A method to change the mechanical and transport properties of conductive polymers

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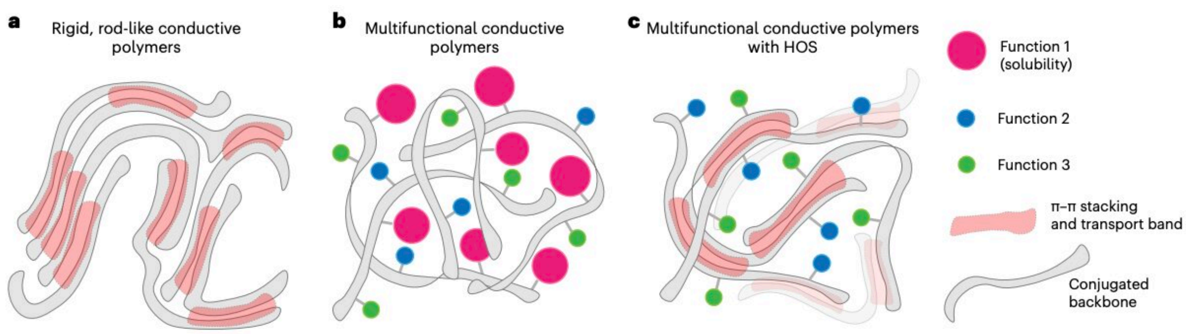

Proposed chemical and morphological evolution of conductive polymers. a–c, Schematic illustration of polymer chain arrangements in rigid, rod-like conductive polymers (a); multifunctional conductive polymers (b) and multifunctional conductive polymers with HOS (c). Credit: Zhu et al. (*Nature Energy*, 2023).

Conductive polymers, synthetic substances with large molecules that can conduct electricity, can have a broad range of valuable applications. For instance, they have been used to create sensors, light-emitting diodes, photovoltaics and various other devices.

In recent years, these conductive materials have proved to be particularly promising for the creation of energy conversion and storage devices, including batteries. However, methods for adding these functionalities are not always reliable, which significantly limits the large-scale implementation of batteries based on these materials.

Researchers at the Lawrence Berkeley National Laboratory and the University of California, Berkeley, have recently introduced a strategy that could help to reliably develop hierarchically ordered structures (HOS) with well-defined shapes in conductive polymers. This strategy, introduced in a paper published in *Nature Energy*, could open new possibilities for the creation of high-performing battery technologies, particularly lithium-ion batteries.

"In the conventional design of conductive polymers, organic functionalities are introduced via bottom-up synthetic approaches to enhance specific properties by modification of the individual polymers," Tianyu Zhu and his colleagues wrote in their paper. "Unfortunately, the addition of functional groups leads to conflicting effects, limiting their scaled synthesis and broad applications. We show a conductive polymer with simple primary building blocks that can be thermally processed to develop hierarchically ordered structures (HOS) with well-defined nanocrystalline morphologies."

Instead of changing the primary structures of conductive polymers, as done in previous works, Zhu and his colleagues explored the possibility of forming well-organized 3D architectures on the materials. These structures could enable desirable functionalities without the need to increase a polymer's primary structural complexity.

The researchers' proposed approach to form these structures is based on a controlled thermal process. As part of their study, they specifically used it to improve the mechanical and transport properties of a conductive polymer called poly(9,9-dioctylfluorene-co-fluorenoneco-methylbenzoic ester) or PFM.

"Our approach to constructing permanent HOS in conductive polymers leads to substantial enhancement of charge transport properties and mechanical robustness, which are critical for practical lithium-ion batteries," Zhu and his colleagues explained in their paper. "Finally, we demonstrate that conductive polymers with HOS enable exceptional cycling performance of full cells with high-loading micron-size SiO_x-based anodes, delivering areal capacities of more than 3.0 mAh cm^{-2} over 300 cycles and average Coulombic efficiency of >99.95%."

Initial evaluations conducted by this team of researchers yielded very promising results, highlighting the promise of their approach in enhancing the functionalities of conductive polymers. Zhu and his colleagues then showed that these enhanced polymers enable the creation of highly performing lithium-ion batteries.

While the researchers so far primarily applied their method to the polymer PFM, it could potentially be used to change the transport properties of a wide range of other conductive polymers. This means that it could aid the development of numerous technologies and devices, including biological sensors, displays and photovoltaics, for instance helping to increase their stability, transport efficiency, and durability.

More information: Tianyu Zhu et al, Formation of hierarchically ordered structures in conductive polymers to enhance the performances of lithium-ion batteries, *Nature Energy* (2023). DOI: 10.1038/s41560-022-01176-6