ADHESION INDUCED NON-PLANAR AND ASYNCHRONOUS FLOW OF A GIANT VESICLE MEMBRANE IN AN EXTERNAL SHEAR FLOW

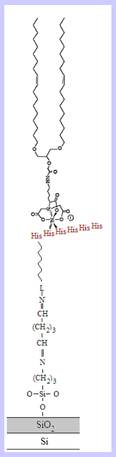
Cyrille Vezy[1], Gladys Massiera[2], Annie Viallat[1],

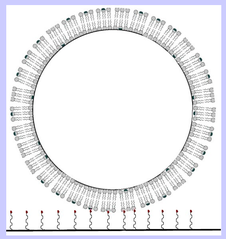
1. Laboratoire Adhésion et inflammation, Inserm U600/CNRS UMR 6212 / Université de la Méditerranée, France

2. Laboratoire des Colloïdes, Verres et Nanomatériaux, Université Montpellier 2 & CNRS UMR 5587 Montpellier France

PROBLEMATIC: Surface flow on soft objects submitted to external shear flow is a problem involved in an increasing number of engineering and biophysical situations: microfluidics, emulsion processing, biomechanics, blood circulation. Membrane flow has been studied for red blood cells, sliding vesicles near a wall for which there is a coupling between the inclination of the object and the rotational frequency (Lorz, B. Europhys. Lett. (2000); Abkarian, M. Phys. Rev. E (2001), PRL (2002)). Here we study the surface flow for an adhering vesicle, in absence of translational motion with a shape and inclination imposed by the adhesion strength, and try to extract the dominant source of dissipation, by measuring velocity field on the membrane surface.

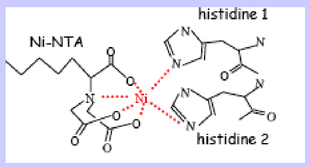
SYSTEM: LIPID VESICLE IN ADHESION SPECIFIC ...



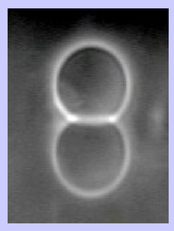


Vésicule (DOPC + lipides tête Ni-NTA (5%))

Substrat recouvert de molécules histidines



Chélation d'un ion Ni par deux histidines



... OR NON-SPECIFIC ADHESION

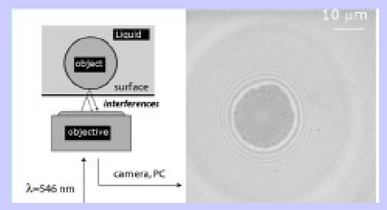
Adsorption of polycationic chains on the glass slide: poly-L-lysin

⇒ stronger non-specific interaction

OBSERVATIONS WITH...

Obj. X10, x20
Resolution < 1 µm

SIDE VIEW



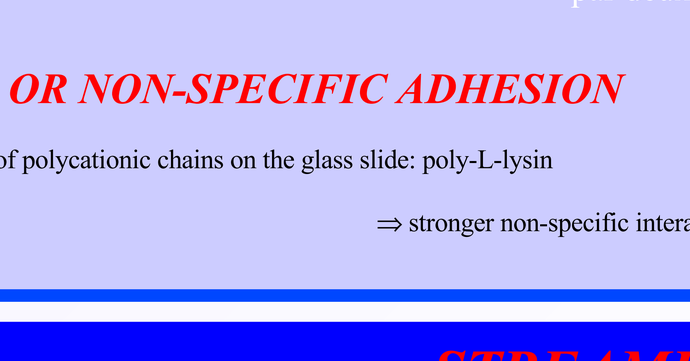
Obj. X63

RICM

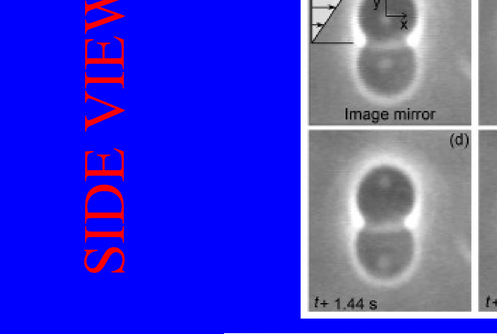
STREAMLINES ON THE MEMBRANE

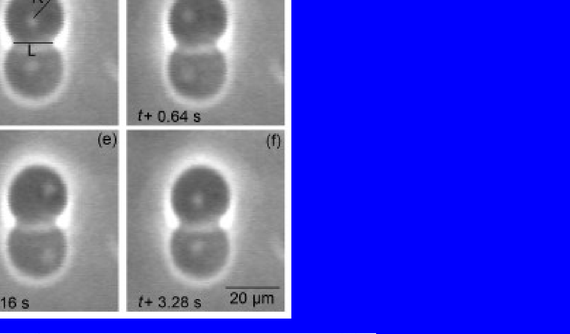
SIDE VIEW

TOP VIEW



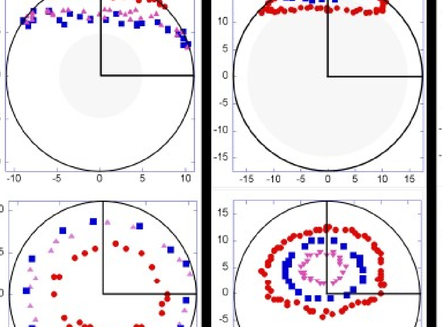
VESICLES SHAPE AND STAGNATION POINT (SP)



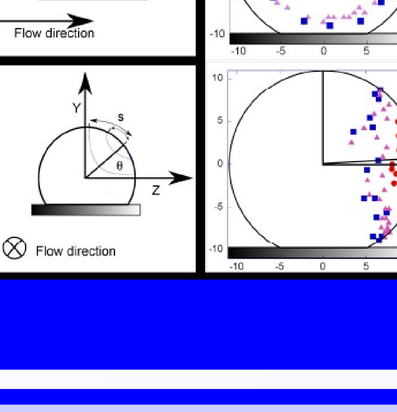


We show the existence of a flow at the surface of strongly adhering giant lipid vesicles submitted to an external shear flow. The surface flow is divided into two symmetric quadrants and present two stagnation points (SP) on each side of the vesicle meridian plane. The position of these stagnation points highly depends on the adhesion strength, characterized by the ratio of the contact zone diameter to the vesicle diameter. Contrary to the case of non adhesive vesicles, streamlines do not lie in the shear plane. By avoiding the motionless contact zone, streamlines result in three-dimensional paths, strongly asymmetric away from the SP. Additional shearing dissipation may occur on the membrane surface as we observed the mean rotational velocity of the membrane increases towards the vesicle SP, and is mainly determined by the adhesion induced vesicle shape.

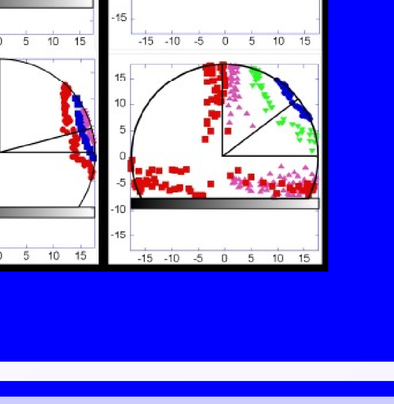
ROTATIONAL VELOCITY



The revolution frequency is proportional to the shear rate as for a rigid sphere, a red blood cell or a non-adhering vesicle under flow.



⇒ **Shear dissipation in the membrane**

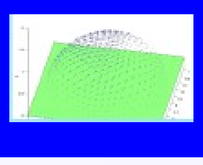


⇒ **Decrease in the angular frequency with adhesion strength**

Possible mechanisms of dissipation:

No friction in the adhesive zone since it's motionless

Different from a drop case: fmuid recirculation
Posrikidis personal communication



Vesicle shape: for high aspect ratio of ellipsoidal vesicle in shear flow, theories predict a decrease in the angular frequency over shear rate ratio: Kraus, PRL (1996), Keller and Skalak, JFM (1982)

Shear dissipation due to a disk (adhesive zone) obstacle to the membrane flow

⇒ Need for numerical studies to better understand the dependence of streamlines and velocity on the vesicle shape and adhesion stregth