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Learning from nature – sustainable bioelectronics based on hydrogen-bonded pigments

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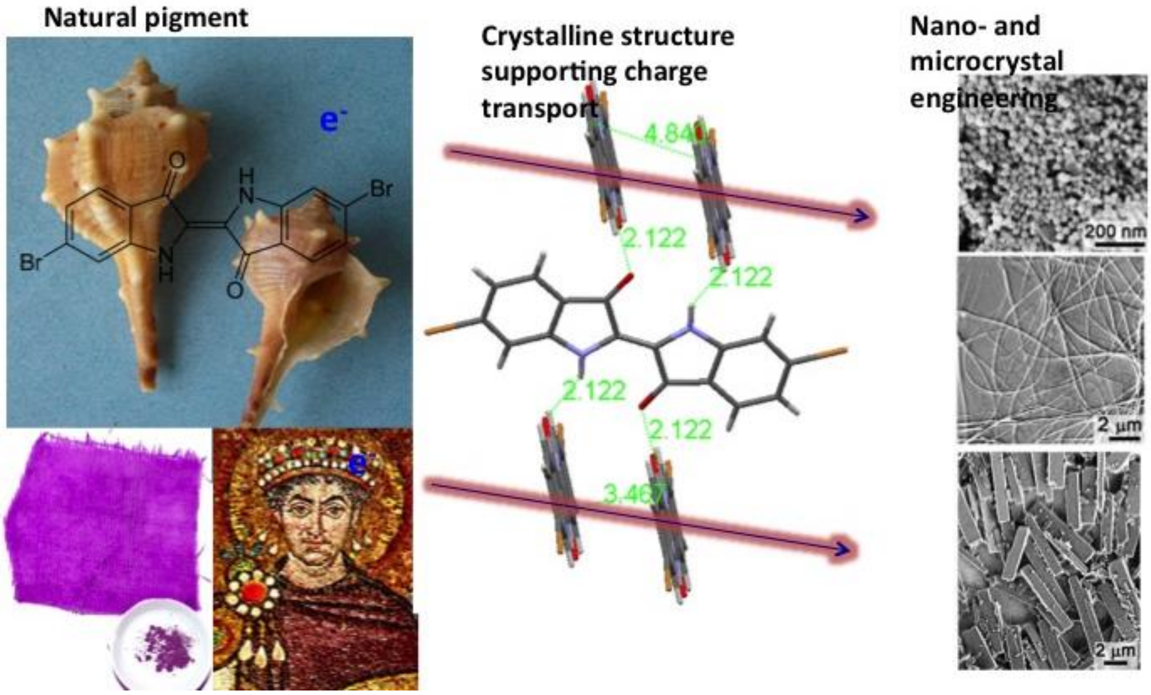
Many natural chromophores have recently emerged as suitable semiconducting materials for (opto)electronic applications. The motivation for exploring such molecules is the realization of biodegradable and biocompatible electronics fabricated from cheap and nontoxic materials. We find that natural pigment-forming dye molecules, such as those from the indigo family, form highly-ordered thin films with excellent π-stacking. Using such films, we have demonstrated field-effect transistors (FETs) and complementary-like circuit elements utilizing exclusively natural materials operating at the state-of-the-art level with respect to mobility and operational stability in ambient conditions. These dyes show air-stable ambipolar charge transport with balanced hole and electron mobilities in the range of $1\times10^{-2} – 2$ cm^2/Vs. A very important property is that these molecules form high crystal lattice energy solids with exceptional operational, thermal, and chemical stability. FETs with indigos can be operated without any passivation in highly-demanding aqueous environments, within a pH range from 3-11 and with a variety of different ions. We report on the results of stressing tests in such underwater environments. The –NH and =O functional groups lend themselves to easy functionalizing, which we have exploited to two ends: 1) creation of stable colloidal nanocrystals with controllable morphology and optical properties, and 2) biofunctionalization. Experiments concerning field-effect transistor biodetectors based on these materials will also be discussed. Hydrogen-bonded natural and nature-inspired materials are an interesting and previously unexplored class of organic semiconductors with inherent potential for biointegrated applications.



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