Experimental report

27/01/2017

Proposal: 9-12-481 **Council:** 4/2016

Title: Shell structure and stability of sophorolipid-coated iron oxide nanoparticles

Research area: Materials

This proposal is a new proposal

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Samples: Fe3O4-sophorolipids-nitrodopamine

Instrument	Requested days	Allocated days	From	To
D33	2	1	25/02/2017	26/02/2017
D22	2	0		
D16	4	3	23/01/2017	26/01/2017

Abstract:

A new class of monodispersed water-soluble iron oxide glyconanoparticles (NPs) is synthesized using a biobased microbial glycolipid called sophorolipids (SL). This compound is composed of a disaccharide (glucose beta1,2) attached to an oleic acid moiety. The free-standing COOH group of oleic acid is modified with nitrodopamine (NDA), a strong stabilizing agent of iron oxide nanoparticles. TEM show NPs with a radius of 2.3+ 0.2 nm and TGA allows to determine a grafting density of 0.7 SL-NDA per nm2. However, DLS indicates an average hydrodynamic radius of > 20 nm. For this reason, we want to investigate the exact nature of the NPs shell, the origin of the very good nanoparticle stability in water and, consequently, the SL configuration at the NP surface. Considering the poor contrast against x-rays between the SL shell and the NP/water system, we use neutrons to accomplish this task. SL structure (size, experimental SLD) and stability (size and SLD variations) against ionic strength, dehydration and purification will be analyzed.

Standard Project

Experimental Report template

Proposal title: Shell structure and stability of sophorolipid-coated iron oxide nanoparticles		**Proposal number: 9-12-481**
Beamline: D16	**Date(s) of experiment:** from: 23/01/2017 to: 26/01/2017	**Date of report:** 27/01/2017
Shifts: 9	**Local contact(s):** V. Cristiglio	*Date of submission:*

Background: Iron oxide NanoParticles (NPs) are used in applications like drug delivery, MRI or hyperthermia, for which NP cores are coated with polymer, lipid or other dispersants for water dispersion. However, rapid aggregation and precipitation occur without a sterically stabilizing shell. For biomedical applications, NPs are generally stabilized by a weakly adsorbed shell of high molecular weight polymer (often dextran) or amphiphiles (block copolymers). However, weakly adsorbed shells lead to low polymer densities on the particle surface, that are further reduced with time under dilute conditions, resulting in low colloidal stability. Chemisorbed shells are more stable, denser and therefore they received increasing attention. With improvements in the synthesis of NPs, monodispersed (SD< 5%) core-shell NPs have been developed, but their synthesis in organic solvents using oleate as ligand is not compatible with biomedical applications. Alternative water-soluble bulky chemisorbed ligands (mainly based on polymers) and ligand-exchange protocols to ensure colloidal stability (control of ligand density, distribution) have then been developed. Here, we propose a new biobased ligand: sophorolipids (SL), microbially-produced, biodegradable, bolaform glycolipids having a bulky sophorose (glucose β1,2 disaccharide) headgroup chemically attached to oleic acid (OA) bearing a free COOH group; the latter is modified with nitrodopamine (NDA), which has a very high affinity to iron oxide. Oleate is then exchanged with SL-NDA on the surface of monodisperse NPs to make biocompatible sugar-coated NPs, also called glyconanoparticles. SLs were previously used to stabilize NPs but with high polydispersity and low grafting density. According to our recent experiments, we are now able to synthesize monodispersed NPs prepared by a heat-up method and grafted with sophorolipids: their core-shell structure will be studied here.

Results and the conclusions of the study (main part):

The experiments have been done with a wavelength of 4.5 Angstrom, a sample-to-detector distance of 955 mm, beam size of 10x5 mm, and diffractometer angles of 11° (gamma) and 5.5° (omega). Neutron absorber was B4C and Hellma 1 mm cells have been used all along. Each sample was acquired for 60 minutes, exception made for the most concentrated ones, which were acquired for 10 minutes.

We analyzed different sophorolipids-stabilized iron oxide nanoparticles of different size, 3.2 nm, 4.6 nm, 10.9 nm, 14.1 nm in diameter. Additional samples constituted by Iron oxide stabilized by PEG were also added to the experiment. The surface ligand, nitrodopamine-modified sophorolipids was also measured. All experiments were performed in D2O, MeOD-d4/D2O and EtOH-d6/D2O. NaCl was added in some samples to test the stability of the particles to the ionic strength.

As an example, two samples, (iron oxide core diameter= 4.6 nm, 3.2 nm) are analyzed at D16 and using SAXS as complementary technique. SANS curves (symbols) indicate the presence of

nanoparticles. A numerical fit of the SANS using a core-shell model and using the fixed values for the core diameters known from TEM (core radius of 2.4 nm and 1.6 nm) as well as the known SLD's for the solvent and core and the estimated one for the shell, one must employ a shell thickness of between 2.2 nm and 2.5 nm, which is in the order of magnitude of one sophorolipids layer. SAXS measurements show a shift of the curves at higher q-values and this feature indicates that SAXS probes nanoparticles with a size of 2.4 nm and 1.5 nm, which are in agreement with the TEM data. No shell is needed to simulate the SAXS data, as expected, because the solvent/shell contrast in SAXS is about two orders of magnitude smaller than solvent and core.

Data treatment

All samples have been treated at the beamline soon after acquisition. The CCD images have been integrated and correction for absolute calibration was done using the correction factor for water (0.9). Background (cell + appropriate solvent) has been regularly measured and subtracted from the data. Incoherent scattering has not been subtracted unless necessary.

Justification and comments about the use of beam time:

The use of the neutrons was necessary because iron oxide nanoparticles have a strong contrast with water in X-rays, while the contrast is less important withy respect to D2O and using neutrons. Neutrons are needed in this project, as being the only method to prove the presence of a ligand monolayer compared to XRD.
The use of D16 was appropriate for only part of the samples, as the size of some of them was beyond the possibilitied of the low-q range offered by D16. However, we were aware of this fact and we will analyze a selection of samples at D33 in February 2017 to complete the data.

Problems during beamtime:

We did not experience any trouble during the beamtime.