Stimuli-responsive bio-inspired catanionic vesicles: from molecular design to tunable biocargo delivery

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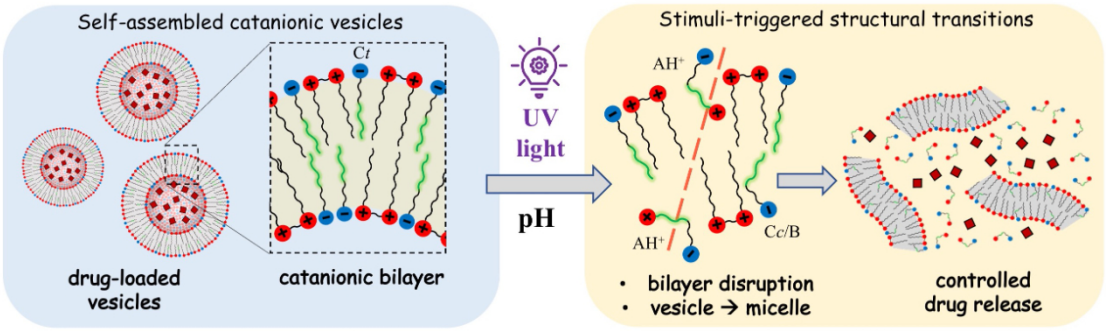
Achieving precise spatial and temporal control over molecular delivery requires nanocarriers whose behavior can be predictably programmed from molecular interactions to mesoscopic structure. In colloidal systems, this remains particularly challenging under multiple stimuli and complex environments.
Here, we present a bio-inspired design framework for catanionic vesicles in which responsiveness is encoded at the molecular level and propagated through self-assembly. Surfactants derived from natural motifs—namely chalcone/flavylium photoswitch units and amino acid-based headgroups—form catanionic mixtures that exhibit strong non-ideal interactions, enabling spontaneous vesicle formation with tunable composition, charge, and stability [1,2].
The chalcone-based systems display coupled pH- and light-responsiveness [1], where photo-induced molecular switching drives structural transitions (e.g., vesicle-to-micelle and vesicle reorganization), thereby modulating encapsulation and release of drugs such as doxorubicin and paclitaxel. Combined analysis of phase behavior, scattering (including SAXS), spectroscopy, and microscopy shows how these molecular transformations translate into changes in aggregate structure and drug release kinetics.
Extending this approach, pH-responsive sarcosinate-based catanionic vesicles [2] are integrated into thermoresponsive block copolymer networks, where polymer–surfactant interactions lead to mixed assemblies and temperature-dependent reorganization. This coupling between vesicles and the polymer matrix enables sustained and localized delivery, while offering insight into the interplay between self-assembly, co-assembly/self-sorting, and functional control of release behavior.



Stimuli-triggered structural transitions in catanionic vesicles enabling controlled drug release.

References:

[1] D. Moreira, O. Regev, N. Basílio and E.F. Marques, *J. Colloid Interface Sci.* , 650, **2023** , 2024.
[2] R. Machado, I.S. Oliveira, K. Santos, A.C. Gomes, E.F. Marques, *Nanoscale,* 17, **2025** , 26129.

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