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Colloids and Surfaces A: Physicochem. Eng. Aspects 282–283 (2006) 475–482
COLLOIDS AND SURFACES A
www.elsevier.com/locate/colsurfa

Electroacoustic characterization of electrokinetics in concentrated pigment dispersions: 3-Cyano-4-(4′-butanesulfonamidophenyl)-5-furylidene-furan-2-one

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Received 17 November 2005; received in revised form 17 February 2006; accepted 20 February 2006
Available online 17 April 2006

Dedicated to Professor Ivan B. Ivanov (LCPE, University of Sofia) on the occasion of his 70th birthday.

Abstract

The surface and colloid chemistry of organic pigment dispersions have largely been ignored in the literature, although organic pigments play a crucial role in classical and ink jet printing and imaging. This paper presents detailed measurements of an aqueous dispersion of the title compound, prepared without added surfactant, and examines the adsorption of various anionic surfactants via electrokinetic sonic amplitude (ESA) measurements. Quantitative adsorption data are compared with adsorption isotherms obtained via phase separation methods and are found to be in good agreement. Determination of saturation monolayer adsorption is significantly faster and more convenient using ESA measurement technology. However, some of the surfactants examined exhibited multilayer or partial multilayer adsorption. A surfactant modeled after the title compound was synthesized and exhibited particularly effective stabilization, although the adsorption appears slightly weaker than the classical surfactants studied. The intrinsic negative surface charge observed in aqueous dispersion of the title compound was identified as due to mechanicochemical activation of surface molecules to hydrolyze the furanone ring to the α-cyano maleic acid moiety. Electrophoretic mobility measurements as a function of volume fraction at various ionic strengths indicate that increasing electrophoretic mobility magnitudes accompanying increasing NaCl concentrations were due to preferential adsorption of chloride to the particle surfaces.

Keywords: Dynamic mobilty; Electrophoretic mobility; Surfactant adsorption; Zeta potential; ESA; Electrokinetic sonic amplitude; Pigment dispersion; Surface charge

1. Introduction

Surface electrokinetic characterizations of pigment dispersions are important for understanding particle–particle interactions, dispersion stability effects, and the adsorption of ionic surfactants and other additives onto the pigment particle surfaces [1–3]. The proliferation of electroacoustic methods over the past 15 years has made such measurements much more experimentally accessible [4–6]. The present study of aqueous dispersions of the title compound, a yellow pigment (**I**), was undertaken to characterize the intrinsic dynamic mobility of the pigment as a function of pH and the effects of surfactant adsorption on this dynamic mobility. This particular pigment has been used in photographic technology for the absorption of blue light and for the control of light transmission between various layers in photographic elements designed for slide film and for the control of light back scattering (antihalation) in microfilm [7,8]. The title compound **I** is a substituted furylidene furanone, it is water insoluble, and it bears no obviously easily ionized functional groups. Our primary motivation in this study was to experimentally evaluate surfactant adsorption onto the pigment particles, and to evaluate electrokinetic sonic amplitude as a means for studying surfactant adsorption. We examined surfactants commonly

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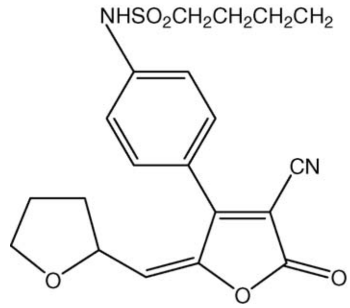
doi:10.1016/j.colsurfa.2006.02.056

used in practice as well as a new surfactant derived from the pigment, **I**:



I

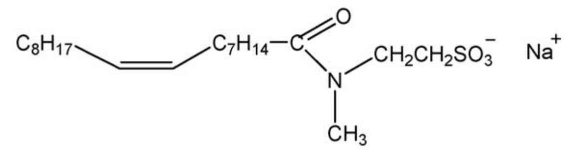
Optically based electrophoretic methods such as classical DC microelectrophoresis [9] and photon correlation spectroscopy [10,11] are not effective for examining opaque dispersions such as those investigated here. We used the electroacoustic method as developed by Oja et al. [12], with theoretical support by O'Brien [13–16], Babchin et al. [17], and Sawatzky and Babchin [18]. We used an electrokinetic sonic amplitude (ESA) system to examine electrokinetic charge effects. ESA is the experimental measurement of choice in aqueous slurries of relatively high conductivity, such as those examined in this study, and is the measurement of the ultrasonic pressure (sound) response to an applied radio frequency (rf) field in the vicinity of 1 MHz. The response of such measurements has been derived by O'Brien and by Cannon. A useful expression is given in Eq. (1) where S is the experimentally measured signal, and γ is a calibration constant [19]:

$$\gamma S = \frac{\mathrm{ESA}}{G(\omega, \varphi)} = c\Delta\rho\varphi\mu(\omega) \tag{1}$$

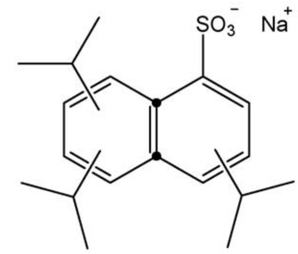
In this expression the ESA is the theoretical ratio of sound amplitude divided (generated) by the applied rf field amplitude, G is a dimensionless factor encompasses acoustic coupling in the experimental cell at the ultrasonic frequency ω and pigment volume fraction. The speed of sound in the dispersion is given by c, $\Delta\rho$ is the difference in density between the pigment and the continuous aqueous phase, and $\mu(\omega)$ is the dynamic electrophoretic mobility at ω. While the ESA response depends on the experimental geometry and acoustic coupling, the ratio ESA/G is a fundamental electroacoustic property of the colloidal suspension.

2. Experimental materials

The title compound **I** was obtained from Mr. John Bishop of the Eastman Kodak Manufacturing, Research, and Engineering Organization, Rochester, New York. The surfactants, OMT (sodium oleoylmethyltaurine) and DTINS (a 50:50 mol mixture of diisopropyl and triisopropyl naphthalene sulfonate, sodium salt) were also obtained from Mr. John Bishop:

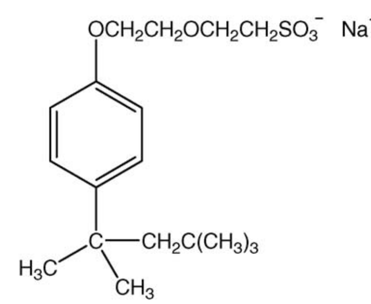


OMT



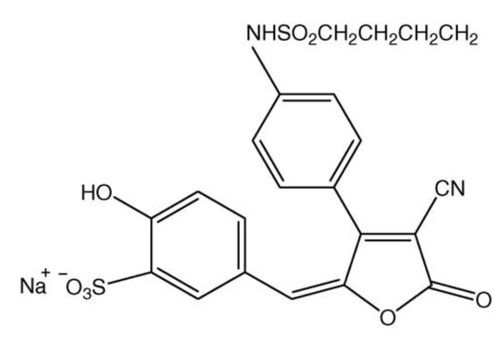
DTINS

The surfactant TX-200 (**TX**) was obtained from Kodak Laboratory and Research Products:



TX200

A variant, **II** (3-cyano-4-(4′-butanesulfonamidophenyl)-5-(3″-sodium sulfo-4″-hydroxyphenyl)-furan-2-one), of the title compound was prepared by Dr. Les Shuttleworth of the Eastman Kodak Research Laboratories, as a potential surfactant, using an old empirical rule of thumb that the best surfactants are those derived from the substrate:



II

High-purity sodium dodecyl sulfate (SDS), used as a titrant standard in surfactant adsorption isotherms assays, and dimidium bromide/disulfide blue VN indicator solutions used in the same assays were obtained from BDH Chemicals. Cetyltrimethylammonium bromide (CTAB), used as titrant in