



nZVI: Design, Performance and Application Possibilities – New Iron based nanoparticles for nanoremediation

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NanoRem Final Conference

**Nanoremediation for Soil and Groundwater Clean-up
- Possibilities and Future Trends**



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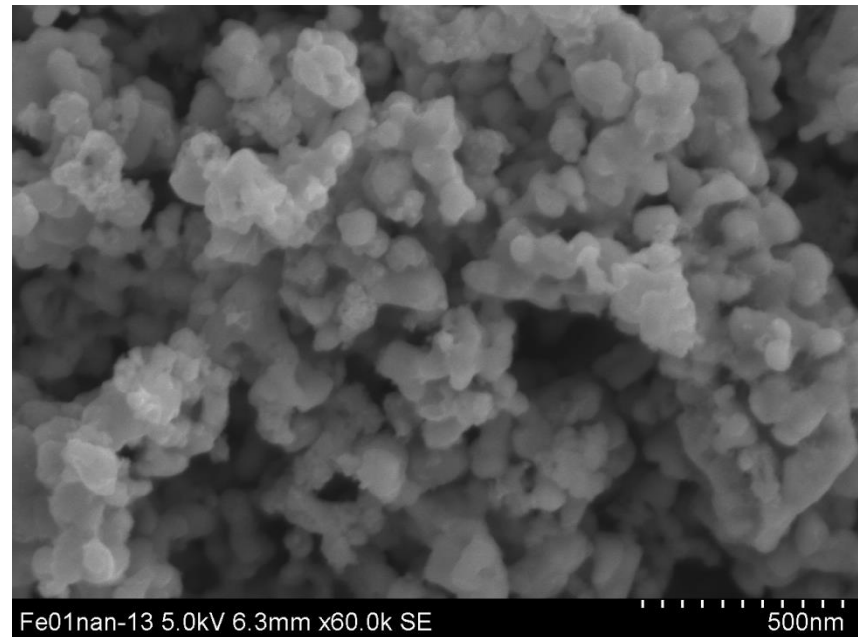
Frankfurt am Main, 21st November 2016





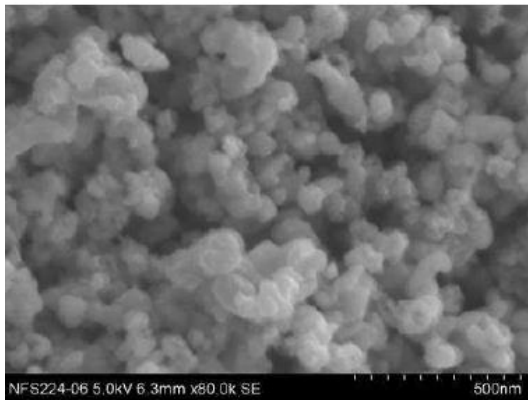
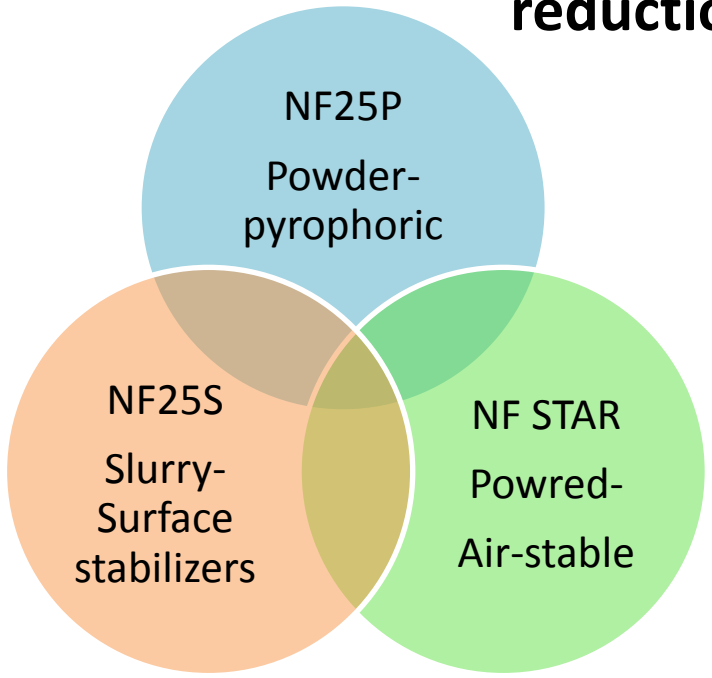
Objective

- Various types of NP available (industrial x labor. quantity)
- Optimized for
 - Reactivity
 - Migration
 - Storage
 - Transport
 - Longevity

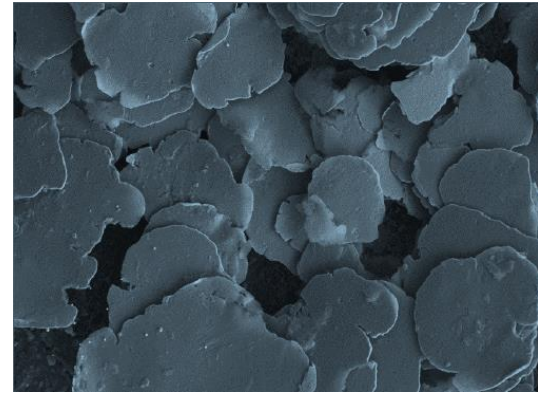
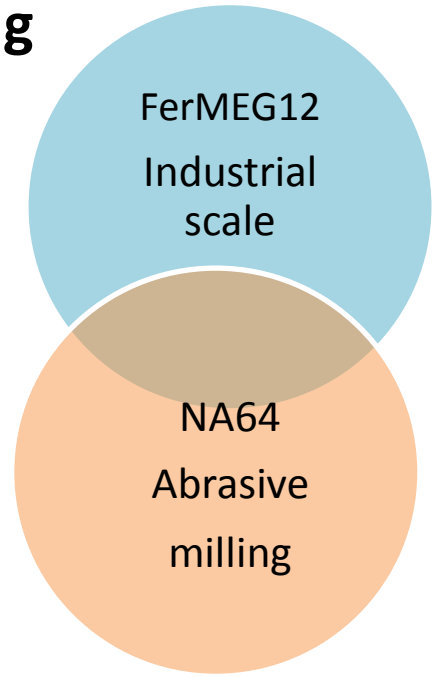




reduction



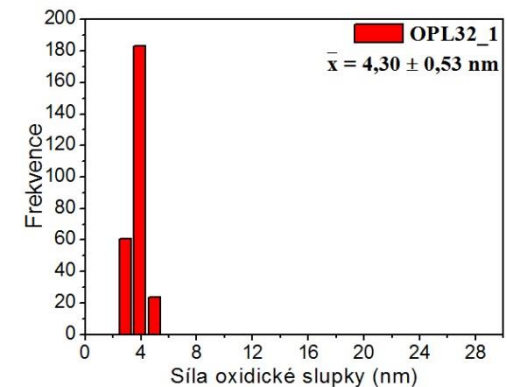
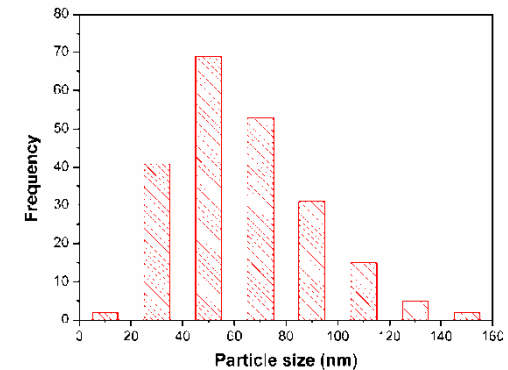
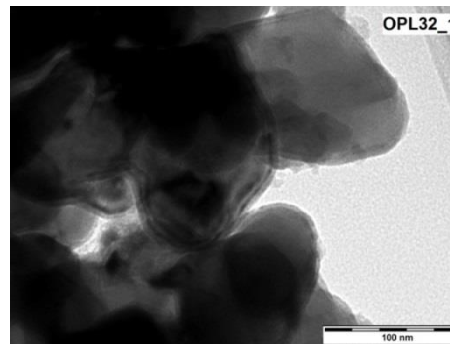
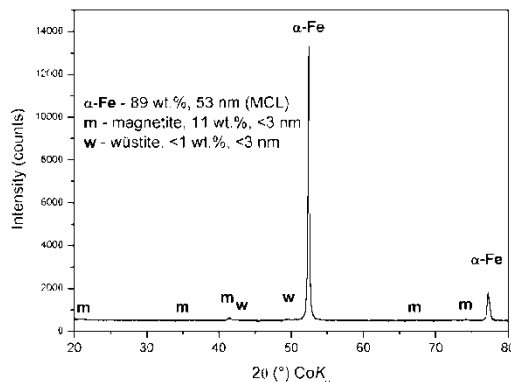
milling





NF STAR – dry NP powder

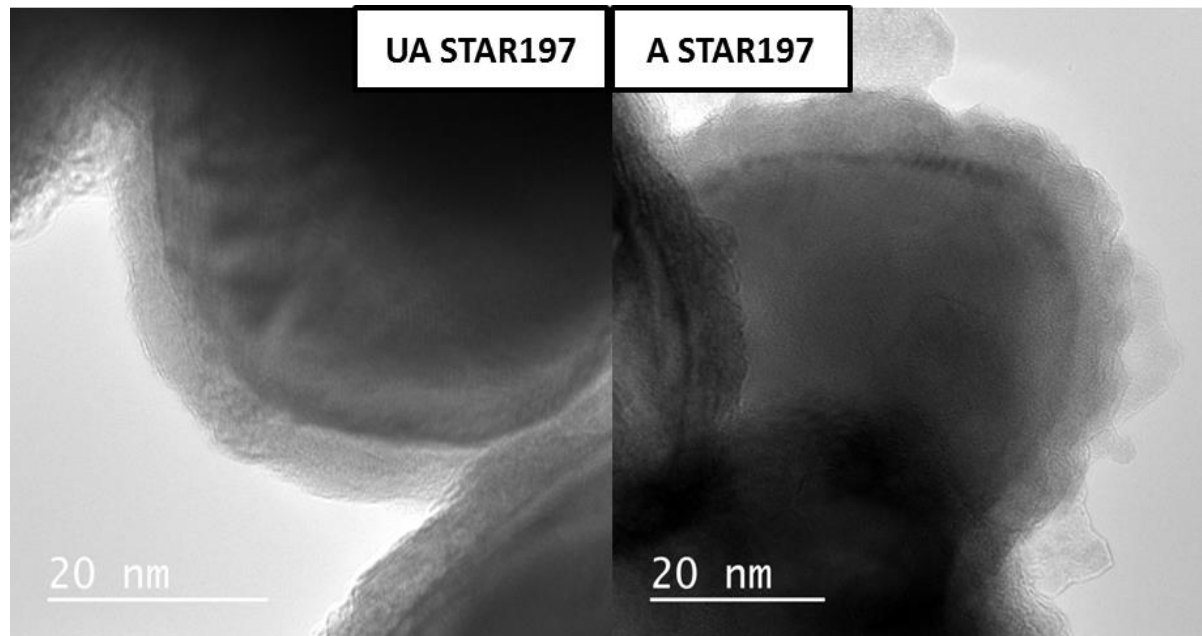
- NANO FER STAR – dry NP powder produced by solid-state thermal reduction of Fe-oxide
- Tiny oxidic layer for NP protection
- Good stability, transpotability
- Sufficient reactivity (activation)
- Mobility (surface modifications)





Activation process

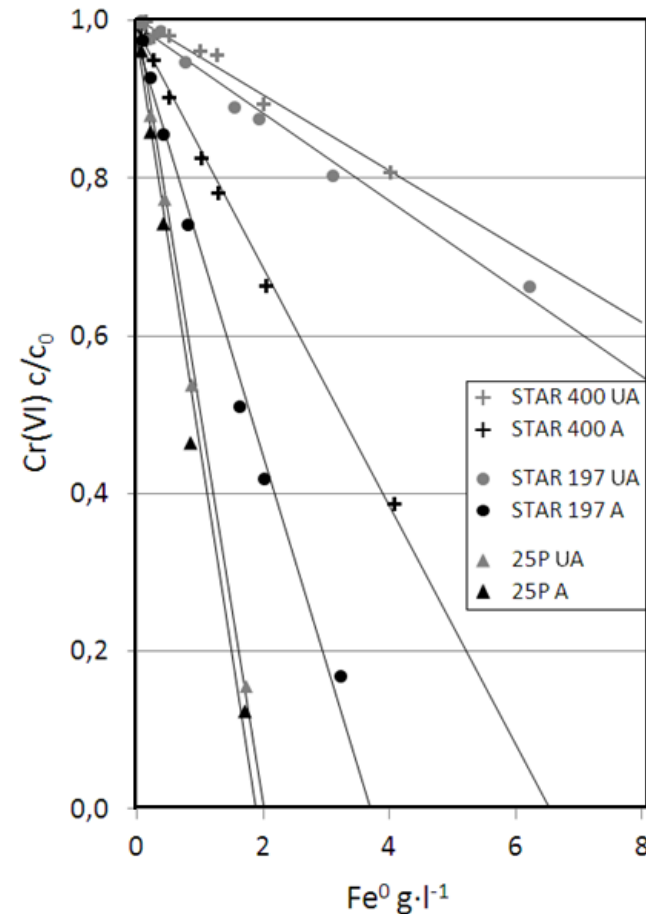
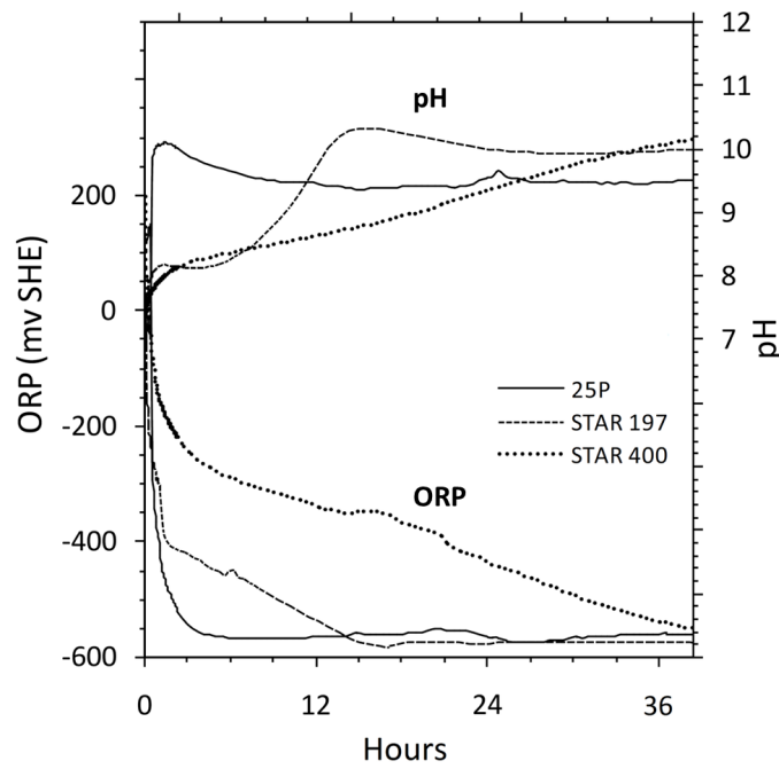
- Dense slurry (200g Fe/l)
- 48h activation → degradation of oxide shell





Activation process

- pH and ORP evolution





Milling process

Major advantage:

- Lower cost
- Non-aqueous environm.
- Good reactivity

Drawback:

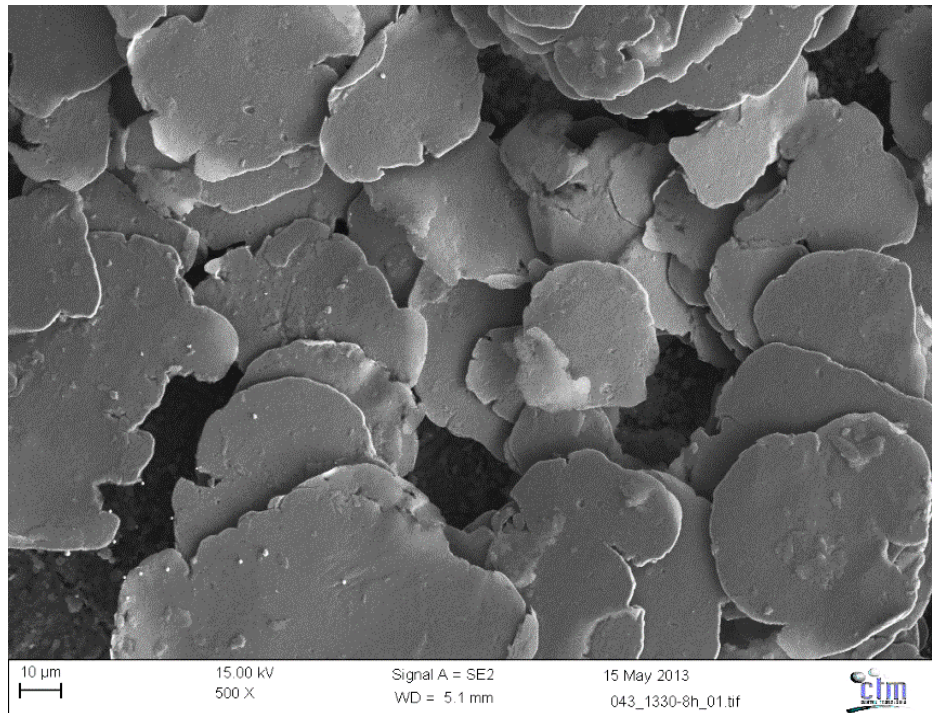
- Bigger particles
- Non-round particles
- Oxidized particles
- MEG needed





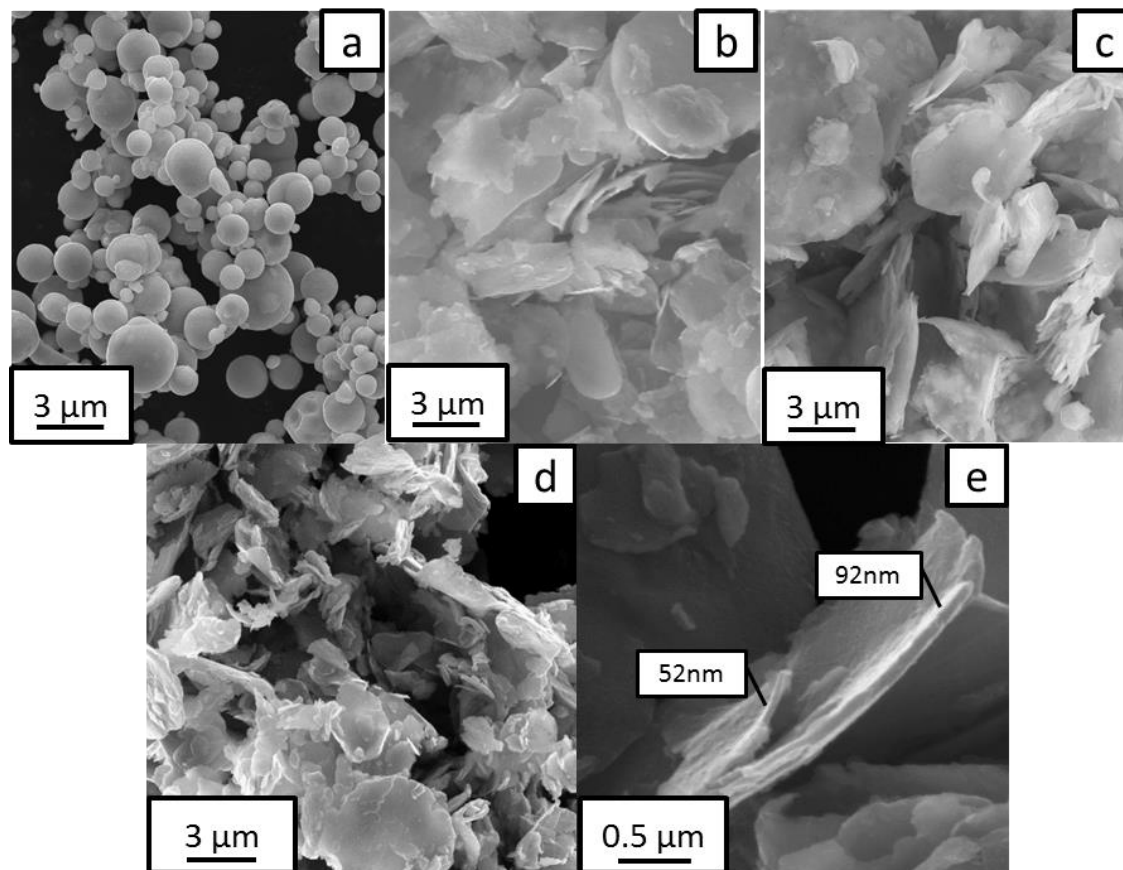
ZVI milling from micro scale

- Preparation of “nano” ZVI particles
- Water or ethanol → flakes (< 100 nm thickness)





ZVI milling from micro scale

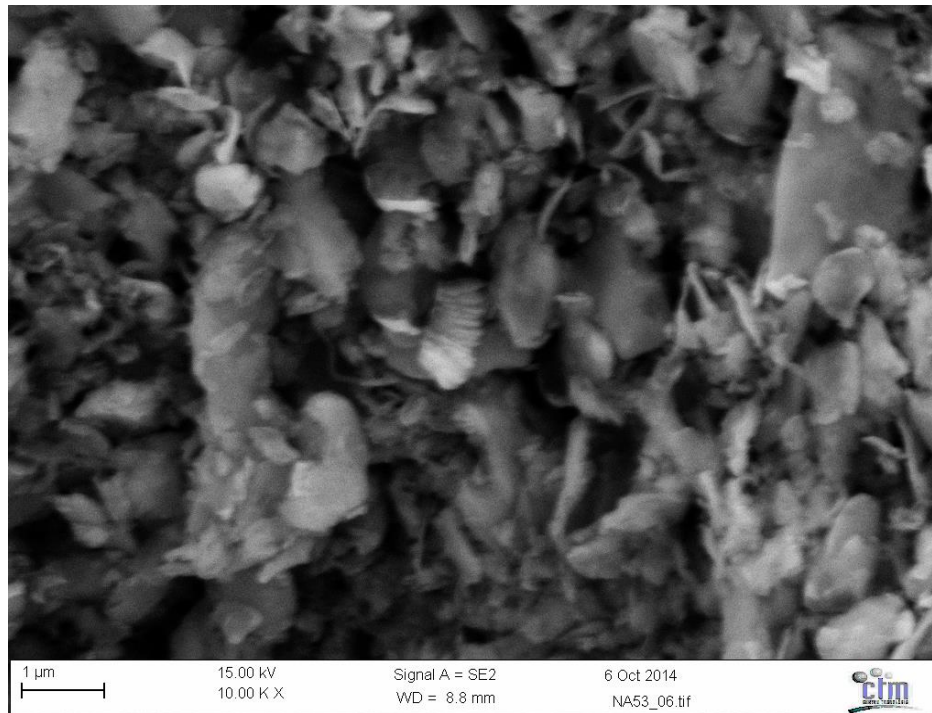


SEM images of the milled particles without alumina. a) Initial iron powder, b) after 24 h, c) after 48 h, d) after 96 h and e) detail of one flake of a 48 h milled iron particle.



ZVI milling with alumina

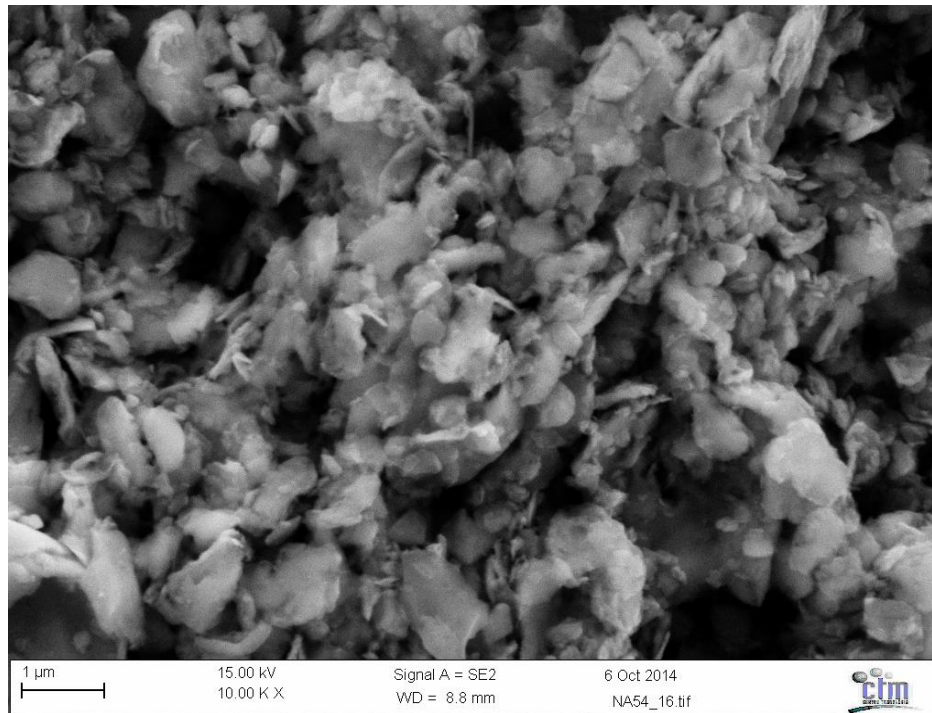
- Preparation of “nano” ZVI particles
- MEG solution (1 g **alumina**)





ZVI milling with alumina

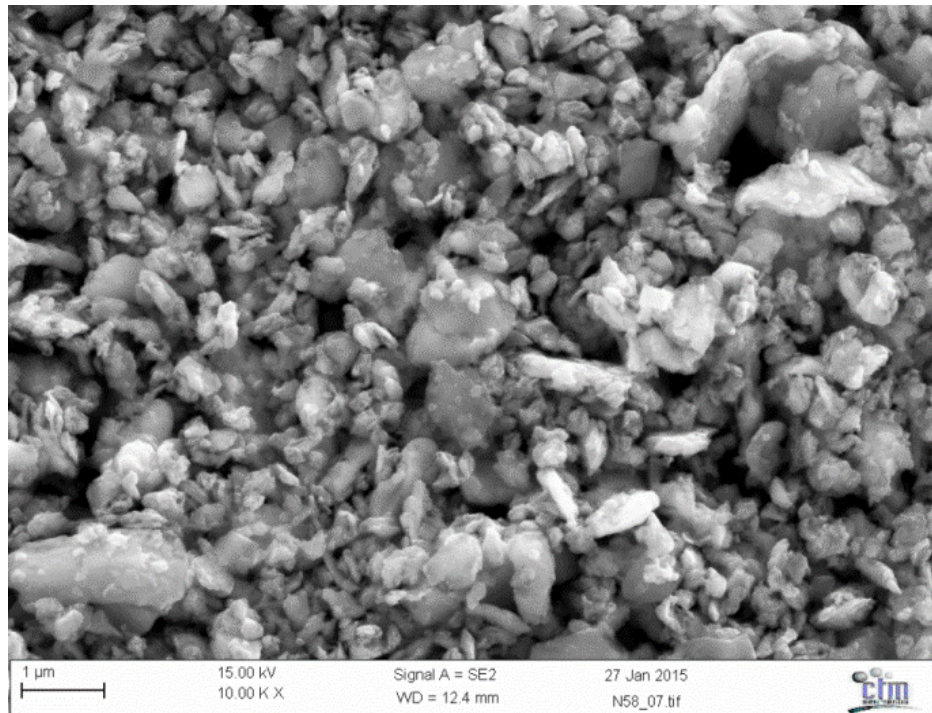
- Preparation of “nano” ZVI particles
- MEG solution (3 g alumina)





ZVI milling with alumina

- Preparation of “nano” ZVI particles
- MEG solution (10 g alumina)



400 nm (med)
Size < 1 µm
(70% volume)

Spherical NP

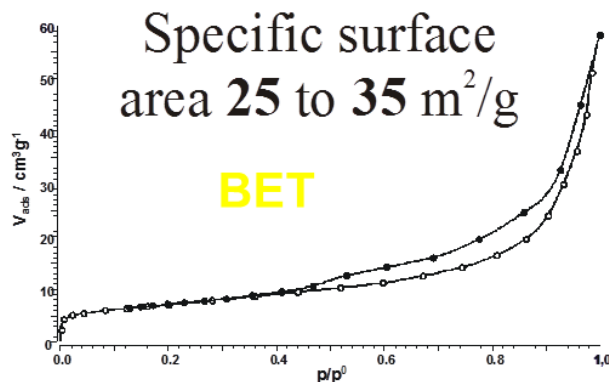
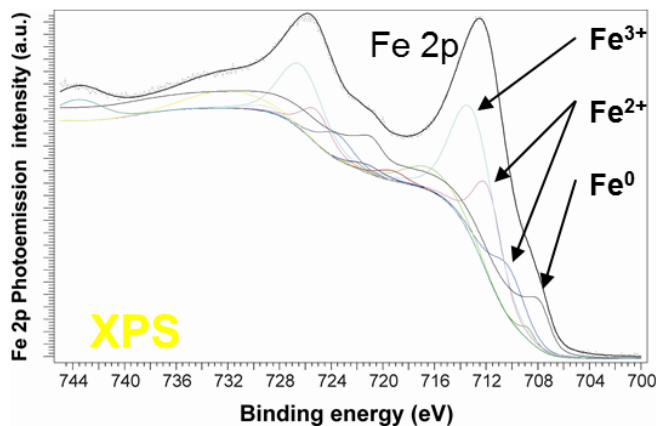
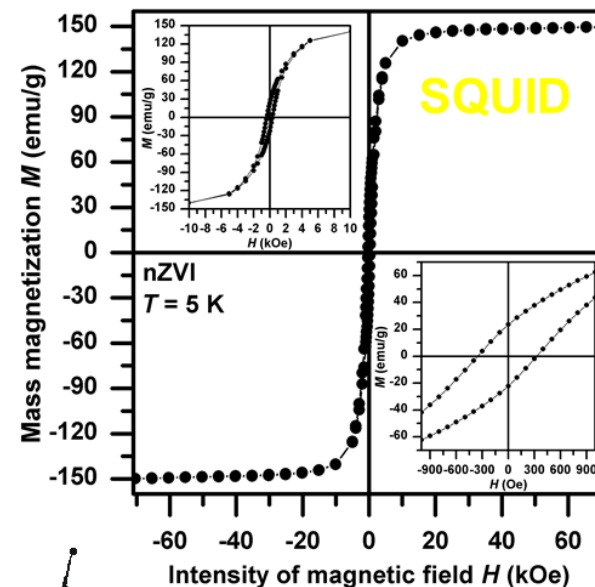
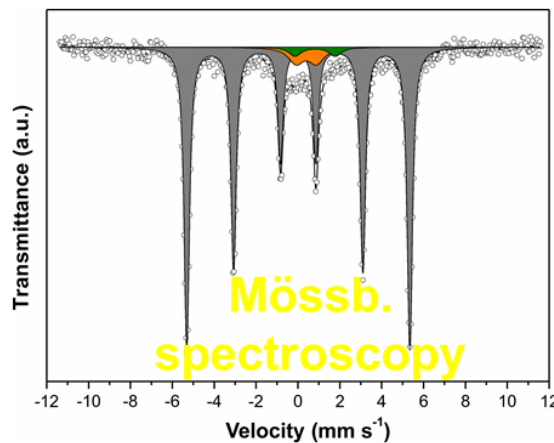
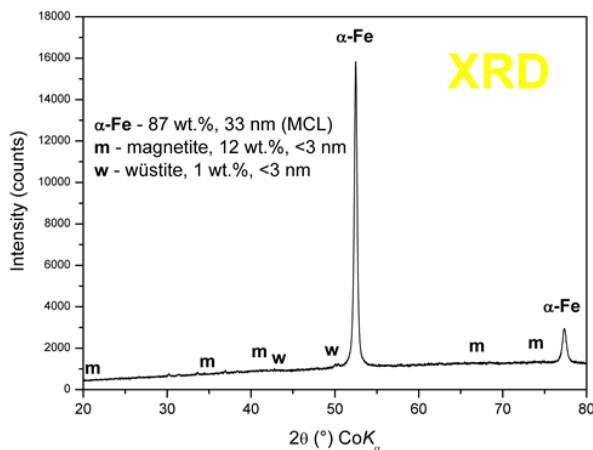


nZVI characterization

- Structural characteristics:
 - zeta-potential,
 - BET,
 - TEM & SEM, XRD & Mössbauer,
 - Size distribution: DLS & DSC,...
- Reactivity tests:
 - Water (production of H_2 and OH^-)
 - Selected contaminants (spiked in water)
 - Contaminated water
- Mobility tests
 - 1-D simple tests for comparison
 - Complex 1-D tests
 - 2-D and 3-D tests



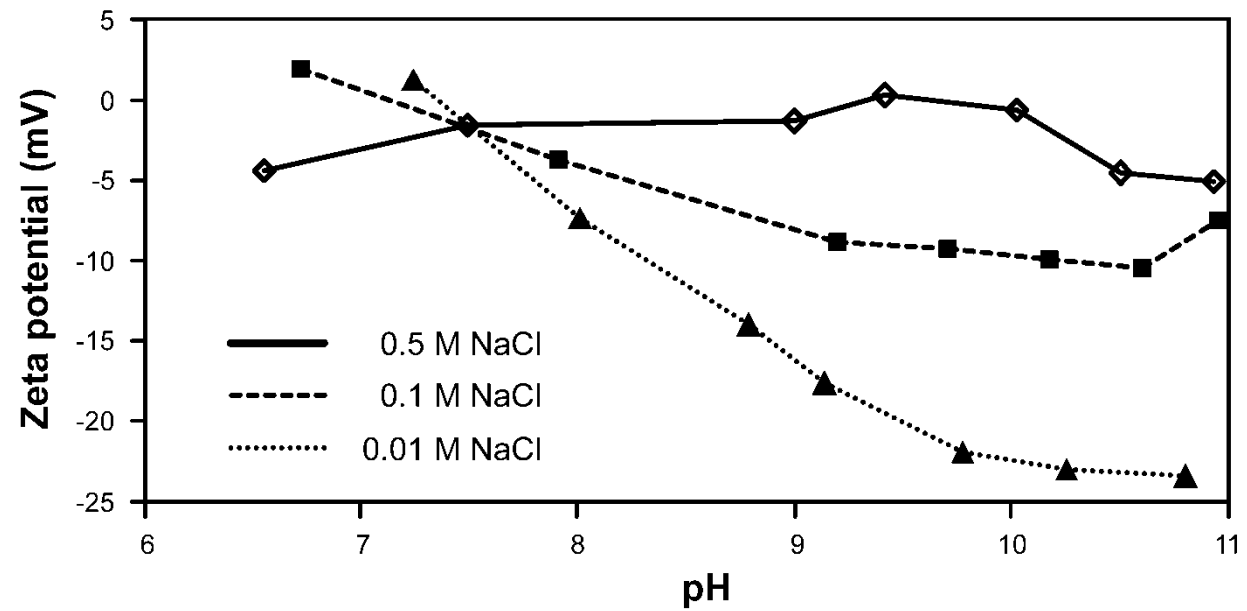
nZVI characterization





Zeta-potential

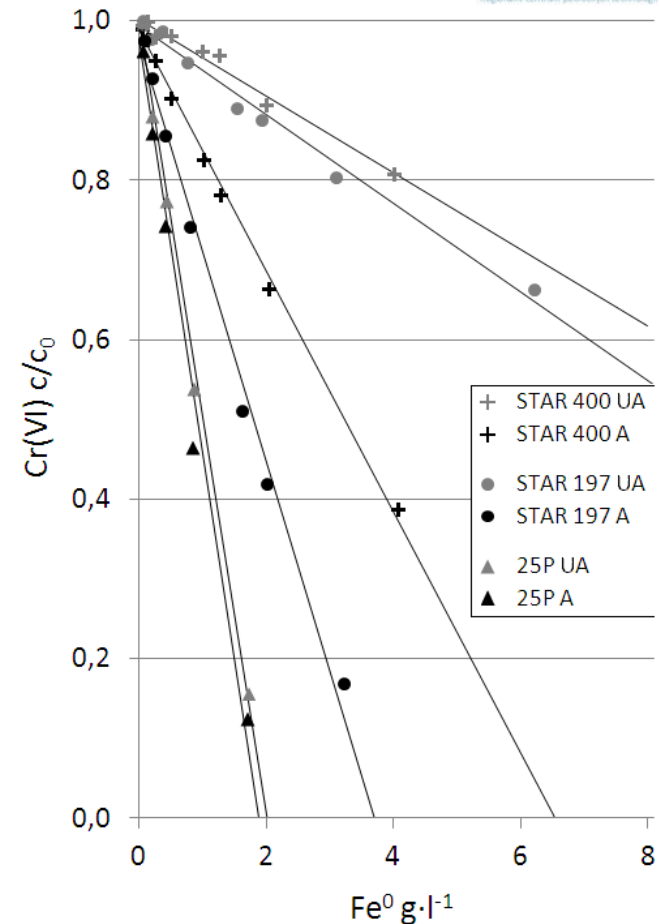
- Addition of NaOH \rightarrow pH increase
- Point of zero-charge
- Important: sign (-) and size (> 20 mV) at gw pH





Reaction with Cr(VI)

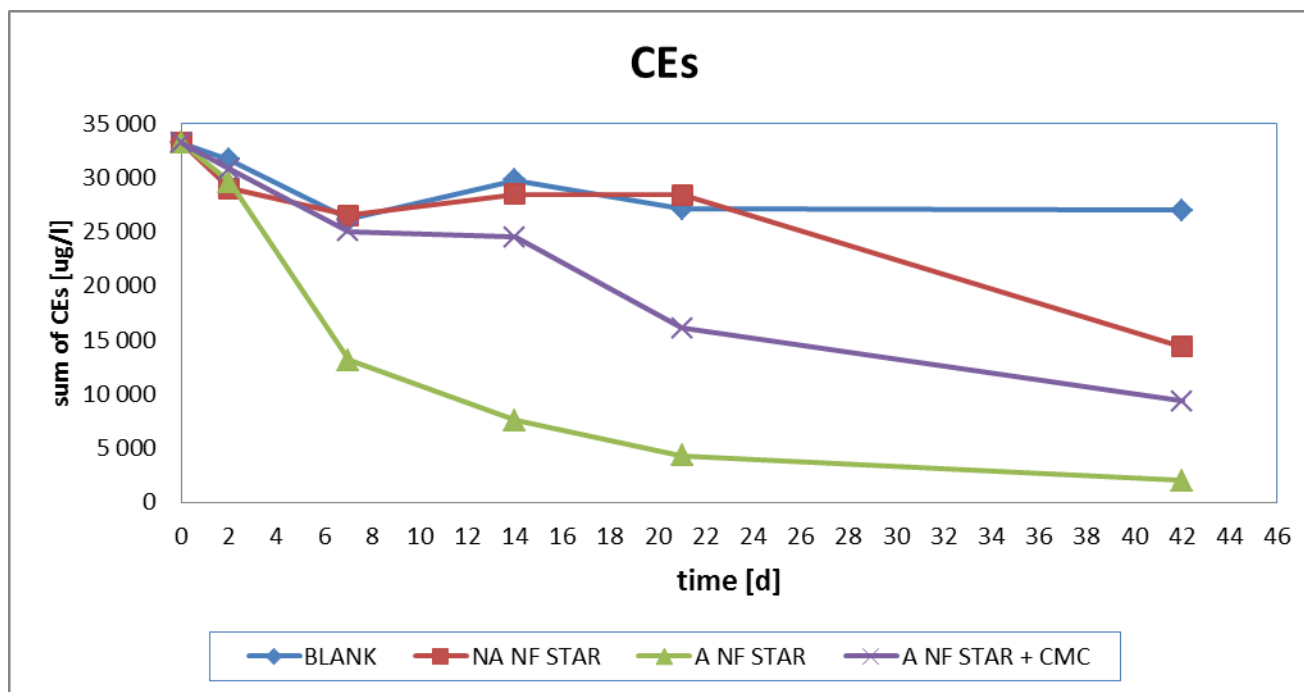
- Comparison of activated and non-activated STARs
- 3 different thickness of oxide layer
- STAR 197 large difference after activation





Reactivity with CE

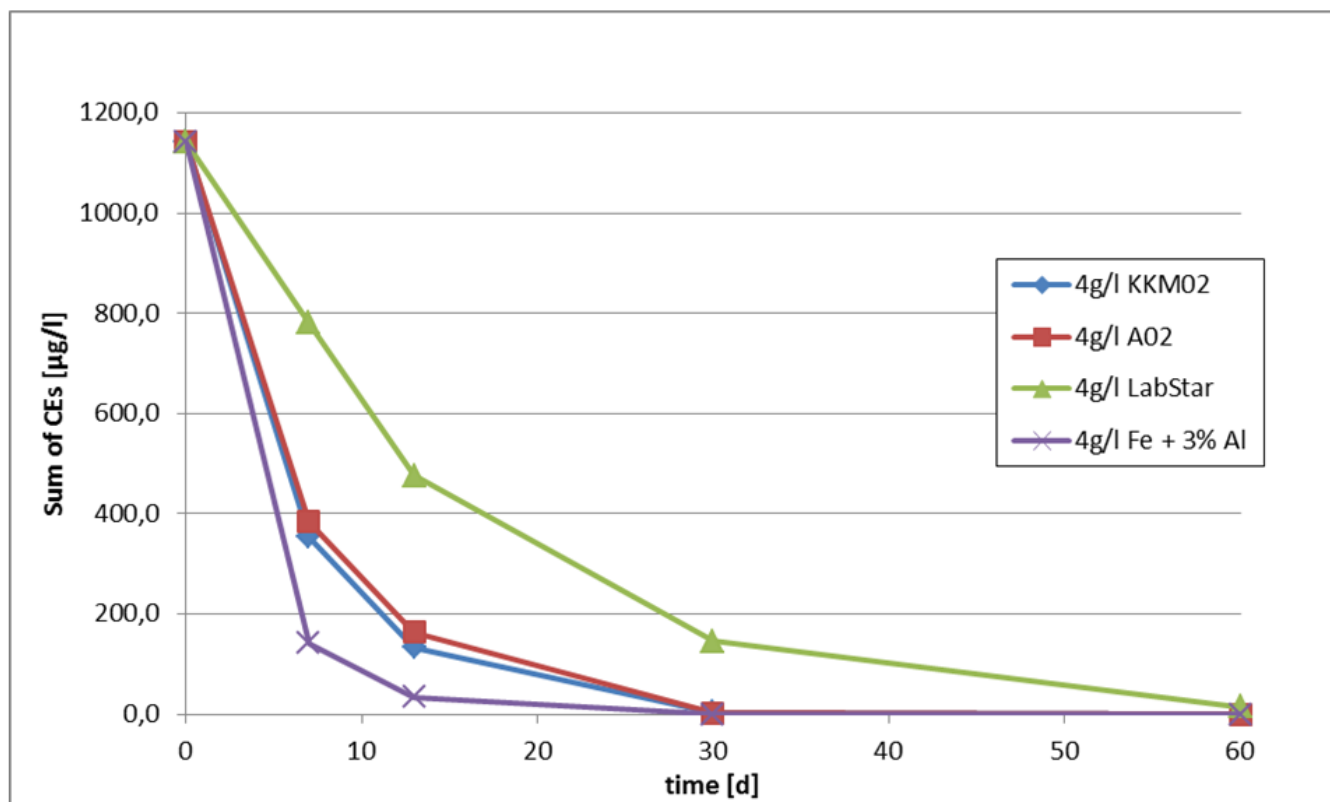
- Surface modification of NF STAR





Reactivity with CE

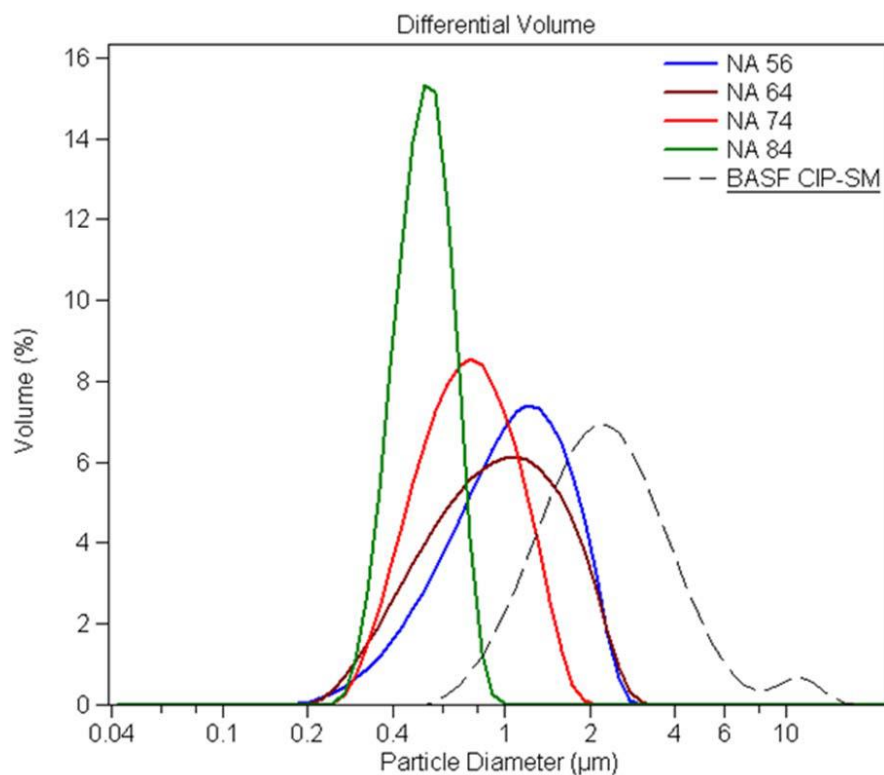
- Milled with alumina (3%) compare to industrial NP





Size distribution

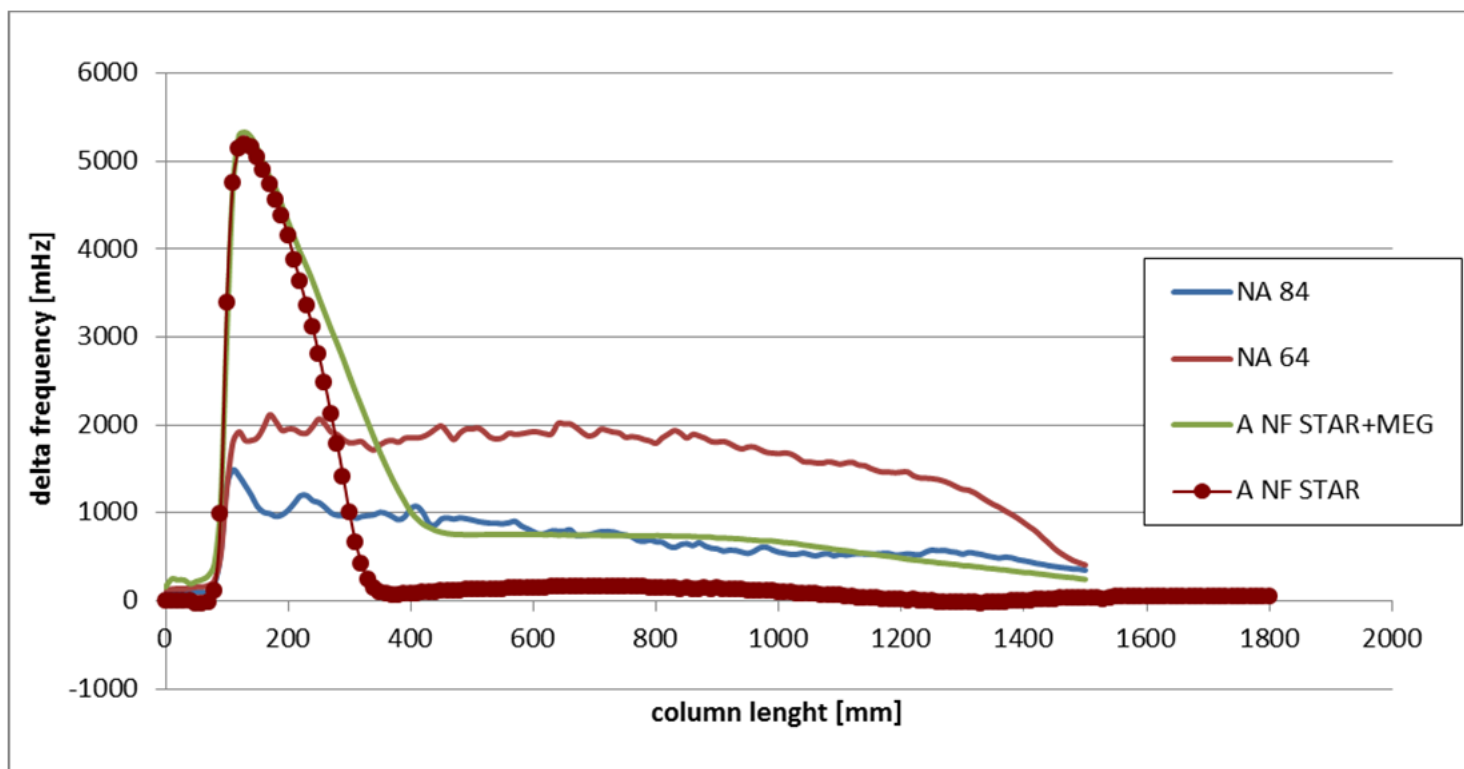
- Different time of milling





Migration

- Comparison milled/alumina x STAR





Conclusions WP2

- Water slurry NF 25S available in large quantity
- Dry NF STAR available in large quantity
- Used for pilot experiments
- Used on other sites in full scale (CZ)

- Milled FerMEG12 available in large quantity
- Milled with alumina up-scaling in progress

- Future of nZVI: chemical modification (S, etc.)



Thank you for your attention



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