ADVANCED EMULSION FORMULATIONS FOR THE PREPARATION OF ENCAPSULATING SYSTEMS

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Hollow or porous polymer particles are employed in a wide range of applications as encapsulating and delivery systems. The use of multiple emulsions as templates is an interesting strategy for the preparation of this type of porous particles. Multiple water-in-oil-in-water (abbreviated as W/O/W) emulsions are complex liquid systems that consist of dispersed oil globules which in turn contain smaller aqueous droplets. It is worth to note that a given application will require a certain combination of particle characteristics, which can be controlled through formulation studies and the type of the material used. Among all the polymers described in the literature, silicones were chosen in the present work due to their interesting properties such as high stability, permeability to organic solvents, high hydrophobicity, low density or biocompatibility. Silicones are particularly attractive polymers in numerous commercial applications and in different formats, for instance as membranes or monoliths. However, bibliography regarding the preparation of silicone particles is limited, mainly due difficulties during the emulsification process on account of the high viscosity of the silicone precursors. Thus, the aim of this research was to study the formulation of novel silicone multiple emulsions, using silicones with a low molecular weight, to serve as templates for the preparation of silicone porous particles. Particles were prepared by simply crosslinking the intermediate oil phase through a thermal-induced crosslinking reaction. The choice of the emulsion preparation method is essential to ensure the intended characteristics to the resulting particles. As a first approach, the two-step bulk emulsification method was proposed (Figure 1a). As the morphology and stability of the emulsion template play an important role determining the morphology of the derived particles, formulation studies were performed. Various formulation parameters such as the concentration of the surfactants as well as the mass fraction of the phases or the nature of the silicone precursors were varied to analyze their influence on particle structure. Examination by scanning electron microscopy of the resulting particles revealed that diverse morphologies could be obtained by changing those formulation parameters. Moreover, it was also possible to change the mechanical properties of the silicone matrix, from stiff to soft, by simply using different silicon precursors. As an alternative approach, droplet-based microfluidic techniques were also used to prepare multiple emulsion templates. Such technique allowed the preparation of monodisperse multiple emulsions with a single inner droplet with an accurate control over the droplet morphology and structure (Figure 1b). Due to the template effect, monodisperse silicone capsules with well controlled dimensions were also obtained. Moreover it was observed that mechanical properties of these capsules were directly related with their geometric parameters. Finally, silicone particles were further characterized. In general, particles showed a high hydrophobicity, high swelling capacity and the ability to encapsulate either active hydrophilic molecules or functional particles such as magnetic nanoparticles. These properties indicated that silicone particles could be used as functional materials.
Figure 1. a) A representative multiple emulsion prepared by the two-step bulk emulsification method and the resulting silicone porous particles. b) A representative multiple emulsion prepared by a microfluidic technique and the resulting silicone capsule. Inset: Cross-section of the shell.