Prospects of bioorganic materials in spintronics and optoelectronics on the example of melanins

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Living systems possess the capability for high-fidelity synthesis of three-dimensional nanoscale architectures comprising both organic and inorganic materials. The levels of spatial resolution and topological complexity achievable through this biological synthesis remain unattainable by even the most advanced lithographic techniques. However, the utilization of living systems for fabricating human-desired nanostructures faces several fundamental limitations:

- The thermodynamic existence range of the target material – primarily defined by parameters such as temperature and pressure – must overlap with the thermodynamic existence range of life.
- The relatively limited repertoire of known catalytic approaches employed by living systems.
- The current constraints of synthetic biology in developing effective prompting approaches to stimulate living systems to synthesize target materials, even when limitations (1) and (2) have been addressed.

Currently, a high degree of topological control over synthetic DNA is achievable [1], enabling the utilization of this polymer as a precision template. Control over protein topology remains more limited; however, this situation is rapidly improving due to the vast repository of protein structural data and advances in neural network approaches [2]. The situation is significantly more constrained for the other two classes of biological polymers: precise topological control of synthetic melanins [3] and polysaccharides remains elusive, despite being characteristic of living systems. Overcoming this limitation is essential, as melanins — being polysemiquinone-stabilized π-radicals — possess unique charge transport characteristics [4], optical properties, magnetic [5], and structural [6] behavior that render them fundamentally distinct from other biopolymers. This presentation will survey current phenomenological data pertinent to biopolymers, primarily melanins, of interest for developing optoelectronic and spintronic devices. Key phenomena to be discussed include photocurrent generation, formation of magnetically ordered phases, chiral-induced spin selectivity (CISS) [7], and others.

Bibliography

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