Electronic supplementary materials *Mendeleev Commun.*, 2021, **31**, 830-832

Interaction of liposomes with silica nanocapsules: from lipid bilayer coating to multi-liposomal composites

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Hollow silica nanocapsules (SNs)

The aqueous dispersion of silica nanocapsules (20 wt.-%) is a product of Shanghai Dilato Materials Co., Ltd. The morphology of SN was studied on a Zeiss Libra 120 transmission electron microscope (TEM); accelerating voltage was set at 120 kV. The samples were prepared by placing a drop of diluted sample dispersion on a Formvar-carbon-coated copper grid of 200 meshes.

According to TEM, nanocapsules have an average diameter of 55 nm (see **Figure S1** below); their mean hydrodynamic diameter measured by dynamic light scattering is 60 nm with PDI 0.2. For all experiments the dispersion was dialyzed against the Tris-HCl buffer with pH 7.4 and diluted with the same buffer to a needed concentration.

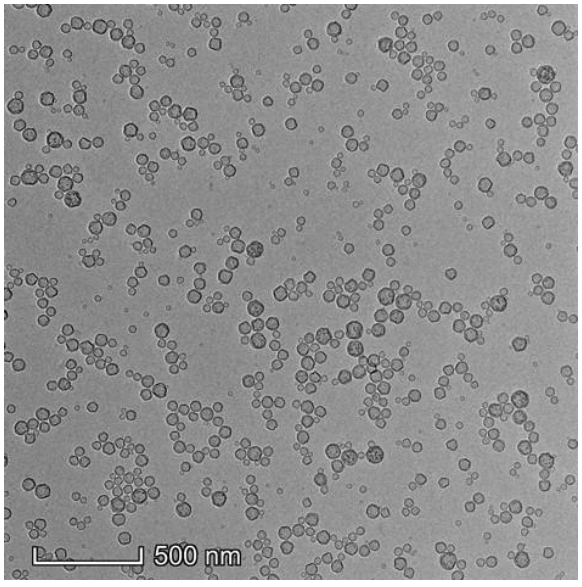

Figure S1. TEM micrograph of bare silica nanocapsules used.

The porosity was calculated to be 86% using the following equation:

$$porosity = (1-\rho_b/\rho_s)*100\%,$$

where ρ_b is bulk density, i.e. the ratio of the mass to its volume, which was estimated to be 0.30 g/cm^3, and ρ_s is skeletal density that is close to the density of the bulk solid, i.e. 2.20 g/cm^3 for silica.

Amorphous silica is "generally recognized as safe" by the US Food and Drug Administration (FDA). According to Russian register of potentially hazardous chemical and biological substances, amorphous silica is approved for application in cosmetic and pharmaceutical industry, and medical products.

Procedure S1. Preparation of Liposomes

Unilamellar cationic liposomes filled with 1M NaCl were prepared by the routine thin film sonication technique. Zwitterionic phosphatidylcholine (PC, Avanti® Polar Lipids), cetyltrimethylammonium bromide (CTAB, Fisher Scientific), and Brij 58 (Serva Electrophoresis GmbH, Figure S2) were used as received. Two types of liposomes were prepared. A lipid mixture containing 90 mol.-% of PC and 10 mol.-% of CTAB, the first type, PC/CTAB liposomes, or 70 mol.-% of PC, 10 mol.-% of CTAB, and 20 mol.-% of Brij58 (Figure S2), the second type, PC/CTAB/PEG liposomes, was dissolved in methanol/chloroform (50/50 wt/wt) and organic solvents were evaporated under vacuum at 30°C. A thin lipid film formed was placed in a 1M NaCl/10^{-3} M Tris-HCl buffer solution and then sonicated with a Cole-Parmer 4710 ultrasonic homogenizer for 10 min (2×5 min). Titanium dust was removed via centrifugation in a J-11 Beckman centrifuge for 5 min at 10000 rpm. The liposome suspension was separated from the excess of salt by dialysis for 1.5 h in a 10^{-3} M Tris-HCl buffer solution, which was changed every 30 min.

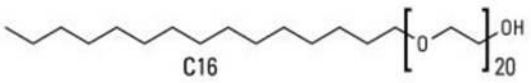

Figure S2. Chemical structure of Brij 58.

Characterization of SNs and liposomes

Electrophoretic mobility (EPM) of SNs and their mixtures with liposomes were measured in a thermostatic cell by laser microelectrophoresis using a Brookhaven Zeta Plus instrument with the corresponding software. Conductivity of suspensions was measured with a CDM 83 Radiometer conductometer. Mean hydrodynamic diameters of liposomes and SN/liposomes aggregates were measured by dynamic light scattering at the fixed scattering angle (90°) in a thermostatic cell with a Brookhaven Zeta Plus instrument. Software provided by the manufacturer was employed to calculate diameter values.