Protocol	#2.1
Title	**BOMB coating ferrite MNPs with silica oxide**
Keywords	magnetic nanoparticles, SiO_2, magnetic separation, silica coating
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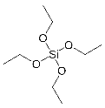
Summary

Here we provide a simple protocol for silica-coating of ferrite MNPs (BOMB protocol #1.1). The silica-coated magnetic beads are synthesised by a modified protocol including the hydrolysis of tetraethyl orthosilicate (TEOS) on the surface of ferrite magnetic core particles according to Stöber et al. 1968 [1].



TEOS - $Si(OC_2H_5)_4 + 2\ H_2O \rightarrow SiO_2 + 4\ C_2H_5OH$

Chemicals

Name	Provider	PN	MW [g/mol]	Safety codes	
Ethanol (C_2H_6O, 99.9 %)	Riedel-de Haën	34963	46.07	 Danger	H: 225-319 P: 210-280-305+351+338-308+313
Tetraethyl orthosilicate (≥99%) (GC)	Aldrich	86578	208.33	 Danger	H: 226+319+332+335
Ammonia solution (NH_4OH, 25%)	EMD Millipore	1.05432	n.a.	 Corrosive Danger	H: 290+314+335+400 P:273+280+301+330+331+305+351+338+308+310

Please consult appropriate MSDS information before working with these chemicals! Use lab coat, gloves and eye protection at all times! The chemicals are available from other providers as well. No preference is given to the indicated vendors.

Equipment and setup

Fume hood

Heated magnetic stirrer (e.g. IKAMAG REO)

Strong neodymium permanent magnet (e.g. NdFeB N45 40x40x20 mm)

Sterile plastic bottles

BOMB Silica-coating

Step	Task	Time	☑
⚠	*All procedures can be performed under inert N_2 atmosphere or standard conditions*		
1	Mix 45 ml of TEOS in 2 L ethanol in a large bottle (2.5 litre) using a magnetic stirrer and mix for 15 minutes at 300-400 rpm	15 min	☐
2	Add 22.5 g (wet mass ~1.2 g dry) of magnetic core particles prewashed with ethanol and stir for 15-30 min	30 min	☐
3	Add 400 ml of pure water and 50 ml of 25% ammonia solution and stir for another 30 min	30 min	☐
4	Switch on the heating and allow the solution to heat up to ~80 °C with constant stirring, allow the reaction to proceed for >4 h (ideally o/n)	4 hours to o/n	☐
5	Cool down the solution	15 min	
6	Separate the coated MNPs using a strong neodymium magnet		☐
7	Wash twice with pure water	15 min	☐☐
8	Wash twice with pure ethanol	15 min	☐☐
9	Wash with pure water until the pH of the solution becomes neutral (3-4 times)	30 min	☐☐
End	Check the yield by weighing the wet mass of the beads	**~12 h** (2 h hands-on)	
	Store @ RT for up to 1 year		

Modifications

By using different ratios of core particles and TEOS one can control the thickness of the glass layer and consequently the size of the particles. The standard ratio used in the above protocol is: 1 g of magnetic core particles, 2 ml TEOS, 20 ml of ethanol, 0.5 ml of 25 % ammonia solution, 4 ml of water, which results in particles with an average size of ~400 nm. Increasing or decreasing the TEOS to beads ratio results in formation of other sizes of coated particles.

Troubleshooting

Problem	Solution
Brown colour of the reaction, low yield of beads retained	• The uncoated magnetic core particles get slowly oxidized during storage, prepare fresh core particles and redo the reaction
Large amounts of white precipitate	• TEOS hydrolyses spontaneously in water solution, thus forming silica nanoparticles. Use fresh TEOS for the reaction

Exemplary results

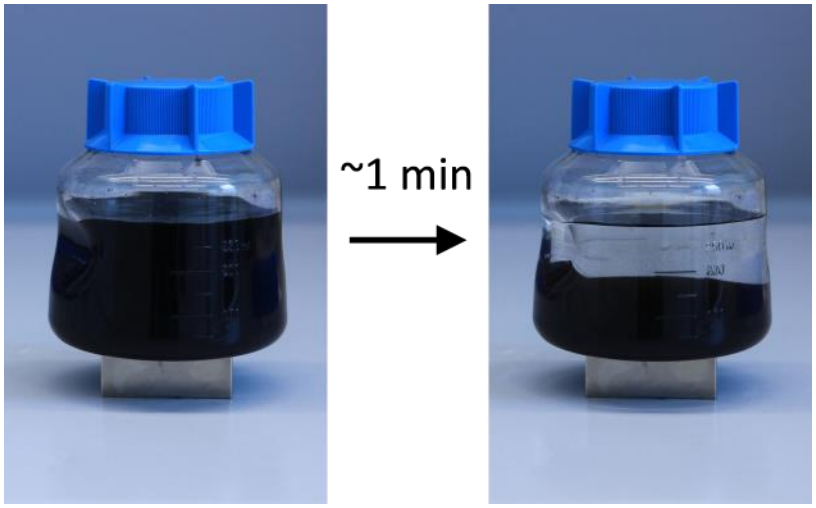


Fig 1: Silica coated MNPs. *Magnetic decantation happens within a minute. The water appears clear indicating no iron oxidation occurring during storage.*

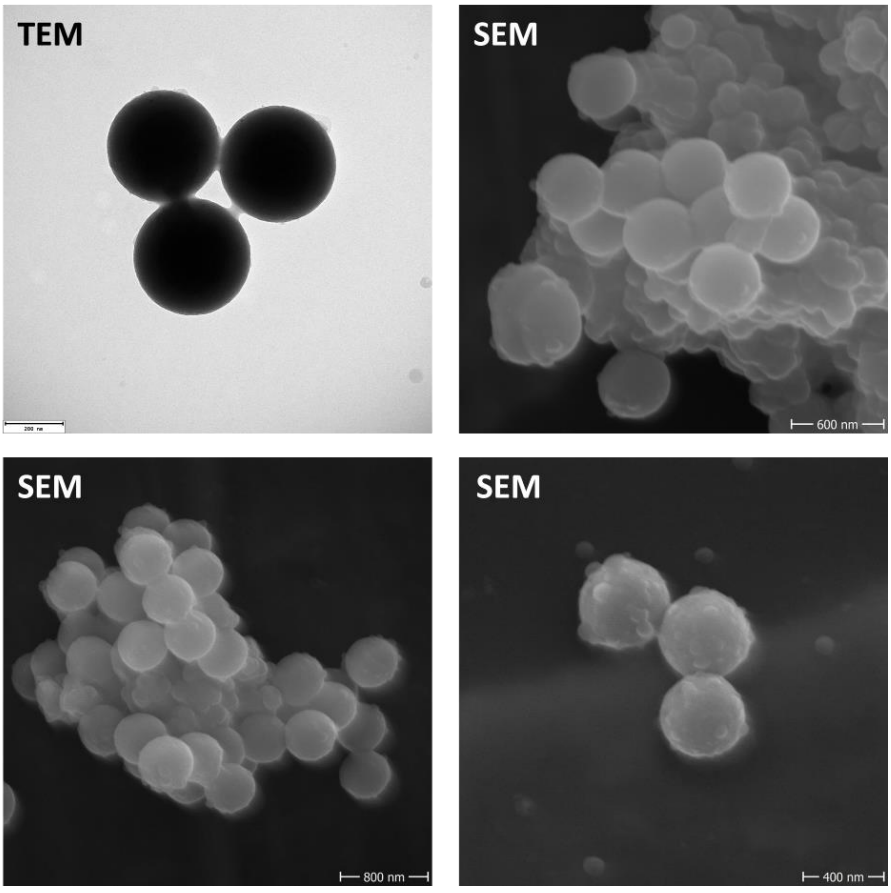


Fig 2:. Electron micrographs of silica coated MNPs.

References

1. Stöber W, Fink A, Bohn E. Controlled growth of monodisperse silica spheres in the micron size range. J Colloid Interface Sci. 1968;26: 62–69. doi:10.1016/0021-9797(68)90272-5