Radiolabelling of silver and titania nanoparticles as a tool for sensitive detection of nanoparticle release from surface coatings

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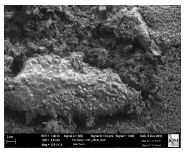
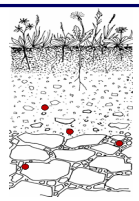
Motivation

NPs in surface coatings

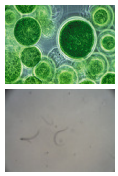
Aging/ abrasion



NPs release



Environmental fate and transport of NPs



NPs impact on aquatic organisms

Radiolabelling for sensitive detection

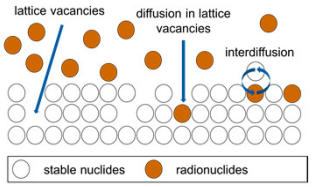
→ **Radiolabelling for detection of NPs in complex media – even at low concentrations** ←

Radiolabelling of engineered nanoparticles

Isotopic radiolabelling of commercial TiO_2 and Ag^0 nanopowder

Labelling method:
→Diffusion of radionuclides into NPs via low temperature annealing

Materials:
→Ag^0 (Sigma-Aldrich, d_p < 100 nm)
→TiO_2 (AEROXIDE® P25, Evonik Degussa, d_p= 21 nm)



Commercial radionuclides:
→ ^{44}Ti ($T_{½}$ = 63 a)
→^{110m}Ag ($T_{½}$ = 249.9 d)

Production with a cyclotron:
→ ^{45}Ti ($T_{½}$ = 185 min)
→ ^{105}Ag ($T_{½}$ = 41 d)

Solid state target system Nirta Solid Compact

Target disk:
Body: Al Ø 24 mm
Target: Sc Ø 12 mm

Radiolabelling yield for Ag^0: > 99 %
→ (0.2 – 1000) kBq $^{110m}Ag^+$/mg Ag^0 NPs
→ Low temperature annealing
T = 50°C – 105°C, t = 3 h

Radiolabelling yield for TiO_2: > 99 %
→ (0.2 – 10) kBq $^{44}Ti^+$/mg TiO_2 NPs
→ Low temperature annealing
T = 180°C, t = 2 h

→ Up to 140 MBq $^{45}Ti^+$/mg TiO_2 NPs
→ Low temperature annealing
T = 180°C, t = 2 h

Specific activities and limits of detection

[^{110m}Ag]Ag^0	1	MBq/mg	→ 125 ng/L
[^{44}Ti]TiO_2	0.01	MBq/mg (costly nuclide!)	→ 7.500 ng/L
[^{45}Ti]TiO_2	140	MBq/mg	→ 0.5 ng/L

Proton activation of TiO_2 and Ag^0 nanopowder using a cyclotron

Ag^0-NP
→ $^{107}Ag(p,3n)^{105}Cd \rightarrow ^{105}Ag$
→ $^{107}Ag(p,p2n)^{105}Ag$
^{105}Ag: $t_{1/2}$ = 41.29 d / β^+ 100 %

Specific activities and limits of detection
[^{105}Ag]Ag^0 69 kBq/mg → 1.8 µg/L

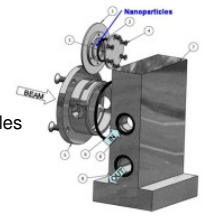
Scanditronix MC40, JRC

TiO_2-NP
→ $^{48}Ti(p,n)^{48}V$

^{48}V: $t_{1/2}$ = 15.97 d / β^+ 100 %

[^{48}V]TiO_2 36 MBq/mg → 2 ng/L

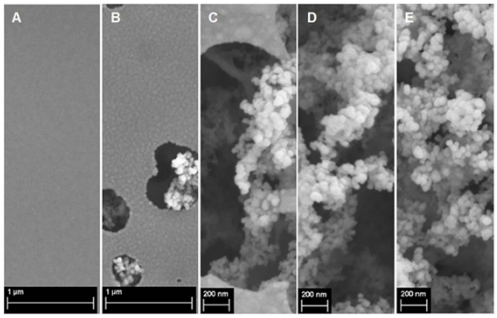
Target system for irradiation of nanopowder samples



Target holder with activated TiO_2 NPs

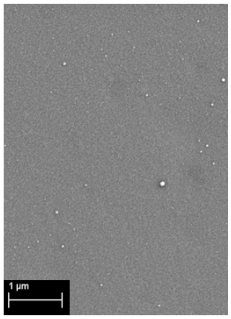
Application of radiolabelled NPs for release studies

labile surface coating → NP release is visible

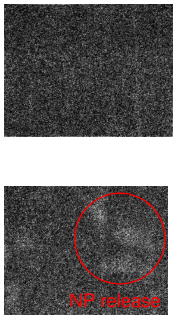


Time-dependent degradation of a polyacrylate TiO_2 nanocomposite by UV-A-irradiation (intensity ~ 15 mW/cm²) ;A) original, B) after 2 days (50.000x); C) 4 days, D) 8 days, E) 16 days (75.000x); SEM micrographs: Leibniz Institute for Surface Modification.

stable surface coating



autoradiography



Degradation of a **stable** TiO_2 nanocomposite by UV-A-irradiation for 10 days (25.000x).

No visible NP release, but ~ 4 % of the applied TiO_2 is released and was only detected by measuring radioactivity!

References

Isotopic radiolabelling of Ag^0-NPs

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Proton activation of TiO_2-NPs

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