

Mechano-capacitive properties of polarized membranes

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Abstract

Biological membranes are capacitors that can be charged by applying a field across the membrane. The charges on the capacitor exert a force on the membrane that leads to electrostriction, i.e. a thinning of the membrane. Since the force is quadratic in voltage, negative and positive voltage have an identical influence on the physics of symmetric membranes.

However, this is not the case for a membrane with an asymmetry leading to a permanent electric polarization. Positive and negative voltages of identical magnitude lead to different properties. Such an asymmetry can originate from a lipid composition that is different on the two monolayers of the membrane, or from membrane curvature. The latter effect is called 'flexoelectricity'. As a consequence of permanent polarization, the membrane capacitor is discharged at a voltage different from zero. This leads to interesting electrical phenomena such as outward or inward rectification of membrane permeability.

Here, we introduce a generalized theoretical framework that treats capacitance, polarization, flexoelectricity, piezoelectricity and thermoelectricity in the same language. We show applications to electrostriction, membrane permeability and piezoelectricity and thermoelectricity close to melting transitions, where such effects are especially pronounced.