Molecular Switching under the Spotlight: A Computational Perspective

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The development of photo-responsive molecular systems is motivated by the human efforts to control and modify properties and functions of materials with high spatiotemporal precision, which can be achieved by light. Compared to other external chemical and physical stimuli, such as e.g. pH, solvent, temperature, or redox conditions, the activation of materials by light is non-invasive and highly localized**.** An important group of photo-responsive systems represents those exhibiting photochromism, i.e., a reversible photoinduced transformation between two chemical forms (states) with different colours, accompanied by changes in spectral, photochemical, and physicochemical properties. It is the reversibility of the process, which makes the photochromic compounds so attractive for practical applications, as it enables to achieve the ON-OFF control of the state -and thus the properties- of materials. Molecular photoswitches (PhSs), as these compounds are referred to as, have already found numerous applications in material science, supramolecular chemistry, nanotechnology and catalysis, but also in biomedicine and (photo-)pharmacology (e.g., the photochemical control of drugs, drug delivery, and bioimaging).

In the past years, we have been involved in the design and the optimization of several important classes of molecular photochromes, including donor–acceptor Stenhouse adducts (DASAs) [1,2], iminothioindoxyls (ITIs) [3-5], azonium salts [6], and hydrazones (HZs) [7,8]. Employing advanced static as well as dynamic quantum chemical methods, we explored thermal as well as photochemical reaction pathways of these systems. In synergy with experimentalists, we proposed structural modifications leading to significant improvement of their photochromic characteristics. For example, in the case of ITIs, which typically thermally relax on a millisecond time scale, we successfully designed derivatives with thermal half-lives exceeding 0.1 s [5], which -in combination with the excellent addressability and the operability in aqueous solutions under visible light- makes them highly attractive for photopharmacological applications. In the class of triaryl-HZs, a recently discovered subclass of photochromic HZs, our computational analysis of various de-excitation pathways enabled to design derivatives with notably increased quantum yields of the *Z*-to-*E* photoisomerization. In the talk, several examples of how computational tools can be used to gain interesting insights into molecular photochromism will be provided.

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REFERENCES

[1] Di Donato M., et al. (2017) *J. Am. Chem. Soc.*, 139, 15596-15599. DOI: 10.1021/jacs.7b09081
[2] Lerch M. M. et al. (2018) *Angew. Chem. Int. Ed.*, 130, 8195 –8200. DOI: 10.1002/anie.201803058
[3] Hoorens M. W. H. et al. (2019) *Nat Commun.* 10, 2390. DOI: 10.1038/s41467-019-10251-8
[4] Medveď M. et al. (2021) *Chem. Sci.* 12, 4588. DOI: 10.1039/d0sc07000a
[5] Boëtius M. E. et al. (2024) *Chem. Sci.* 15, 14379. DOI: 10.1039/d4sc01457j
[6] Medveď M. et al. (2023) *J. Am. Chem. Soc.*, 145, 19894−19902. DOI: 10.1021/jacs.3c06157
[7] Mravec B. et al. (2021) *J. Org. Chem. 86, 11633–11646*. DOI: 10.1021/acs.joc.1c01174
[8] Hegedüsová L. et al. (2024) *Chem. Eur. J. 30, e202303509*. DOI: 10.1002/chem.202303509
[9] Mravec B. et al. (2025) *J. Am. Chem. Soc.*, 147, 2421-2431. DOI: 10.1021/jacs.4c12510