

Visible Light-Responsive Polymers based on Donor-Acceptor Stenhouse Adducts

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Molecular photoswitches comprise chromophores that can be interconverted reversibly with light between isomers with different physicochemical properties. The incorporation of photoswitches into polymers enables the fabrication of light-responsive materials that can be controlled with high spatial and temporal precision. This is particularly promising when addressing complex systems in biomedical applications. However, the development and practical use of such materials is limited by the fact that most photoresponsive molecular tools available are only addressable by harmful ultraviolet light. Donor-acceptor Stenhouse adducts (DASAs), as a new class of one-photon visible light-activatable photoswitches, have great potential to overcome these limitations. This thesis is focused on further expanding the synthetic scope of DASA photoswitches and integrating them into various polymers to create new visible light-responsive materials.

Synthetically readily accessible and tunable photoswitches are crucial for successful application in material science. To this end, synthetic conditions were developed to promote the DASA-forming reaction between activated furans and secondary amines based on the highly polar fluorinated alcohol 1,1,1,3,3,3-hexafluoro-2-propanol (HFIP) as a co-solvent. This has proven useful in broadening the synthetic scope of this reaction to prepare previously unattainable DASA derivatives from weakly donating aromatic amines and to enable more efficient integration of DASAs into polymeric materials. Photoswitches operating with near-infrared light in the so-called "phototherapeutic window" would be ideal for medical applications, but for DASAs this requires a further redshift of their absorption wavelengths. For that purpose, novel target structures have been devised by altering the acceptor moiety through increased conjugation. A DASA photoswitch addressable with far red light above 700 nm was synthesized from an isoquinoline-1,3(2H,4H)-dione-derived acceptor.

The photoswitching properties of DASAs are highly dependent on the environment. Therefore, the photoswitching properties of various DASAs in different media, including macromolecular systems, were studied in detail. Modular post-polymerization modification strategies were employed to covalently conjugate DASAs to various methacrylate copolymers and polydimethylsiloxanes. The matrix dependency of DASAs in polymers in solution and in the solid-state was investigated.

Combining the advantages of light-responsive materials with nanoparticle formulations has prospective application in targeted drug delivery, allowing release from nanocarriers to be remotely controlled with high precision. To this end, a library of amphiphilic block copolymers with DASAs conjugated to the sidechains of the hydrophobic polymer block was synthesized. Self-assembly of these polymers in water generated visible light-responsive nanoparticles that can undergo light-induced permeabilization. Moreover, irreversible isomerization of DASAs in water in the dark could be prevented by localizing them in the hydrophobic microenvironment of the polymer membrane. Different first, second and third generation DASA derivatives were applied at different concentrations in order to gain a better understanding on how DASA characteristics or concentration effects influence the photoswitching and photo-induced material property changes in this system. The extent to which DASA isomerization in the nanoparticles causes changes at the macro- and supramolecular length scales was investigated using various spectroscopic and scattering techniques.

Finally, the DASA nanoparticles were immobilized in a gelatin-based hydrogel matrix, in which they retained their reversible photoswitching behavior. This further highlights the potential of encapsulation and compartmentalization strategies to preserve DASA functionality in aqueous environments and points the way for future biomedical applications of these photoswitches.

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