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Pickering Emulsification using MCM41-Type Mesoporous Silica

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Abstract

The performance of MCM-41 type mesoporous silica (MPS) as an emulsifier for Pickering emulsification was investigated. Compared to silica gel powder, the MPS powder showed stronger adsorption of organic molecules into its uniform nanosized pores, in addition to good dispersibility in a solvent.

Adsorption of oil into the MPS pores yielded an O/W emulsion, even without any organic surface treatment. Ethanol treatment helped in further improving the emulsification ability of MPS under mild stirring conditions and yielded a uniform O/W emulsion phase over a wide range of water/oil ratios, without any oil phase separation.

Key-words: *Mesoporous silica, Pickering emulsification, Organic surface treatment, O/W emulsion*

1. Introduction

Pickering emulsification is a technique in which amphiphilic powder is used as an emulsifier. In this case, a powder layer is formed at the water/oil interface, which enables emulsion formation in the absence of a surfactant[1-3]. Typically, silica powder is used for Pickering emulsification, but because of its hydrophilic surface, surface modification with organic substances like silicone (dimethyl polysiloxane) is necessary. Micro-sized silica spheres can act as an emulsifier even without surface treatment when oils with specific polarity are used, such as unsaturated triglyceride oils[4]. However, ordinary cosmetic oils such as synthetic triglycerides like 2-ethyl hexanoic acid triglyceride are unfortunately emulsified by this method. Further, in order to disperse the powder in a liquid phase and form a Pickering emulsion, a strong mixing force is required; for this purpose, an ultrasonic disperser or a homogenizer is used.

The powder developed for Pickering emulsification, for application in the cosmetics industry etc., should preferably be capable of forming an emulsion under a gentle mixing force such as agitation, shaking, or stirring. In addition, the powder should be ready for use without surface treatment.

It has been described theoretically that the surface roughness (the presence of pores) of powder particles can affect the wettability of them, which improves or deteriorate the properties of the powder particles as an emulsifier[5]. According to this theory, in this study, we focus on mesoporous silica (MPS), which is silica powder with uniform nanometer-sized pores. MPS was originally developed for catalysts showing shape selectivity[6]. When used as an extender pigment, MPS powder shows unique physical properties such as high dispersibility in both oil and water phases, which is due to its large pore volume (ca. 1 mL/g) and surface area (>1000 m^2/g). Among various types of MPS, MCM41-type MPS has the highest dispersibility[7]. Further, the organic molecules are strongly and tightly adsorbed by the MPS pores, and subsequent desorption is minimal. For example, anthocyanidin dye adsorbed on MCM41-type MPS is hardly eluted to organic solvents or water[8]. In this study, we examine the performance of MCM41-type MPS, which strongly adsorbs organic molecules and shows good dispersibility in a solvent, for Pickering emulsification. The main aim of this study is to determine whether (1) MPS without organic surface treatment can emulsify typical cosmetic oils and (2) MPS with hydrophobic treatment is suitable for emulsification under gentle stirring conditions.

2. Experimental

2.1 Preparation of mesoporous silica

MCM41-type MPS was synthesized by a known conventional method described in the literature[9]. The silica powder was ground in an agate mortar until its secondary particle size became less than 7 μm, as observed by scanning electron microscopy (SEM, **Fig. 1**). As a comparative sample, commercially available silica gel (Wako Pure Chemical) was crushed in an agate mortar in the same manner mentioned above and used.

Both silica samples were subjected to hydrophobic treatment. For ethanol treatment, 0.3 g of MPS or silica gel was mixed with 6 mL of 99 % ethanol, transferred to a PTFE autoclave, and heated at 413 K for 48 h. For propanol treatment, 2.0 g of