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Manual for preparation of an aqueous suspension from dry stabilized iron powder NANOFER STAR

NANOFER STAR is dry air-stable nZVI powder, where the surface of iron nanoparticles is stabilized by a thin layer of iron oxide, which prevents immediate oxidation in contact with atmospheric oxygen. Please be informed that produced nanoparticles are in form of clusters and agglomerates (see SEM image bellow), therefore it is necessary to "activate" the nanoparticles by preparation of aqueous suspension (slurry) from this powder.

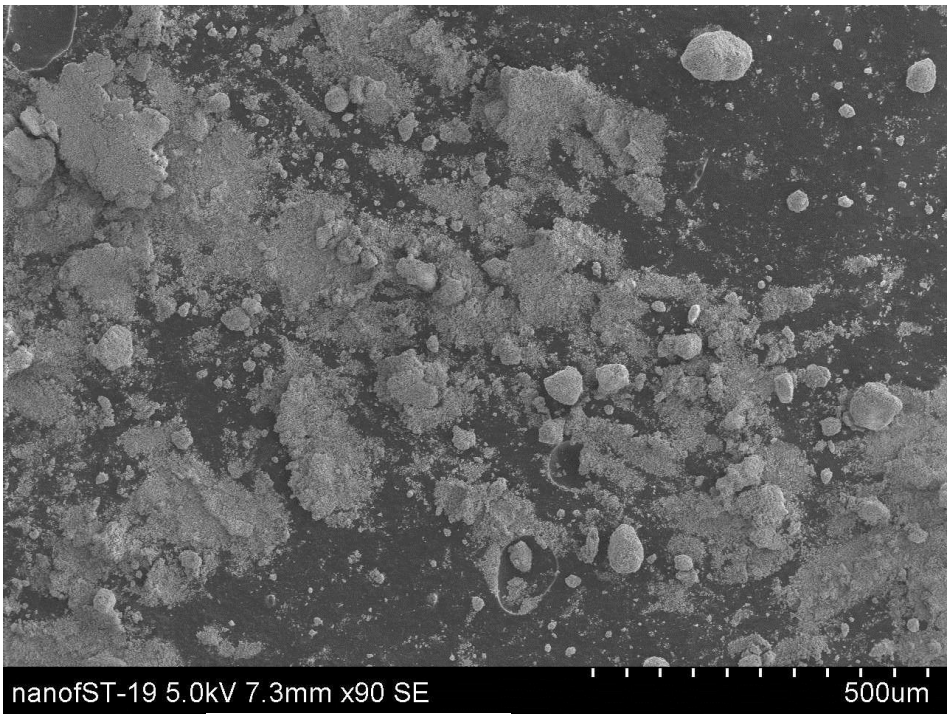

Figure 1: Scanning electron microscope (SEM) image of NANOFER STAR.

1. Basic characteristic of the product

Chemical name	Fe^0 concentration / range	Iron oxide content	Warning symbol to Fe^0	ES number (EINECS, ELINCS)	CAS number	R-phrases
iron and iron oxides (mixture)	**≥ 65-80%**	**35-20 %**	**F**	**231-096-4 215-721-8**	**7439-89-6 1345-25-1**	**10**

1.1. Properties of NANOFER STAR powder

The product is dangerous classified (UN 3089, class 4.1). R-phase: 11

1.2. Notice

NANOFER STAR is classified as a **flammable**, it become pyrophoric at temperatures above 60 °C or during extensive friction of the powder causing elevated temperatures. **DO NOT HEAT THE POWDER AND DO NOT MIX IT DRY IN PRESENCE OF OXYGEN** (dry mixing is possible only under inert atmosphere).

1.3. Storage

Please store the product in a cool and dry environment in closed packaging. Avoid contact with water and excessive heat. Store in the original packaging.

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2. Preparation of slurry from NANOFER STAR

2.1. Concentration dose

Minimum amount of dry powder	Maximum amount of distilled water or other liquid
20%	80%

2.2. Mixing method (dispersing) and recommended equipment

Prepare 20% aqueous suspension: mix 1 part of the product in 4 parts of demineralized water using one of following methods.

NOTICE: It has been found that NANOFER STAR powder applied directly into a liquid without dispersing or dispersed in lower ratio than recommended may result in low decontamination rate, poor migration etc. so it does not have to provide expected results. **THE METHOD OF HOMOGENIZATION HAS SIGNIFICANT INFLUENCE ON FINAL PERFORMANCE OF THE PRODUCT IN WATER.**

DISPERSING OF SAMPLES IN LABORATORY (up to 2kg uf slurry in one batch)	**Laboratory dispersing unit LD 05** is designed for direct manufacturing of aqueous suspension from any dry powder. The equipment provides manufacturing capacity of 500 grams of slurry in one batch. This unit is equipped with vacuum pump and can work under protective atmosphere, it is also possible to connect cooling or heating liquid to the mixing reactor.	
	Use any type of **high-shear mixer** (e.g. IKA Ultra Turrax or similar). It is recommended to perform mixing in closed bottle to minimize access of fresh air to the slurry during mixing. Recommended mixing time: 10minutes/100g of NANOFER STAR in 400ml of water	
	Use ordinary **kitchen blender**. It has been proved in our laboratory experiments that it is able to provide same result like mixing by professional high-shear mixer. Moreover it is equipped with a closing cover, which minimizes access of fresh air to the slurry during mixing. Use more powerful units with high RPM. Recommended mixing time: 10minutes/100g of NANOFER STAR in 400ml of water	

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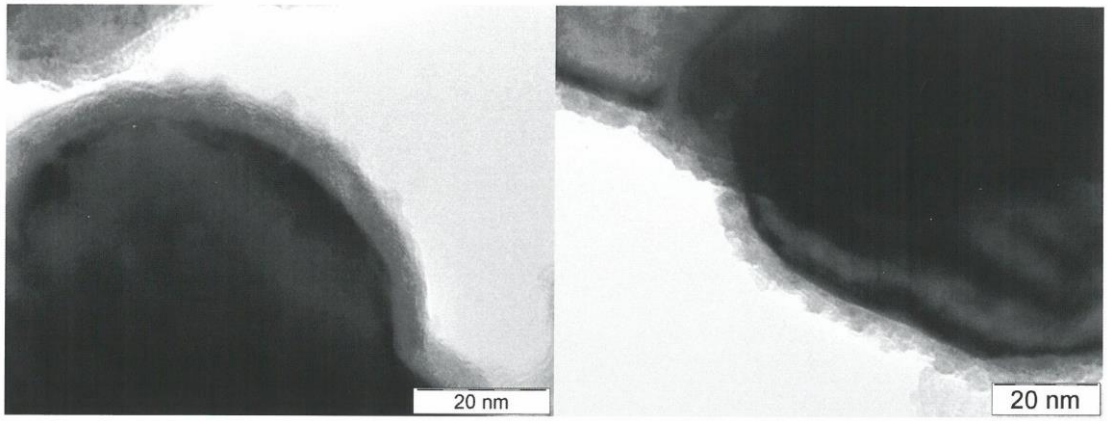
DISPERSING OF LARGE VOLUMES (field application)	Industrial dispersing units are available for purchase or rent. Batch capacity: 50-200kg slurry Processing time: approx. 100kg of slurry in 20minutes Dispersing unit can be optionally equipped with a frequency controller to adjust the speed of mixer, smaller unit can be then powered also from one phase power network (3 phases are required for larger units)	

3. Processing and storage of prepared slurry

NANOFER STAR product becomes very reactive in water environment, hydrogen gas is produced during reaction of the product with water and Fe(0) nanoparticles are transformed to iron oxides and hydroxides. Therefore it is necessary to process the slurry as soon as possible. If you need to store the slurry please place it into refrigerator (recommended temperature is 2-4°C) in closed plastic bottles (PET bottles in standing position are recommended). **DO NOT USE GLASS BOTTLES, increasing hydrogen pressure can result in breakage!**

OUR LATEST EXPERIMENTS SHOWED THAT THE HIGHEST REACTIVITY OF SUSPENSION WAS RECORDED THE SECOND DAY AFTER ITS MANUFACTURE, THEREFORE WE RECOMMEND TO LEAVE THE FRESH-MADE SUSPENSION 48 HOURS TO REST ("ACTIVATE") AT AMBIENT TEMPERATURE AND APPLY IT SECOND DAY AFTER THE PREPARATION.

TEM image of the compact Fe-oxide layer on the left (fresh NANOFER STAR) and eroded layer on the right (20% of NANOFER STAR in 80% of water after 48hours)



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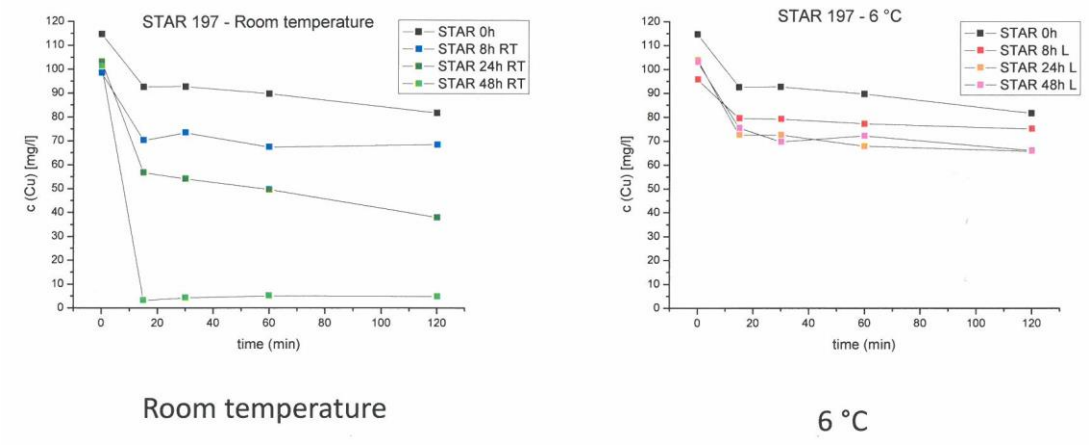
Reactivity of NANOFER STAR (Cu2+ removal) depending on the age of stock dispersion stored at various conditions:

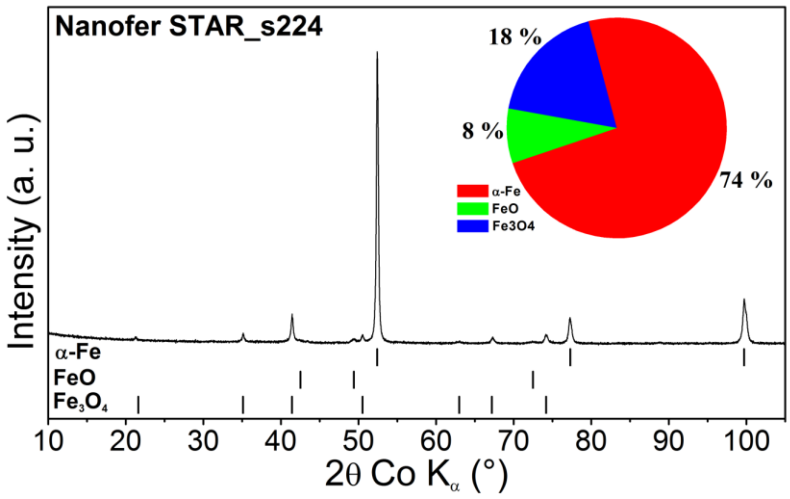


The ageing process of the water slurry is dependent on temperature, presence of oxygen, frequency of bottle opening and the kinetic can also vary among different batches (depending on amount of nZVI and shell thickness).

4. Particle characteristics (sample batch no.224)

Phase analysis (batch 224)

Phase	Phase content (wt. %)	MCL (nm)	Cell parameter (nm)
α-Fe	74	46	0.2887
FeO	8	17	0.4287
Fe_3O_4	18	42	0.8394



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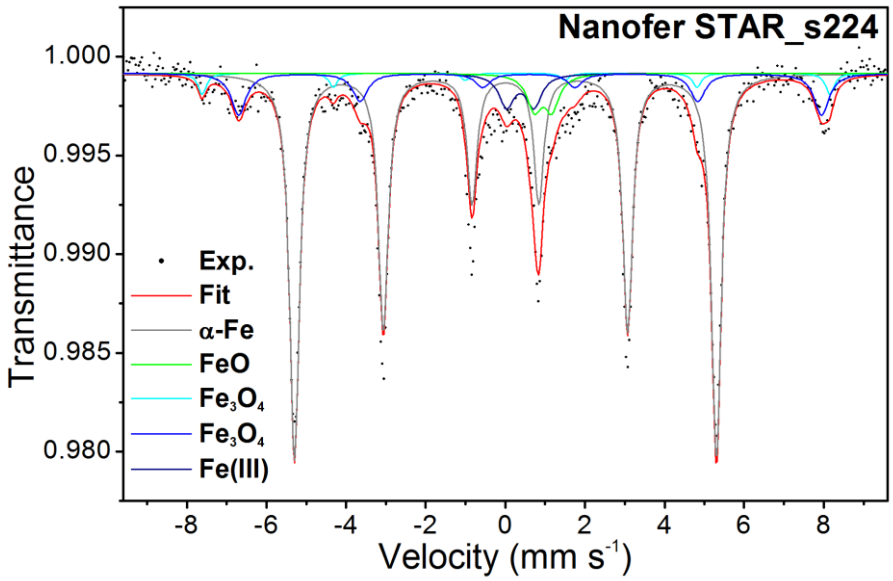
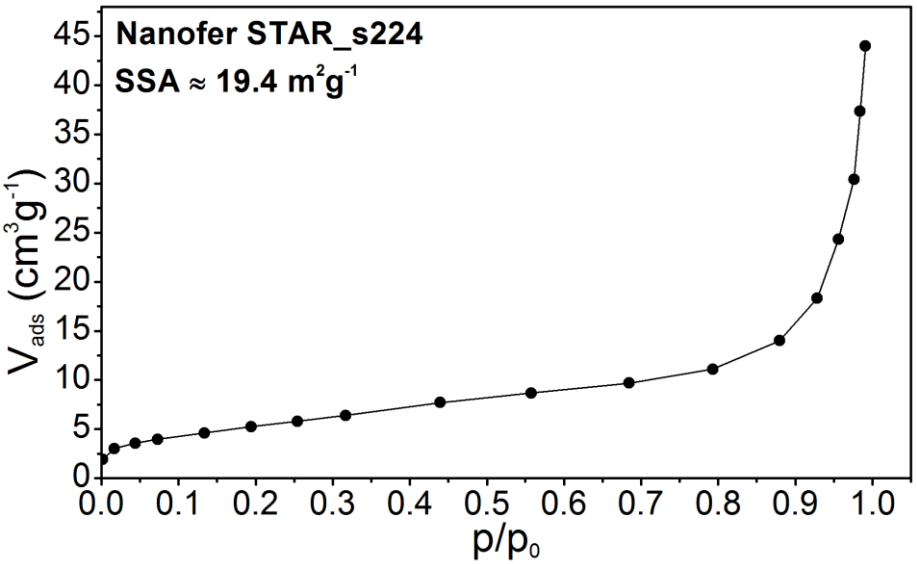
Mössbauer spectroscopy (batch 224)



Comp.	δ±0.01 (mm/s)	ΔE_Q±0.01 (mm/s)	B_{hf}±0.3 (T)	Γ±0.01 (mm/s)	RA (%)	assignment
sextet 1	0.00	0.00	32.9	0.30	74	α-Fe
sextet 2	0.26	0.02	49.0	0.26	4	$^{Tet}Fe^{3+}$ (Fe_3O_4)
sextet 3	0.61	0.03	45.5	0.45	12	$^{Okt}Fe^{2.5+}$ (Fe_3O_4)
dublet 1	0.37	0.69	---	0.47	5	Fe^{3+} (Fe_3O_4)
dublet 2	0.95	0.44	---	0.44	5	Fe^{2+} (FeO)

BET analysis (batch 224)



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Microscopical analysis (batch 224)