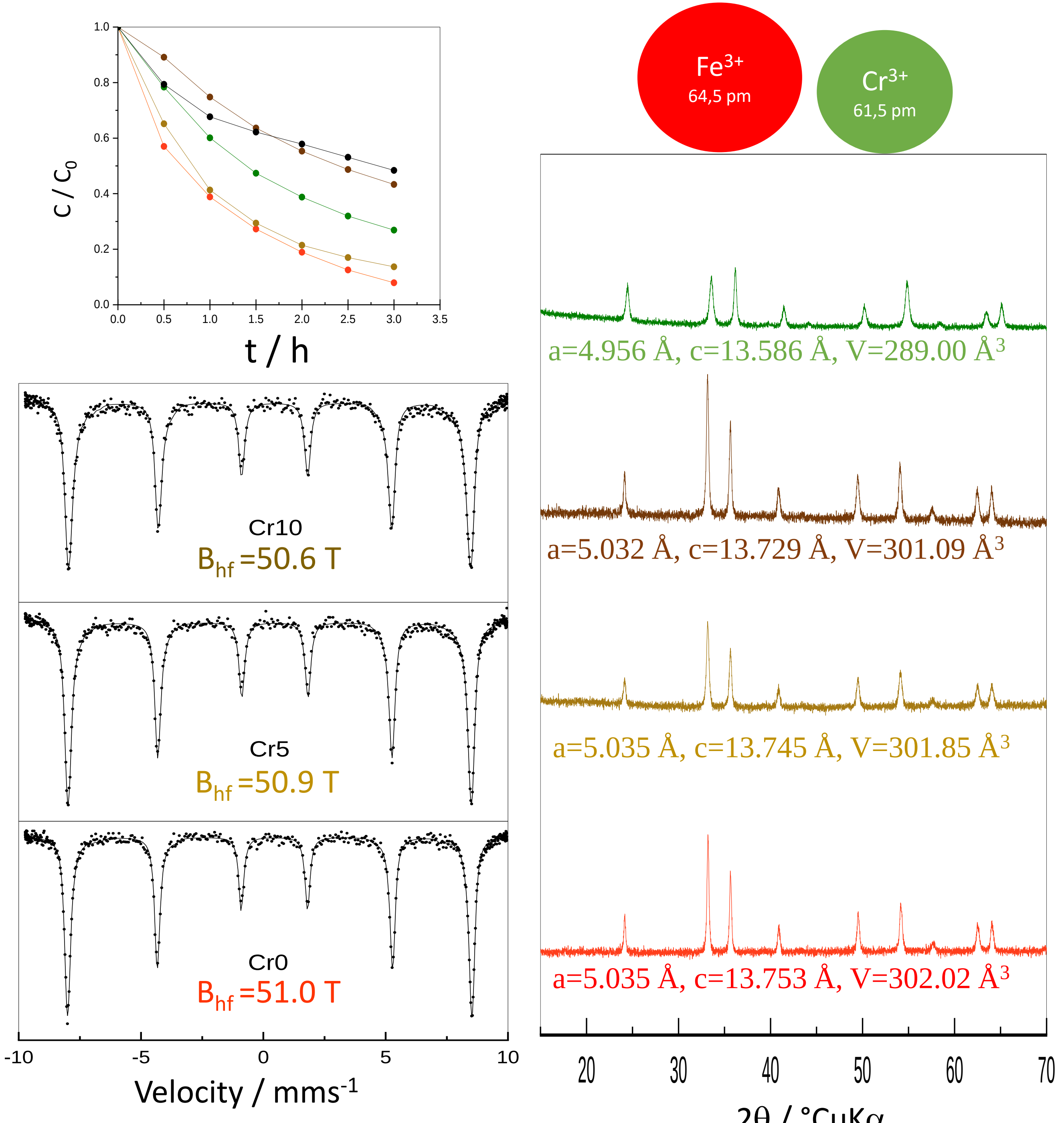
recoil

Postives aspects about the method:

1) 100 % selective for ^{57}Fe
2) Valence state of iron
3) Useful even for amorphous samples (an advantage over XRPD)
4) Insight in magnetic ordering

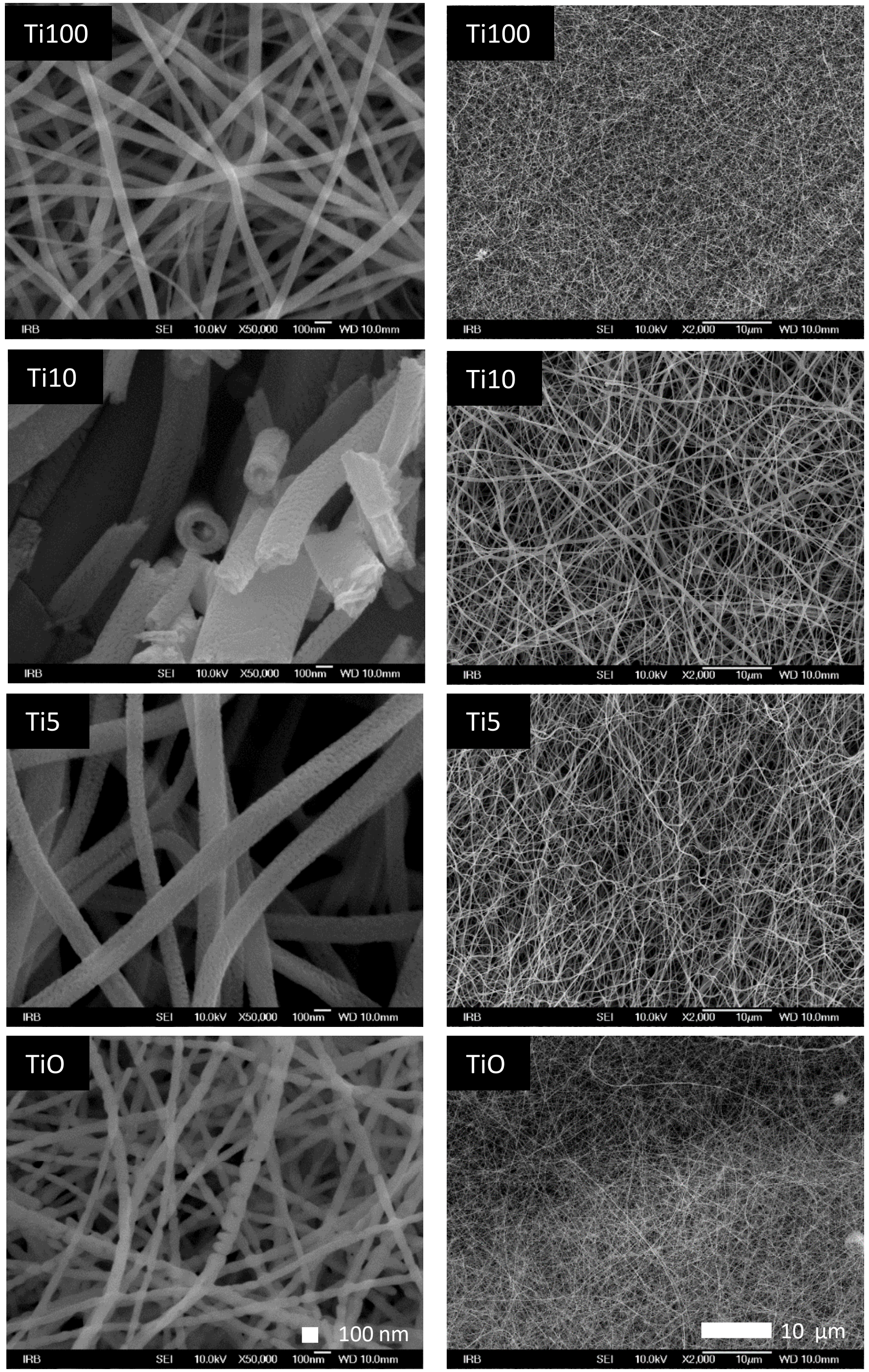
Cr^{3+} doping

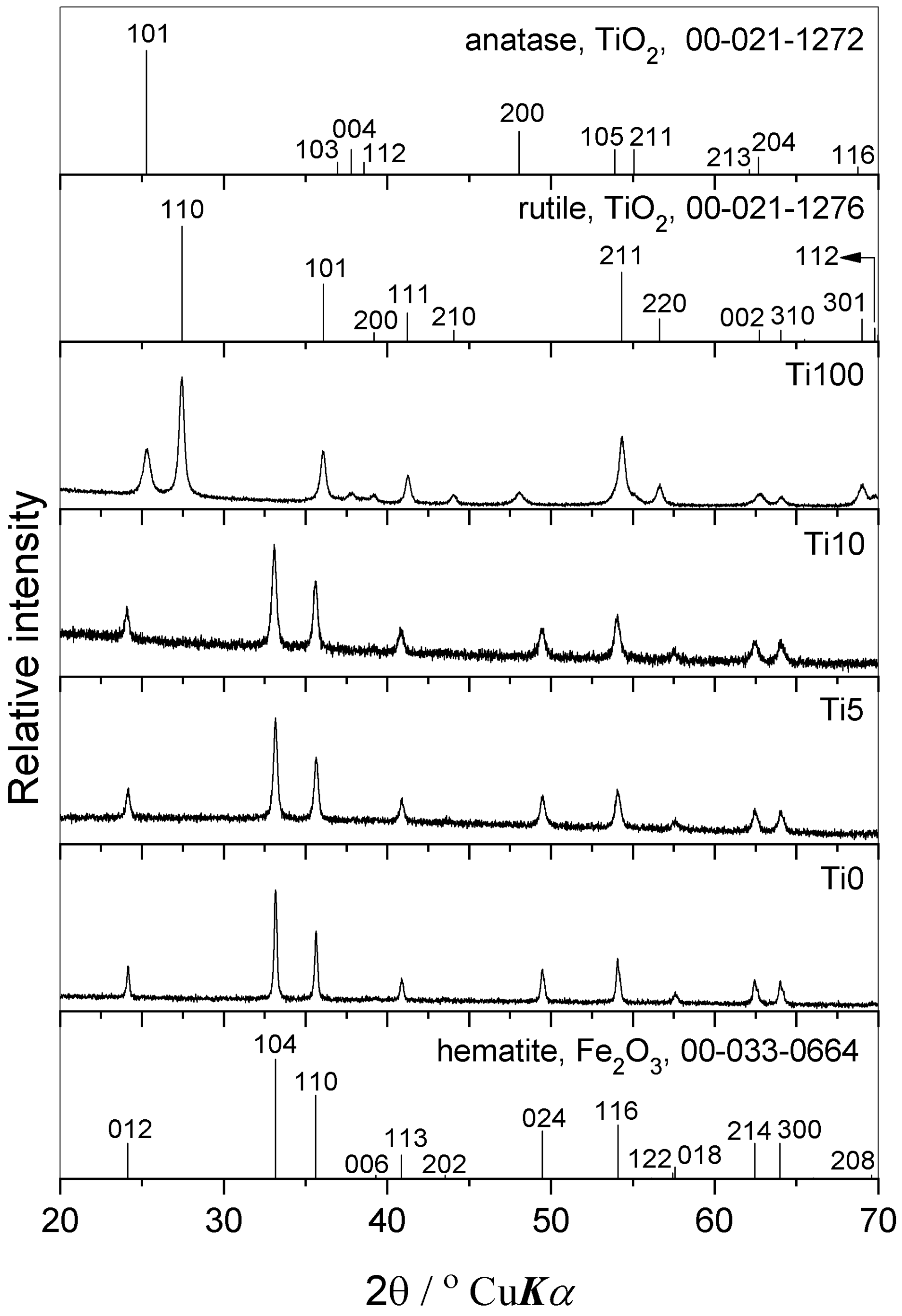




M. Robić, M. Ristić, M. Marciuš, S. Krehula, S. Musić, *Chem. Pap.*, **74** (2020) 4345–4353

Ti^{4+} doping

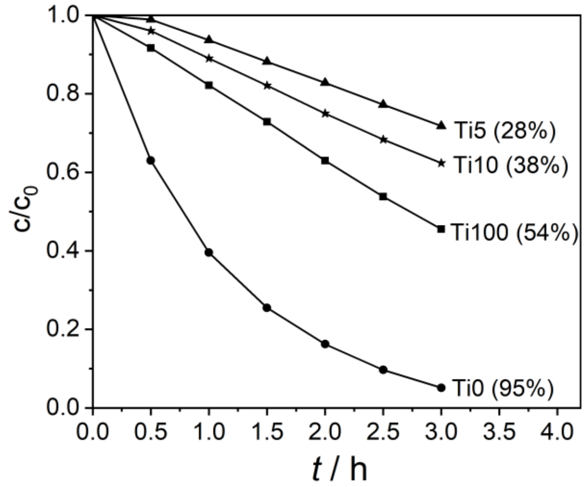


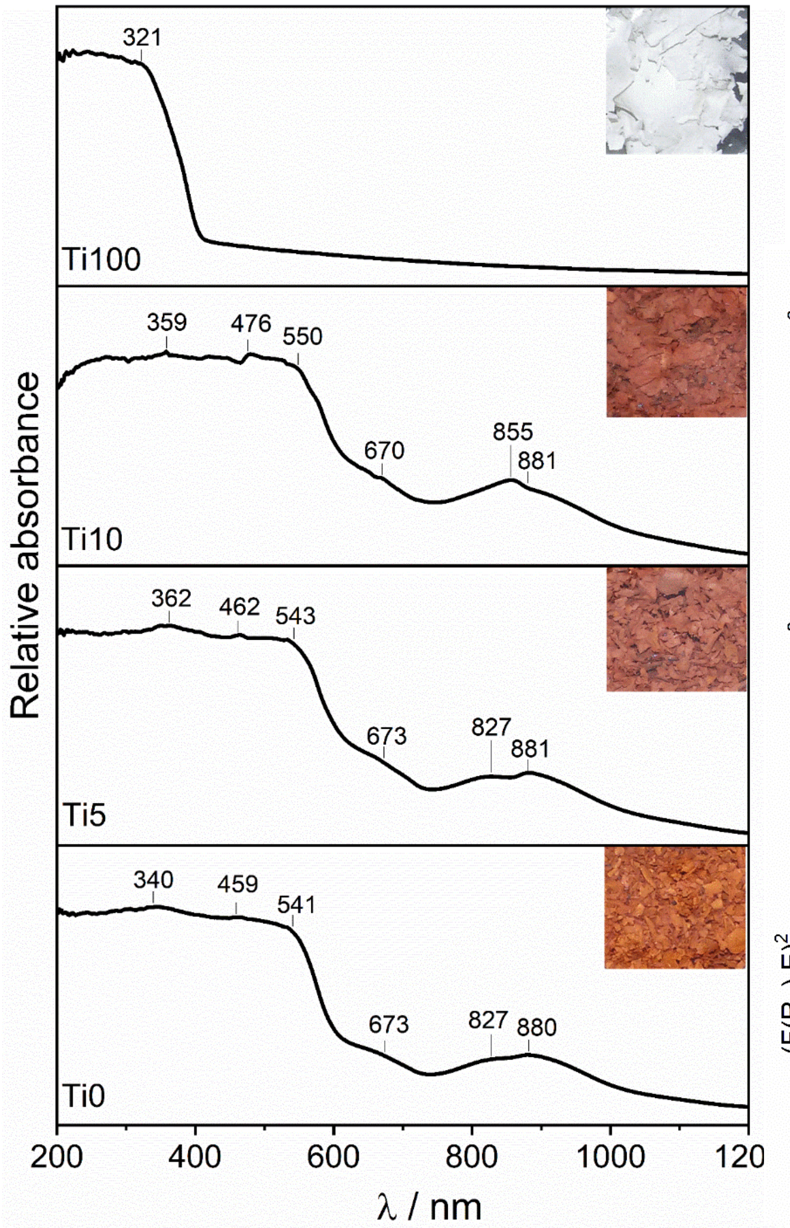


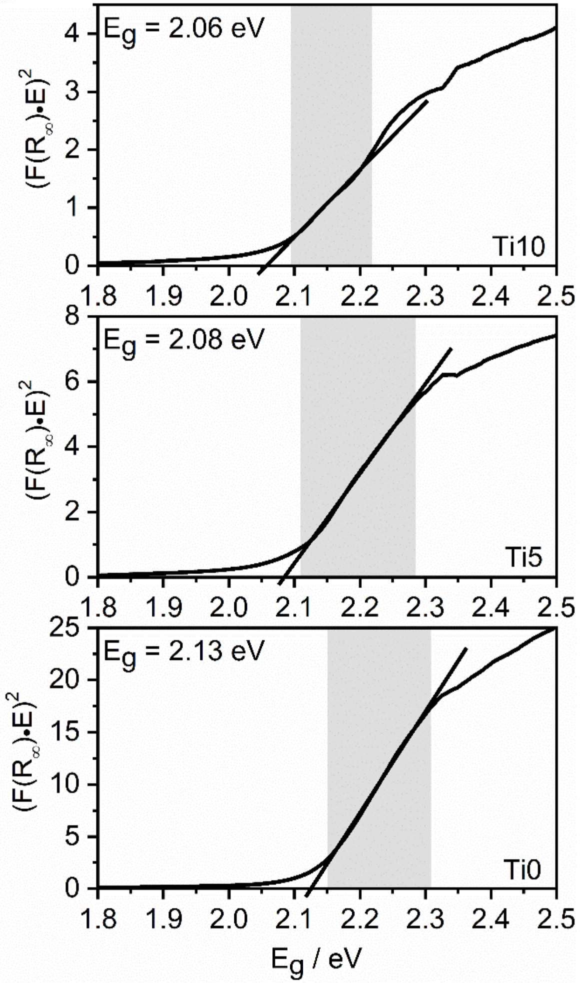
M. Robić, M. Ristić, M. Marciuš, S. Krehula, S. Musić, 2020, *J. Nanopart. Res.*, **22**(2020) 358

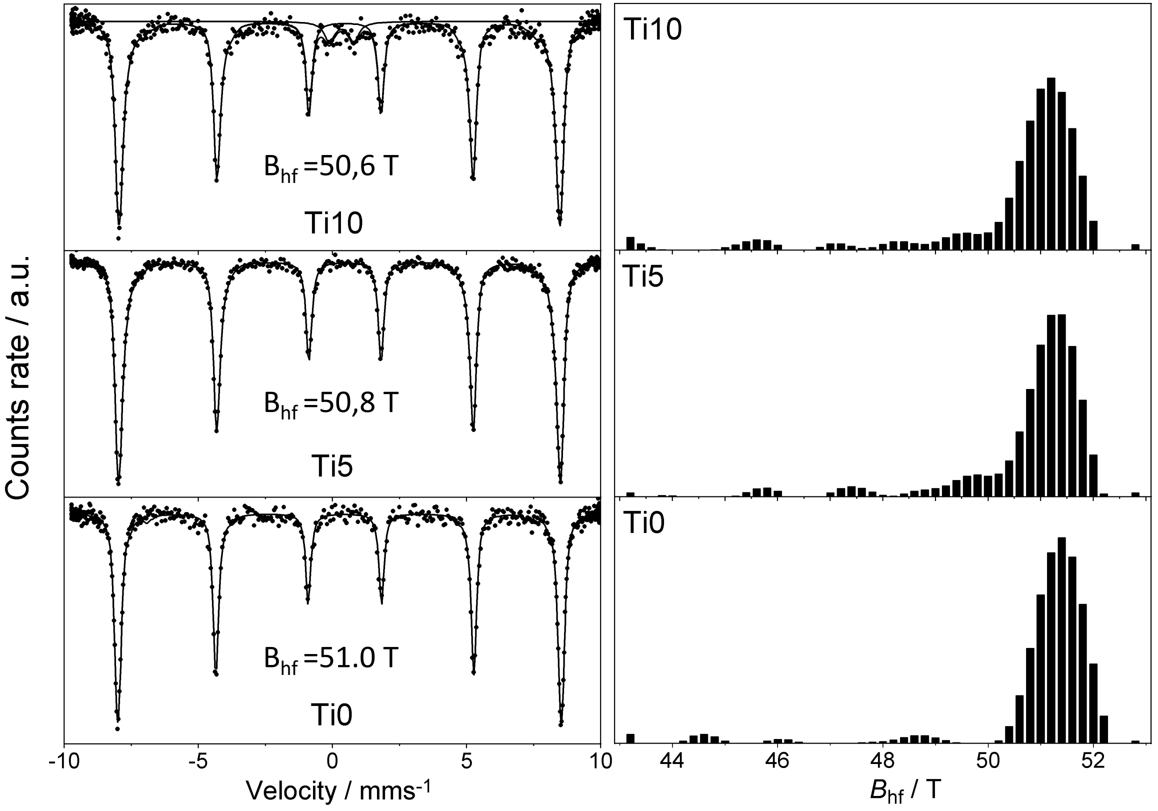
Ti^{4+} doping

Sample	*a* / Å	*c* / Å	V / Å³	Crystallite size / Å
Ti10	5.0306	13.750	301.37	359
Ti5	5.0327	13.751	301.65	439
Ti0	5.0361	13.756	302.16	1067



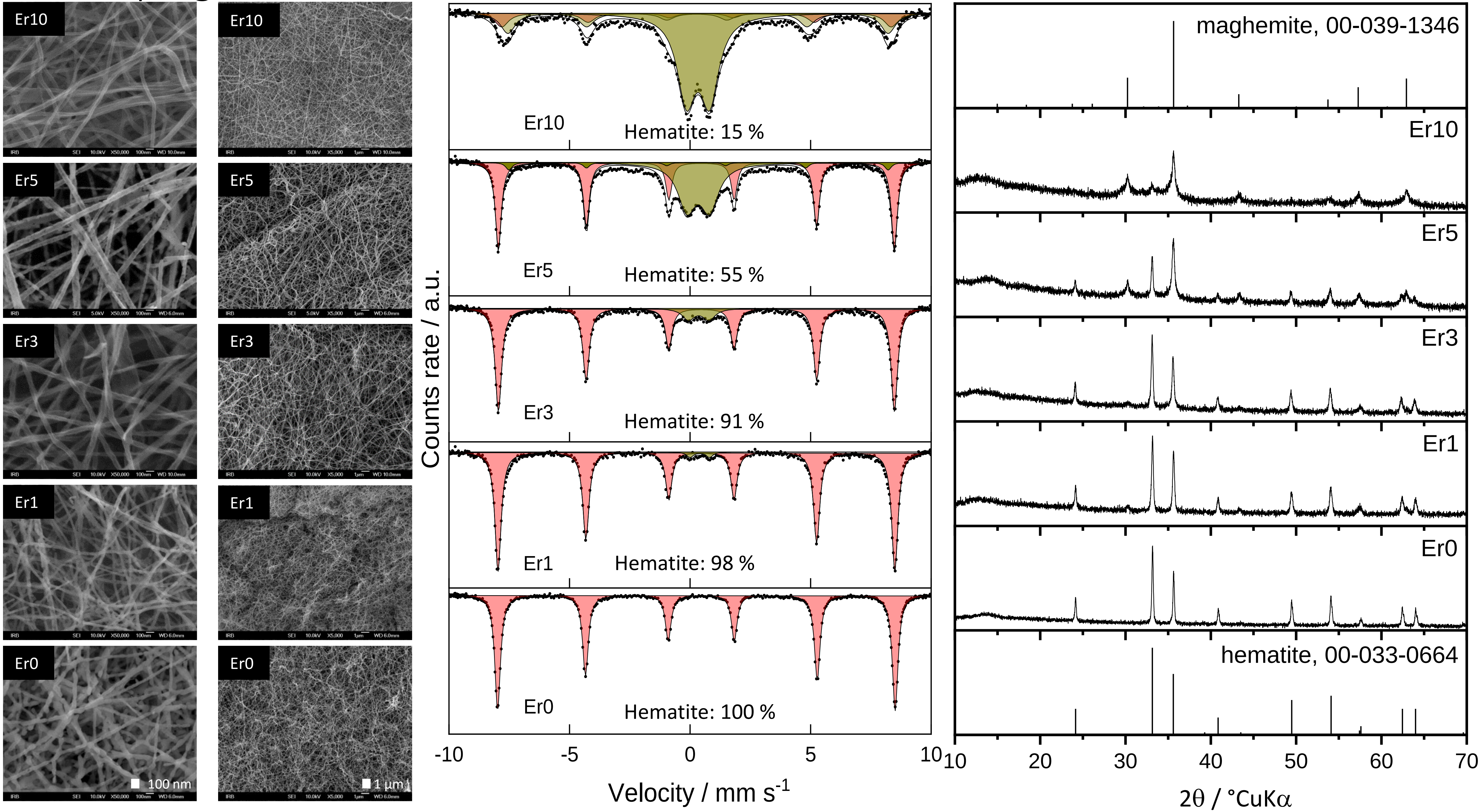


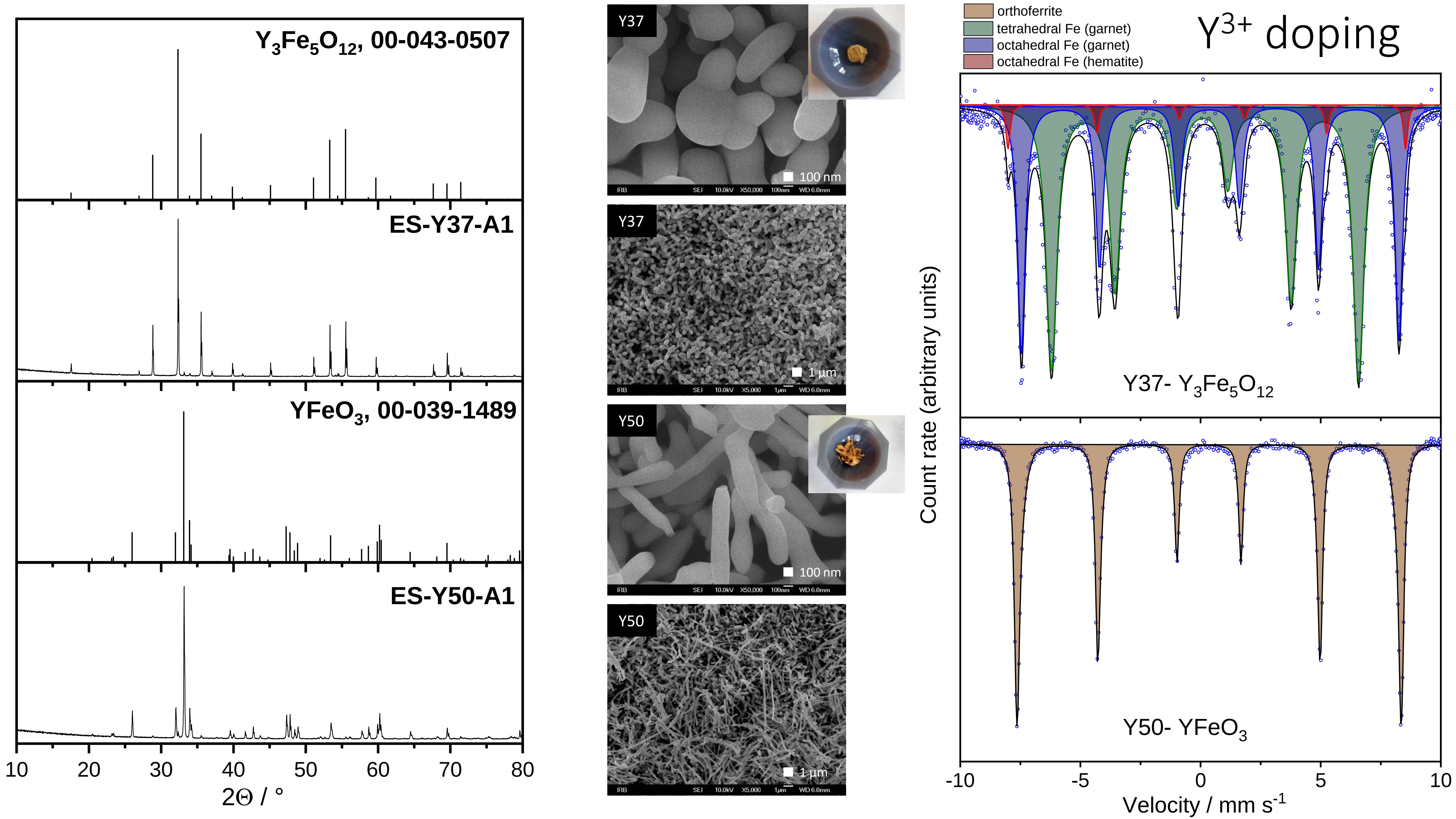




M. Robić, M. Ristić, M. Marciuš, S. Krehula, S. Musić, 2020, *J. Nanopart. Res.*, **22**(2020) 358

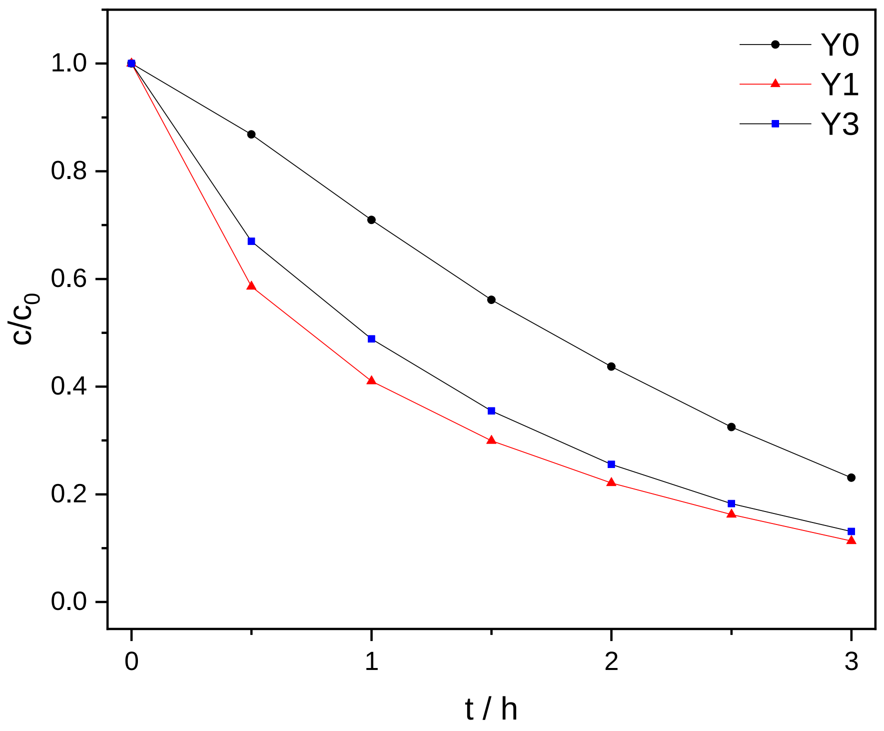
Er^{3+} doping


Er10
Er5
Er3
Er1
Er0
100 nm
1 μm
Hematite: 15 %
Hematite: 55 %
Hematite: 91 %
Hematite: 98 %
Hematite: 100 %
Counts rate / a.u.
Velocity / mm s-1
-10
-5
0
5
10
maghemite, 00-039-1346
hematite, 00-033-0664
2θ / °CuKα
10
20
30
40
50
60
70

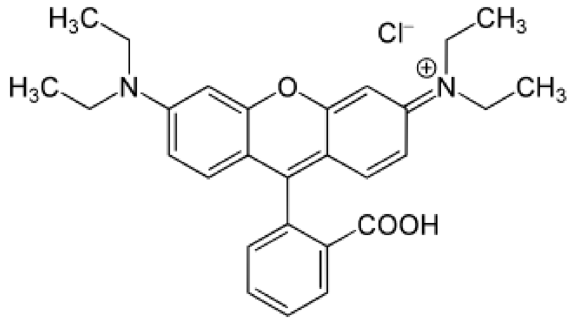


$Y_3Fe_5O_{12}$, 00-043-0507
ES-Y37-A1
$YFeO_3$, 00-039-1489
ES-Y50-A1
10
20
30
40
50
60
70
80
2Θ / °
Y37
100 nm
Y37
1 µm
Y50
100 nm
Y50
1 µm
orthoferrite
tetrahedral Fe (garnet)
octahedral Fe (garnet)
octahedral Fe (hematite)
Y^{3+} doping
Count rate (arbitrary units)
Y37- $Y_3Fe_5O_{12}$
Y50- $YFeO_3$
-10
-5
0
5
10
Velocity / mm s^{-1}

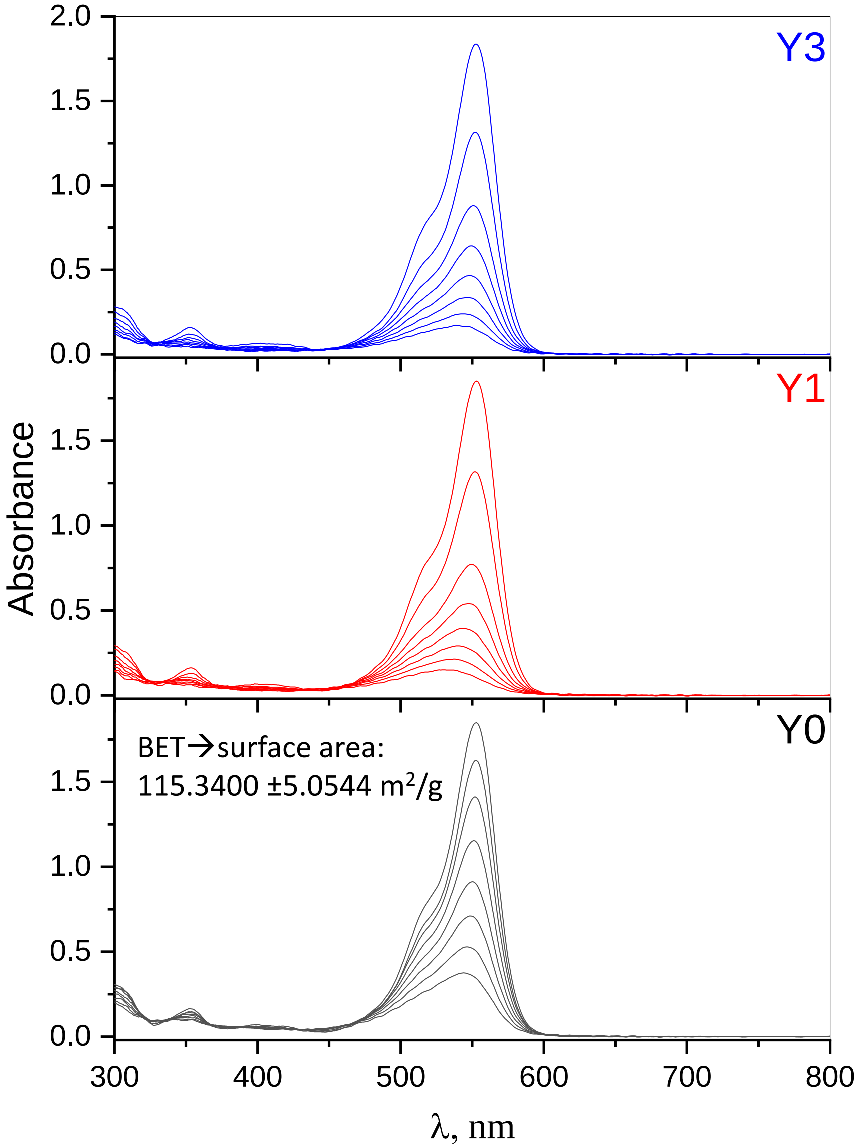
Y^{3+} doping



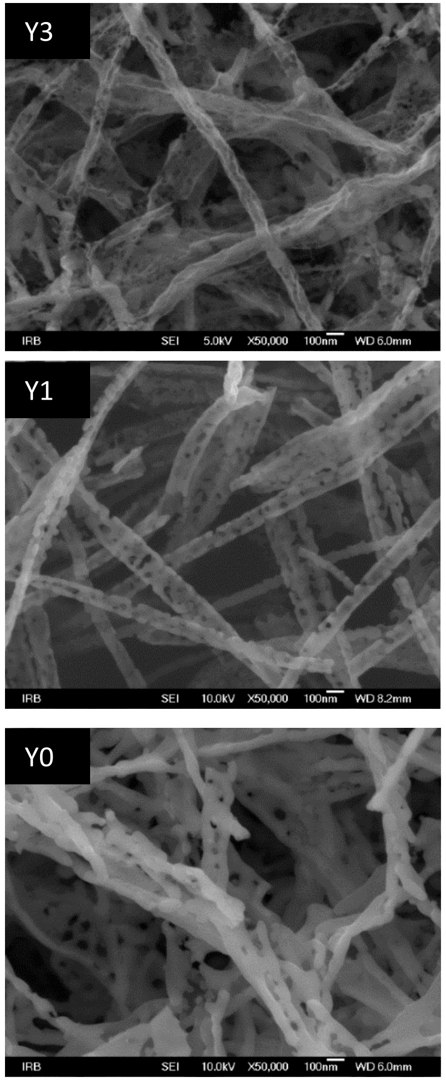
Y0
Y1
Y3
c/c0
t / h
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3



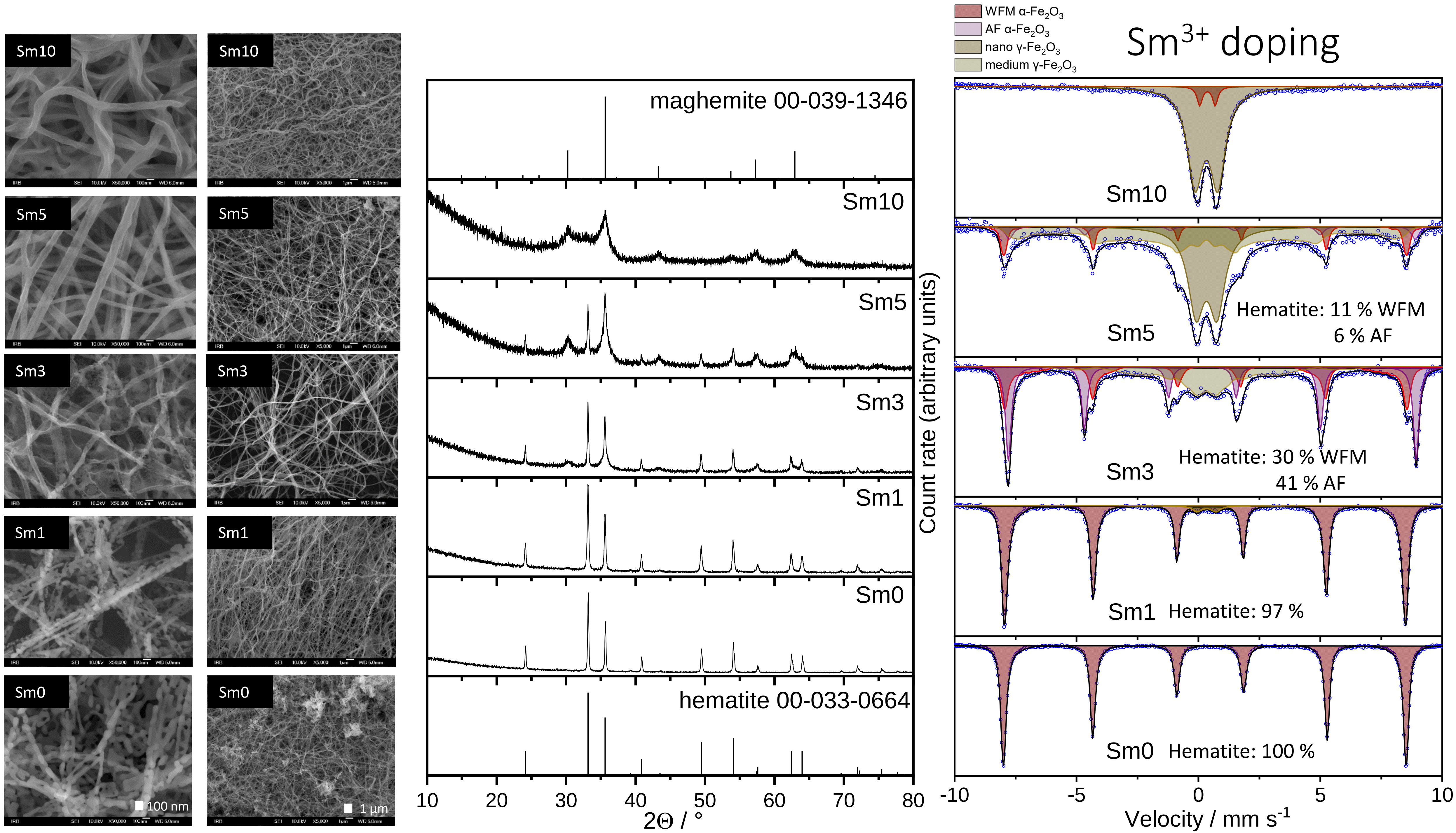
H3C
H3C
N
O
Cl⁻
CH3
N
CH3
COOH



Y3
Y1
Y0
BET→surface area:
115.3400 ±5.0544 m²/g
Absorbance
λ, nm
300
400
500
600
700
800



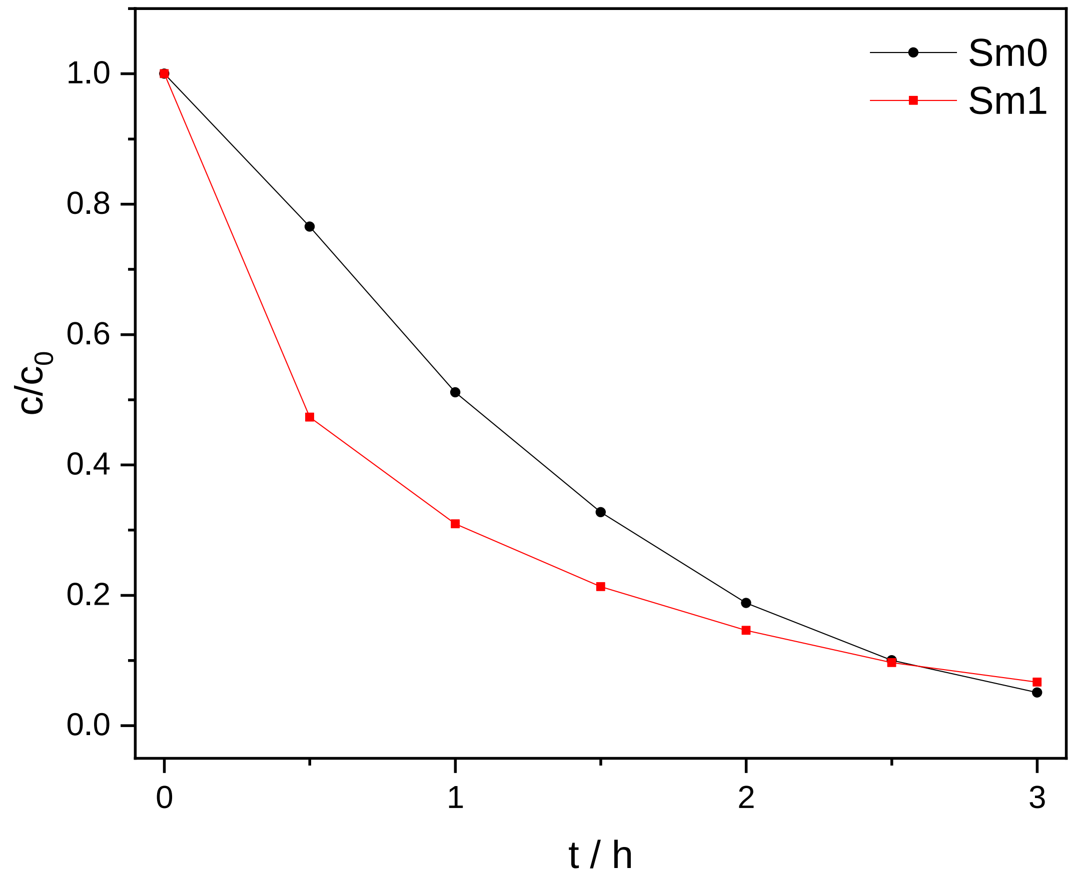
Y3
Y1
Y0

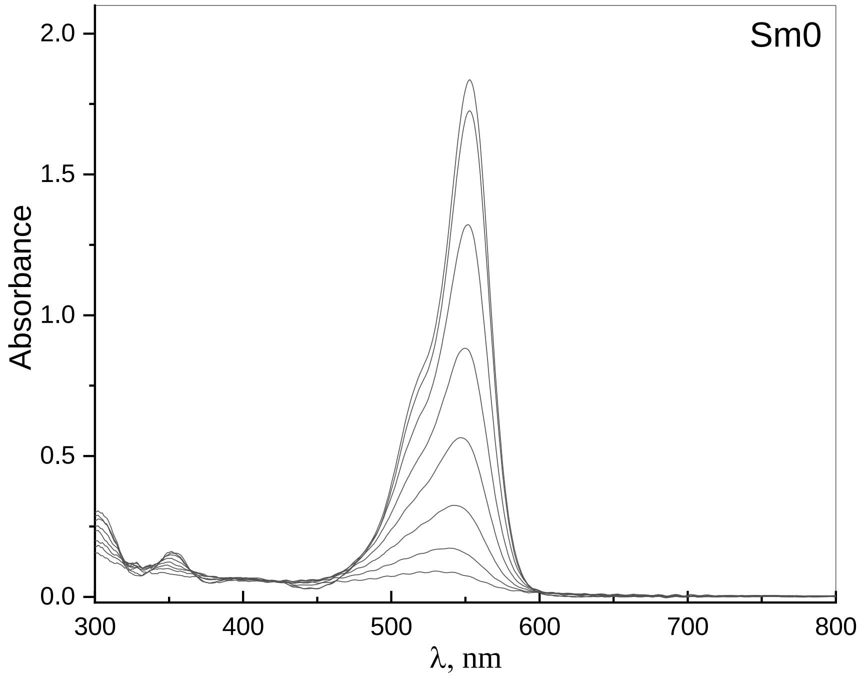


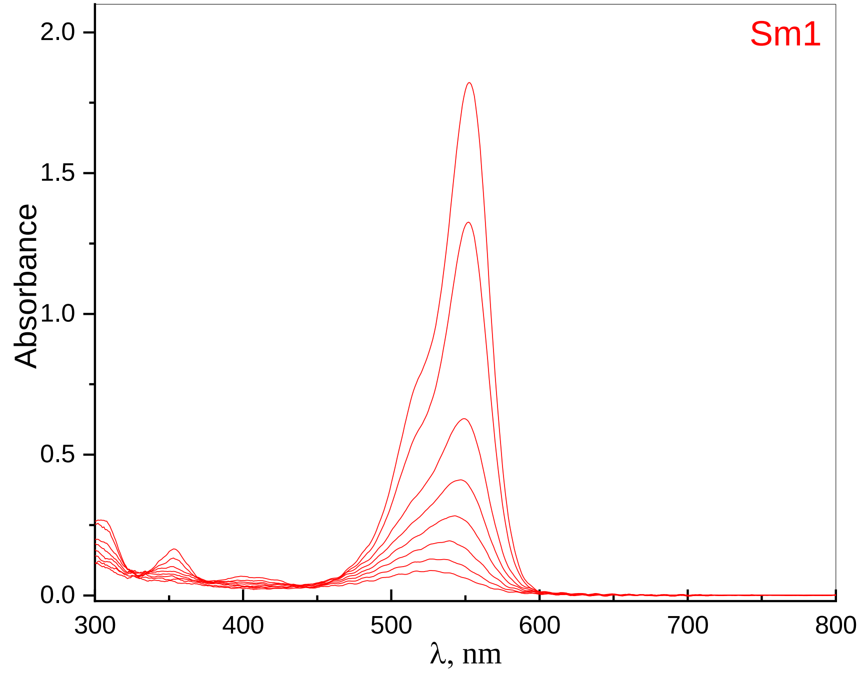
Sm10
Sm5
Sm3
Sm1
Sm0
100 nm
1 µm
maghemite 00-039-1346
hematite 00-033-0664
2Θ / °
Count rate (arbitrary units)
WFM α-Fe2O3
AF α-Fe2O3
nano γ-Fe2O3
medium γ-Fe2O3
Sm3+ doping
Hematite: 11 % WFM
6 % AF
Hematite: 30 % WFM
41 % AF
Hematite: 97 %
Hematite: 100 %
Velocity / mm s-1

Sm^{3+} doping

Photocatalysis







Conclusions

- Calcined electrospun nanofibers containing rare earths ended up with magnetic composite phases
- Doping with chromium nad titanium yielded with hematite as a single phase
- Cr^{3+}, Ti^{4+} doping→ decrease in band gap
- Chromium doping→ most significant difference in sample colors
- Photocatalysis: pure hematite nanofibers gave the best result

Special thanks <3

IRB research group

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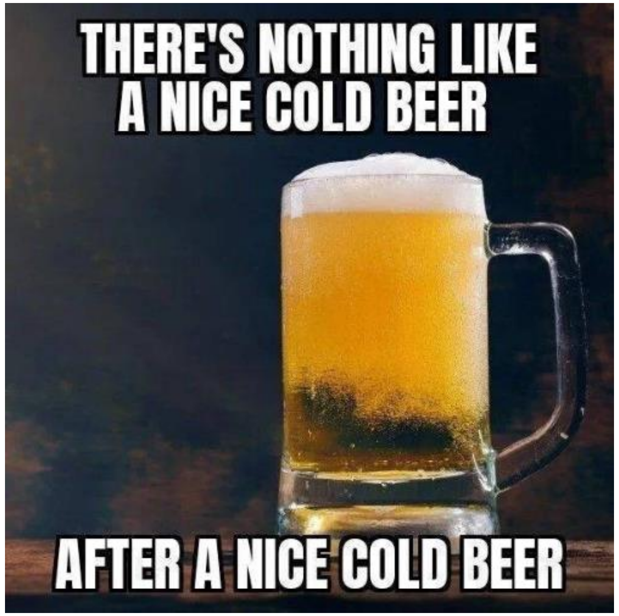
Ivana Landripet

Matej Bubaš



Lidija-Androš Dubraja

Andreas Puškarić

Marko Dunatov


THANK
YOU
FOR
YOUR
ATTENTION