Enhanced adsorption-limited process for model surfactants in the EDGE microfluidic device

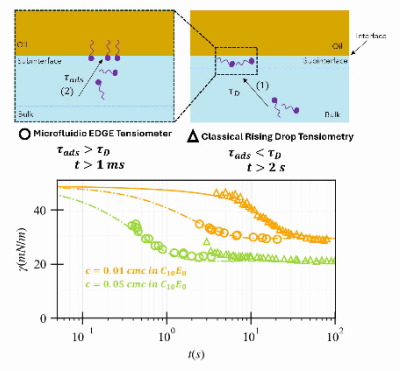
Camille Brigodiot[a], Boxin Deng[b], Christine Dalmazzone[c], Karin Schroën[b], Annie Colin[d]

[a] *Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands*
[b] *Wageningen University and Research, Laboratory of Food Process Engineering, Bornse Weilande 9, 6708 WG Wageningen, The Netherlands*
[c] *IFP Energies nouvelles, 1 et 4 avenue de Bois-Préau, 92852 Rueil-Malmaison, France*
[d] *MIE, CBI, ESPCI Paris, Université PSL, CNRS 75005 Paris, France*

c.brigodiot@uva.nl

In numerous industrial processes such as spraying, foaming, or emulsification, interfacial dynamics are crucial for efficiency and stability. Interfacial tension is governed by the adsorption of surfactants at the interface. Understanding these transient dynamics requires quantifying the relationship between interfacial tension, adsorbed surfactant amount, and subinterface concentration, along with diffusion coefficients, adsorption timescales, and convective effects. However, no single experimental method currently captures all these parameters simultaneously.
With classical tensiometers, it is difficult to study mass transport occurring below a few seconds, and diffusion is typically the limiting process. Adsorption and diffusion are therefore coupled, making it impossible to quantify kinetic parameters independently. Microfluidic devices offer a complementary approach, providing experimental conditions where adsorption-limited processes are enhanced while diffusion is no longer the limiting mechanism.
We studied the dynamic interfacial tension of two model surfactants, and SDS, at the water/hexadecane interface, combining a microfluidic EDGE tensiometer and a classical pendant drop tensiometer to cover timescales from 10 ms to 200 s[1]. Diffusion parameters were extracted from pendant drop data using the Ward and Tordai[2] framework, while adsorption kinetics were characterized in the EDGE device through the rigorous thermodynamic model of Diamant and Andelman[3] — which we show to be the limiting mechanism for in these conditions.
This combined approach allowed us to accurately interpret the full evolution of interfacial tension and to extract key physical parameters governing surfactant mass transport: diffusion coefficients, adsorption and desorption rates, and equilibrium isotherms. The resulting framework provides a unified and experimentally grounded methodology for measuring and modeling interfacial dynamics, with direct relevance to industrial processes involving rapid interface formation.

Keywords:
Interfacial tension, surfactant mass transport, microfluidics, adsorption kinetics, millisecond timescale



Dynamic interfacial tension captured by the EDGE microfluidic device compared to the classical tensiometry technique. Scheme of the adsorption process.

References:

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