Microdomain structure and mechanical properties of lipid monolayer mimicking red cell membranes: influence of oxidative stress

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Red blood cells (RBCs) have remarkable mechanical properties that are major determinants of blood flow. This is made possible by the unique structure of the erythrocytes. The bilayer lipid membrane accounts for the bending rigidity of RBCs whereas the membrane skeleton, built mainly of spectrin dimers in the form of a network sparsely anchored to the lipid bilayer, regulates the shear elasticity.[1] Deformation of RBC is a key property to ensure efficient passage through the microcirculation. A number of diseases such as diabetes may cause changes in the RBC's deformability and the physical properties of the erythrocyte plasma membrane due to oxidative and other chemical stresses.[2] To reduce the complexity of the system, model membranes and lipid monolayers have been used to determine membrane properties.[3]

We investigate the microdomain structure of synthetic lipid monolayers mimicking the composition of the inner or outer leaflet of the erythrocyte plasma membrane by means of the Langmuir trough technique coupled with fluorescence microscopy, gracing incidence X-ray diffraction (GIXD) and X-ray reflectivity (XRR) to study domain structures. Surface relaxation (dilational rheology) is used to quantify the dynamic interfacial rheological properties of the lipid film and Molecular Dynamics (MD) simulations reveal details in monolayer organization at molecular length scales. In particular, we investigate the effect of oxidation of key membrane constituents to clarify the role of oxidative stress on the plasma membrane organisation and physical properties.

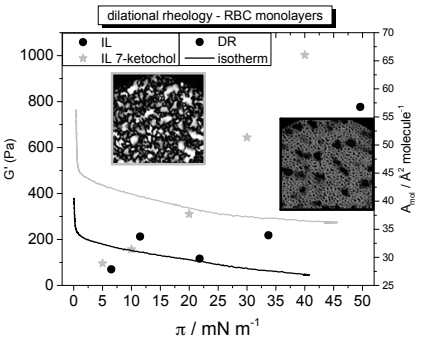

Figure1. Langmuir monolayer compression isotherms, storage moduli from dilational rheology experiments and fluorescence micrographs at 25 mNm^{-1} for the RBC inner leaflet mixture with cholesterol (grey) or 7-ketocholesterol (black).

We show that a replacement of cholesterol by 7-ketocholesterol as a main oxidation product leads to a significant stiffening of the monolayer at surface pressures above 20 mN/m (Figure1), in the range of the bilayer equivalence surface pressure ($\pi \approx 30$ mN/m). Fluorescence imaging was used to reveal crystallite-like microdomain structures of the monomolecular layers containing 7-ketocholesterol whereas the monolayer with non-oxidized cholesterol features more circular domain shapes. We also report differences in the monolayer organisation as detected by GIXD and XRR.

References

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