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Compatibility of nonionic surfactants with membrane materials and their cleaning performance

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A B S T R A C T

Membranes applied in industrial processes, such as for the desalination of seawater as well as for dairy and beverage industry are subjected to fouling resulting in a decline of their performance. In order to regain the flux of the membranes, cleaning procedures are conducted, whereby inorganic scale is often removed with acids and organic matter with surfactants under alkaline conditions. Currently, either ionic surfactants or alkylphenol ethoxylates are utilised to clean membranes of organic matter. Other nonionic surfactants (i.e. fatty alcohol ethoxylates) are not applied, due to the assumption that they irreversibly adhere to the membrane surface and thereby clog the pores. At BASF we have studied the adsorption of a wide range of nonionic surfactants to membrane materials. It was shown, that the affinity of nonionic surfactants critically depends on their structure. Linear alkyl ethoxylates irreversibly adsorb to the membrane surfaces, whereas branched alkyl ethoxylates do not. In a second step, we tested the cleaning performance of nonionic surfactants. Similar to the results for adsorption, a structure-performance relationship was discovered where several branched alkyl ethoxylates showed excellent cleaning results. In a third step, combinations of nonionic surfactants, chelating agents and enzymes were tested in terms of cleaning efficiency. All tested combinations showed excellent cleaning performance on bacterial fouling layers.

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1. Introduction

In microfiltration, ultrafiltration, nanofiltration, reverse osmosis, electrolysis and dialysis membranes are used to separate liquids from salt and/or further impurities. In these processes, the membranes are subject to fouling by adsorption or deposition of substances or organisms from the feed resulting in decreased membrane performance in the separation process. Fouling mainly originates from three sources, namely particles in the feed, concentration of sparsely soluble minerals and microorganism growth. All of these fouling events require frequent cleaning of the membranes. These cleaning processes usually apply cleaning solutions containing surfactants at acidic, neutral or basic pH (intensive cleaning) and/or exerting an inverse pressure to the membrane (chemically enhanced

backwash). Commonly, the cleaning solutions contain anionic surfactants (e.g. LAS). However, LAS has the disadvantage that it produces foam during the membrane cleaning process. Other supplements including alkylphenol ethoxylates (nonionic surfactants) are not used anymore due to their ecological drawbacks (Soares et al., 2008) and unfavourable affinity for the membrane surface (Koo et al., 2002; DOW Filmtec, 2013; Hydranautics, 2002; Yamagiwa et al., 1994), respectively. Other effective nonionic surfactants that do not adhere irreversibly to the membrane surface, such as alkylglycosides or—pentosides, show either the same foaming level as anionic surfactants or are currently not known.

In this paper we report a systematic study to investigate (a) the affinity and (b) the cleaning performance of nonionic surfactants to/of relevant membrane materials. Thus it was

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possible to correlate the structure of the nonionic surfactants to their compatibility and cleaning performance under relevant conditions used for industrial membrane cleaning and give suggestions for optimal application in cleaning formulations.

2. Experimental

2.1. Thin film preparation

Freshly cleaned glass slides were oxidised in a mixture of aqueous ammonia solution and hydrogen peroxide before they were subjected to hydrophobisation with hexamethyldisilazane. Subsequently, polyamide and polyethersulfone thin films were produced by spin coating. Briefly, 0.2% PA-12 (VESTAMID® L2101 F, Evonik Industries, Germany) and

0.3% PES (Ultrason® PES Type E 6020 P, BASF SE, Germany) were dissolved in hexafluoroisopropanol or dichloromethane, respectively, and were subsequently spin coated at 4000 rpm for 30 s. The polyamide (VESTAMID) and polyethersulfone (Ultrason PES) thin films showed a thickness of 25 ± 2 nm and 30 ± 2 nm, respectively (ellipsometry, SE 400, Sentech, Berlin, Germany).

2.2. Surfactant (cleaning agent) adsorption by quartz crystal microbalance (QCM)

Adsorption of surfactants on polyamide and polyethersulfone thin films was analysed at constant temperature (23°C) by using a QCM-E4 (Q-Sense AB, Gothenburg, Sweden). The polymer-coated QCM crystals were swollen in deionised water to achieve a stable baseline and subsequently treated with

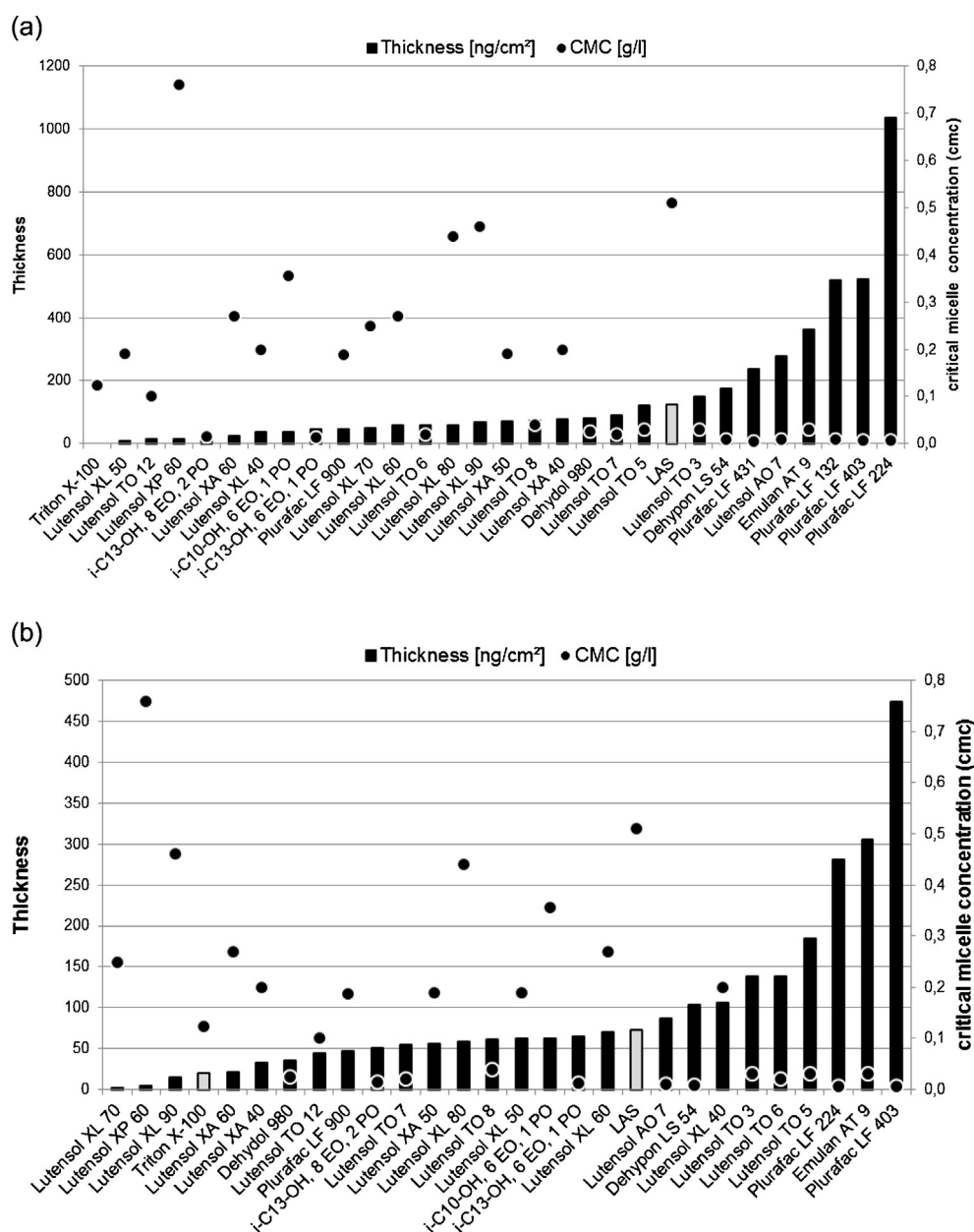


Fig. 1 – (a) Critical micelle concentration of nonionic surfactants and their residual amount remaining on the polyamide layer after treatment with 0.025% surfactant solution and rinsing with deionised water. The sequence was repeated four times, surface coverage was measured by QCM. (b) Critical micelle concentration of nonionic surfactants and their residual amount remaining on the polyethersulfone layer after treatment with 0.025% surfactant solution and rinsing with deionised water. The sequence was repeated four times, surface coverage was measured by QCM.

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