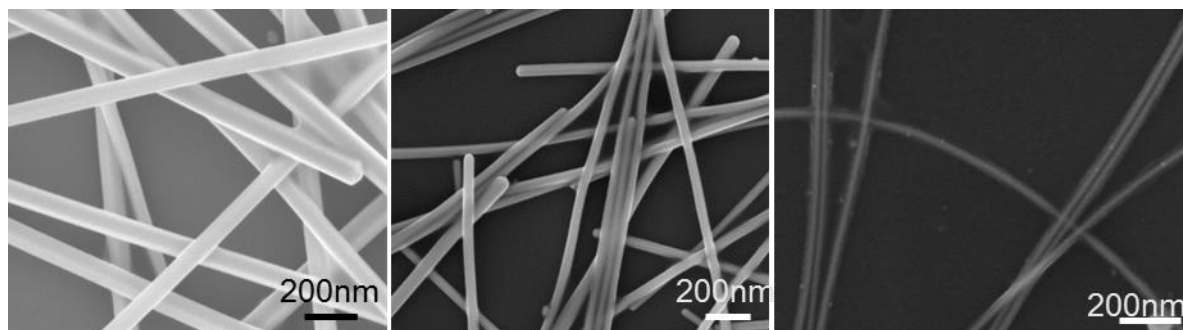


Morphology of silver nanowires: between performances and toxicity



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Summary

- Current context
- Synthesis of AgNW by polyol process:
Control of morphology by a parametrical study
- First toxicity results

Context

- **Transparent conductive films**

→ Indium Tin Oxide (ITO)

- **New needs towards flexible devices**

→ ITO = Brittleness

Supply dependance

Costly process

- **Promising alternatives materials**

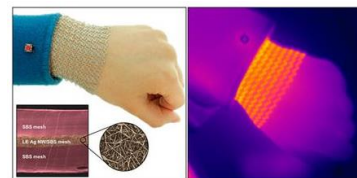
→ Silver nanowire networks

AgNWs

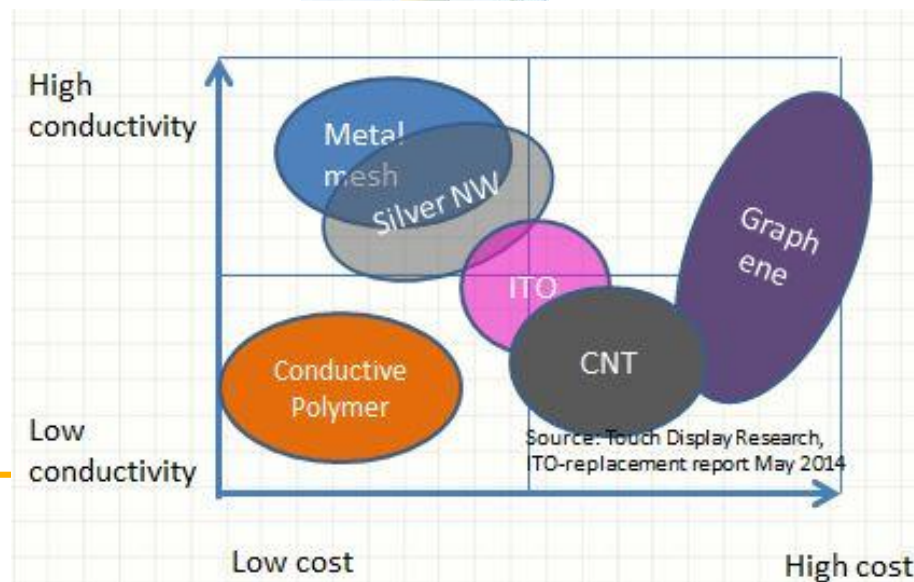


Heating films

Flexible displays



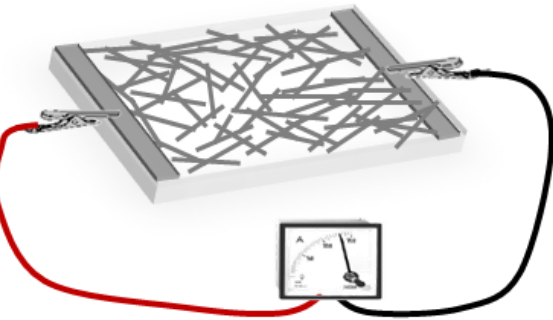
Solar cells



AgNW based transparent electrode

- Integration into a large panel of devices

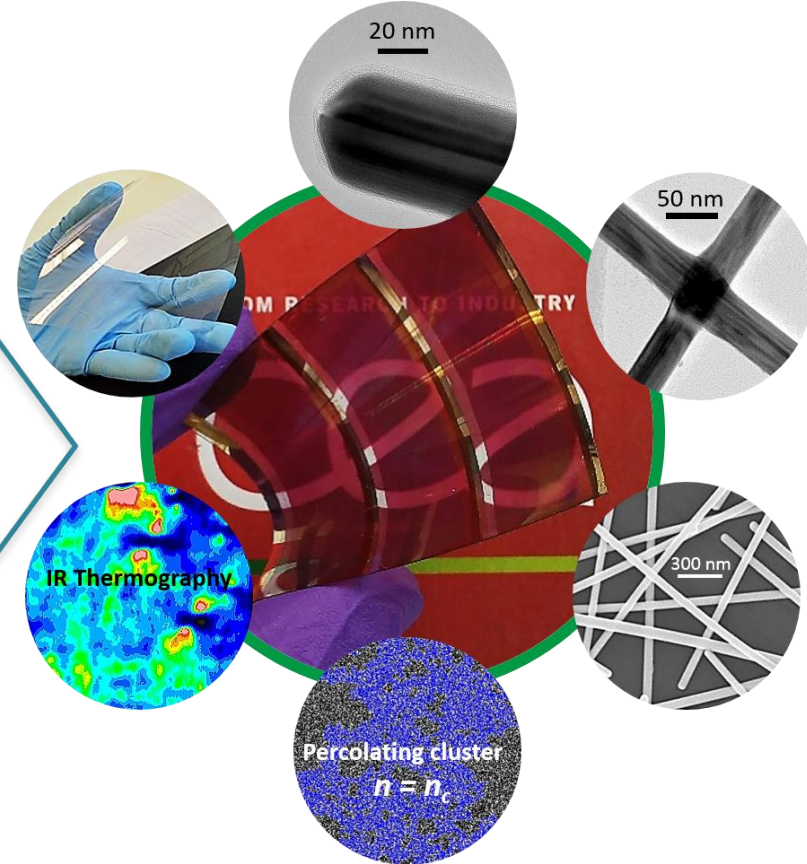
Percolating network



→ *interest of length or diameter modification*

Modulation of performances

Transparency
Sheet resistance
Haze



PhD guidelines

Safer By Design approach

- Chemical modifications
- Modulation of morphology or shape



→ various diameter / length

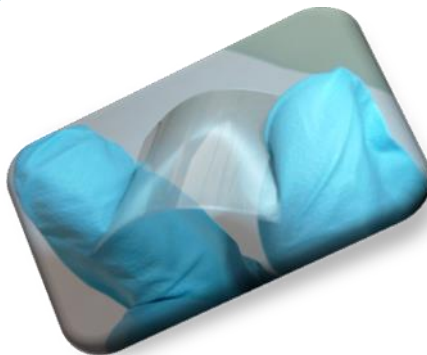
Yes

Synthesis of AgNW

AgNW performances

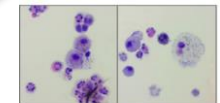
Toxicity tests

< 50Ω/sq
90% T



Yes

No



Frustrated phagocytosis
&/or inflammation



R. M. Silva et al, *Part Fibre Toxicol* 2014

Integration into devices
-Touch sensor, TFH...



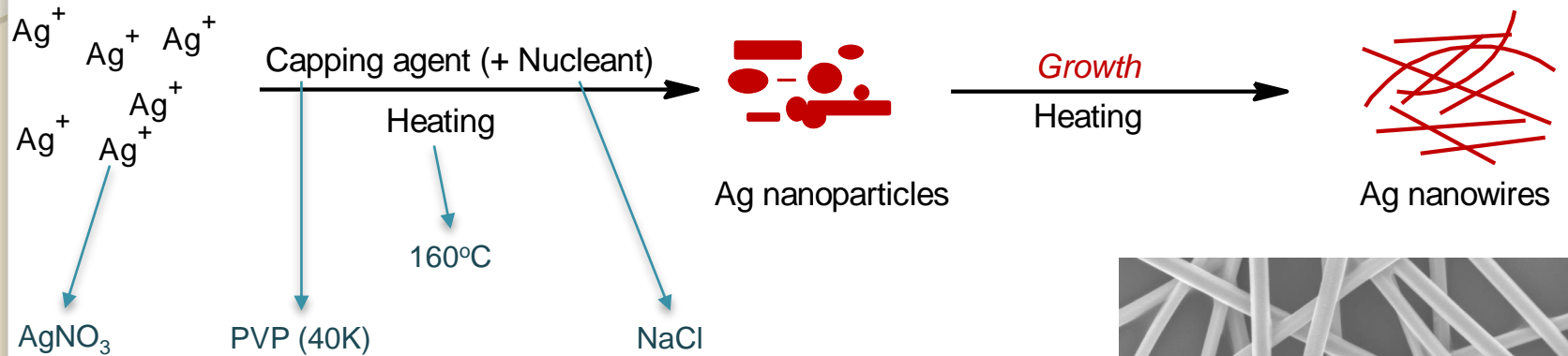
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Control of morphology by a parametrical study
- First toxicity results

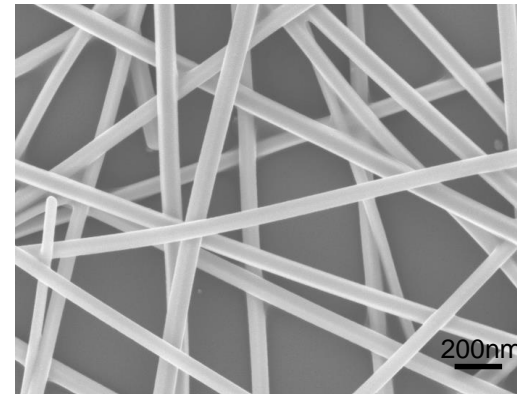
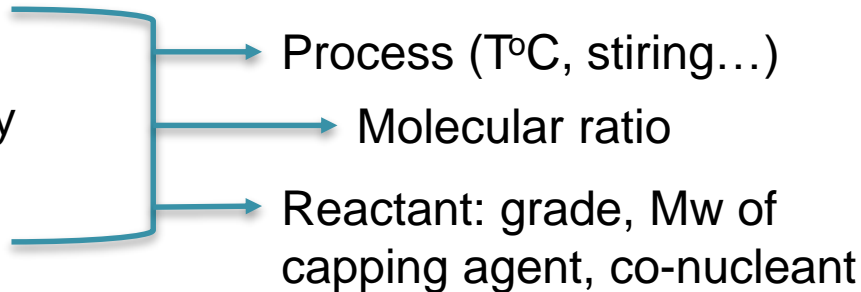


Control morphology of AgNW

• Polyol synthesis



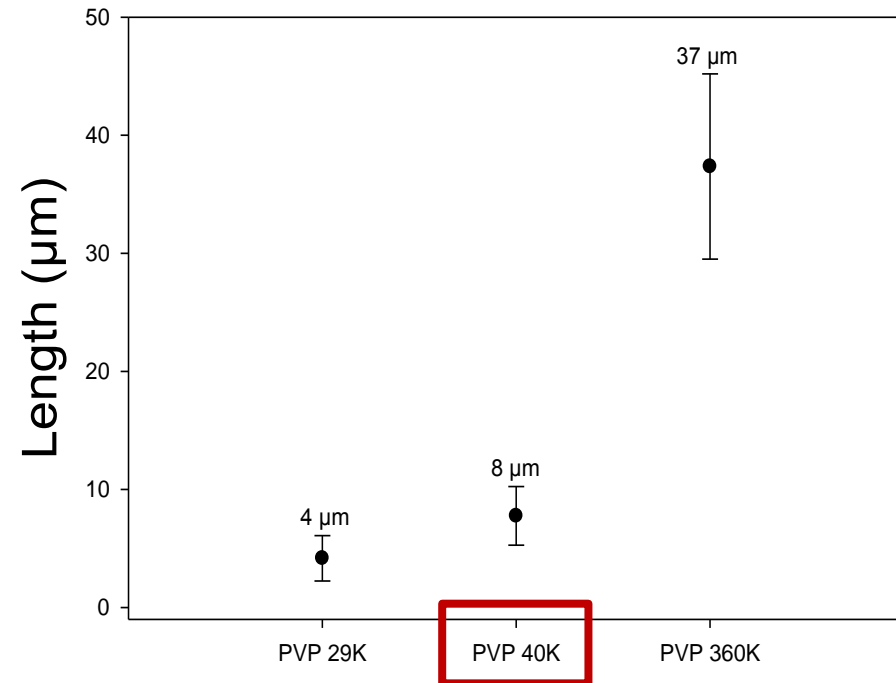
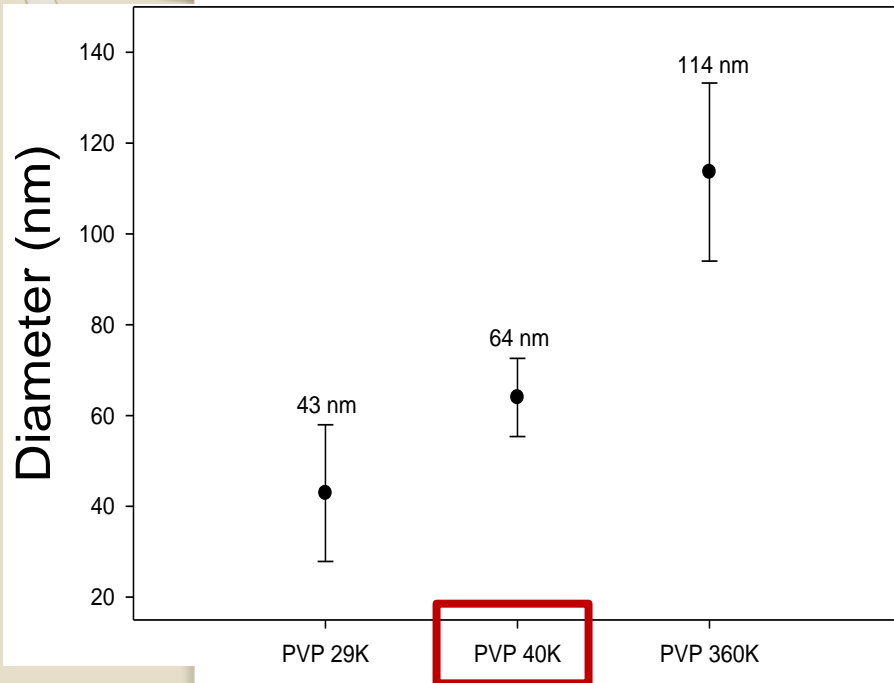
Parametric study



Std AgNW $\approx 60\text{nm}$, $\approx 8\mu\text{m}$

Control morphology of AgNW

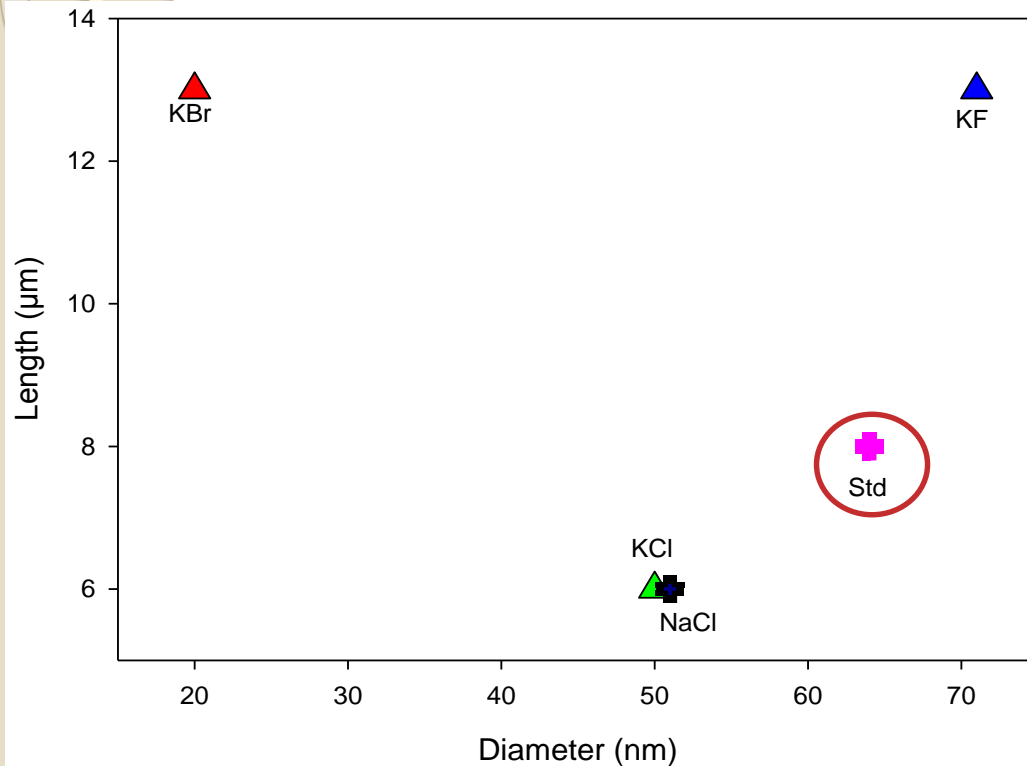
- Example of molecular weight of capping agent



→ Length and diameter increase with molecular weight of capping agent

Control morphology of AgNW

- Effect of halide: F^- , Cl^- , Br^- , I^-

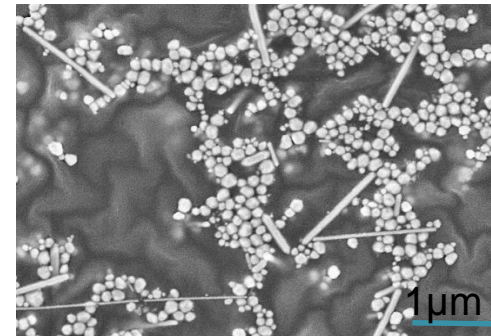


KCl: same trend as NaCl

KF: \nearrow length, slightly increase diameter

KBr: \nearrow length, \searrow diameter

Synthesis with KI



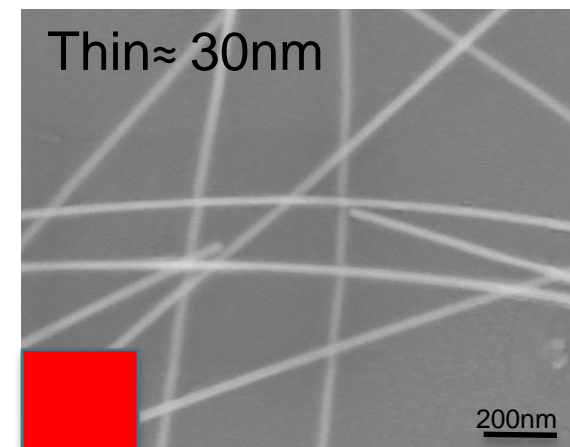
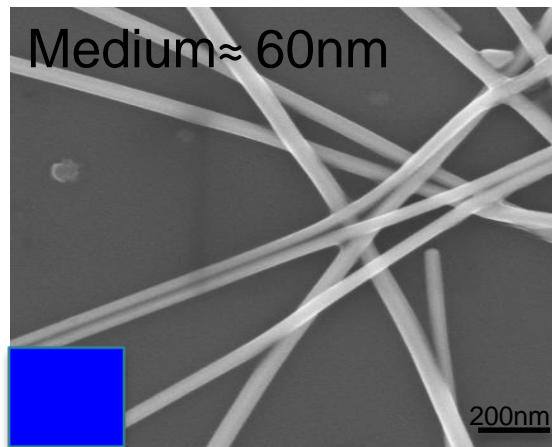
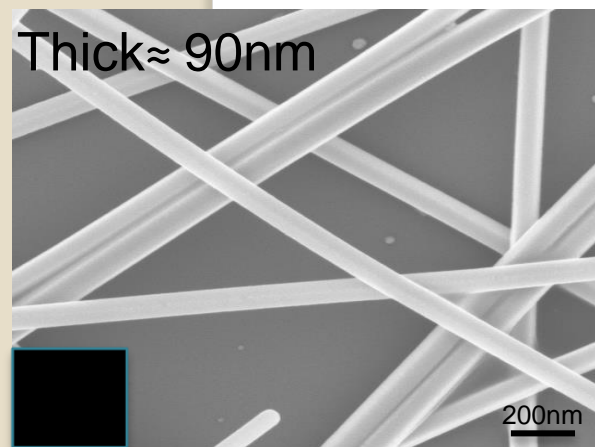
- Strong effect of halide on nanowires morphologies
- Only bromide ions allow to decrease diameter

Summary

- Current context
- Synthesis of AgNW by polyol process:
Control of morphology by a parametrical study
- First toxicity results → Cytotoxicity
→ Reactive Oxygen Species
→ Caspase 3 activation

Toxicological studies

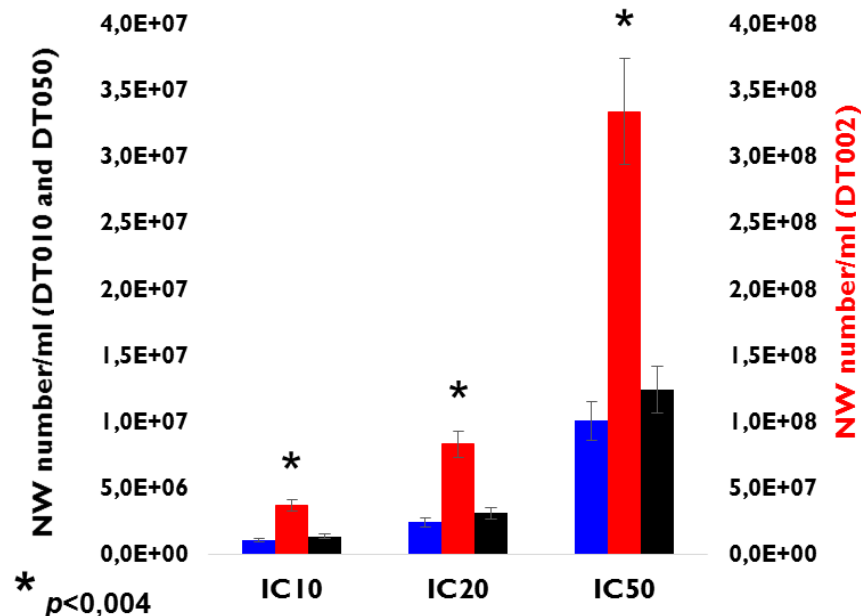
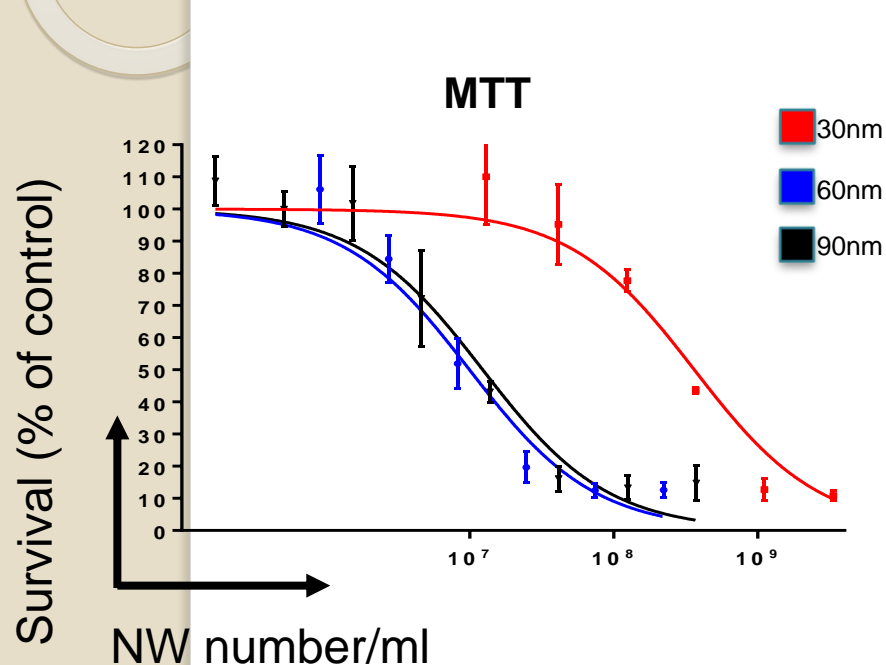
- Length below $10\mu\text{m}$ ($\approx 8\mu\text{m}$)
→ Avoid frustrated endocytosis



- Human primary fibroblasts (HPFM 168)

Toxicological studies

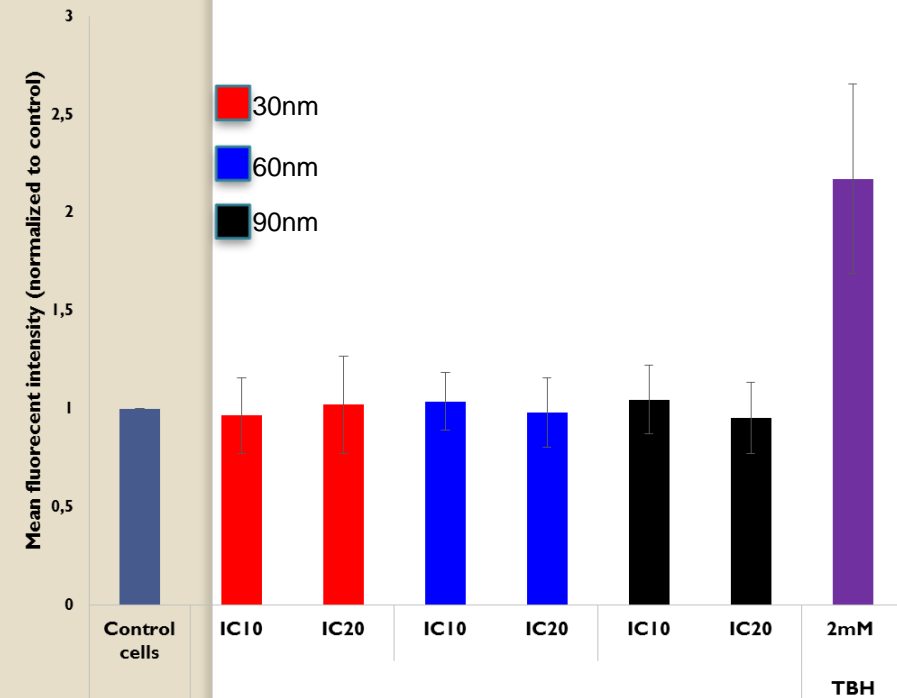
- Cytotoxicity



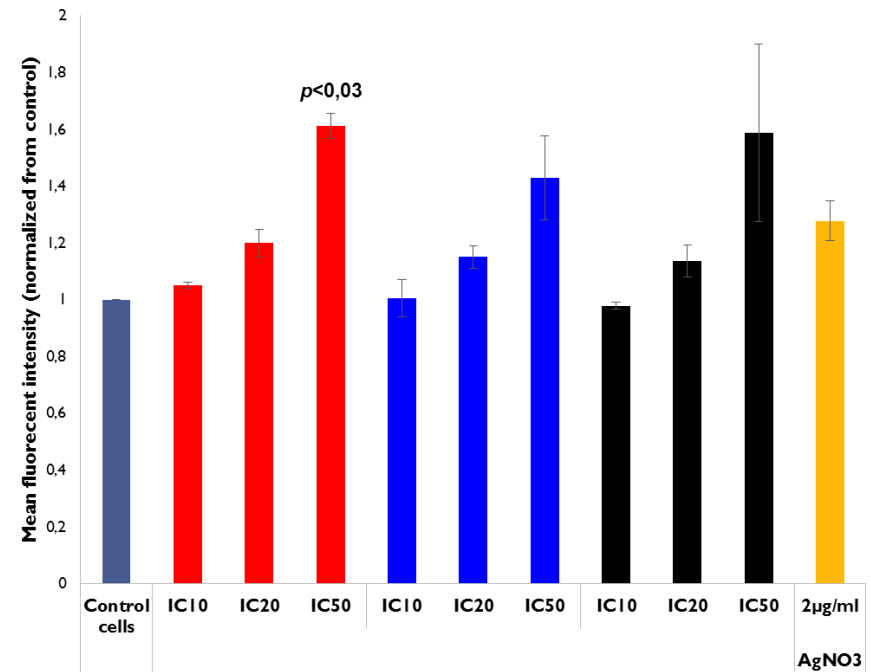
→ Thick and medium AgNWs seem 30x more toxic than thinner one

Toxicological studies

- Reactive oxygen species (ROS)



- Caspase 3 activation



→ Slight effect on ROS induction and apoptosis after 24h

Conclusion

- Successful control of the morphology of AgNWs
 - Effect of Mw of PVP and co-nucleant
 - Tuning of both diameter (30-200nm)
and length (3-30 μ m)
- Very first toxicological assays :
 - Toxicity decreases with diameter
 - ROS induction are not the main path of toxicity



Outlook

- Check ROS induction earlier ($\approx 2h$)
- Look for other toxicity pathways
- Electrodes properties
- Integration into devices





Thank you for your attention

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