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# Symposium SB12-Conductive Biological Materials

## Self-Assembling Proteins for Bio-Electronics

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Bioelectronics is a fast-growing field of research aimed at controlling the interface between biological systems and electronic devices, which requires the conversion of biological signals into electrical signals usable by conventional electronic devices. Here we demonstrate the potential of protein nanowires resulting from the self-assembly of the prion domain of a filamentous fungus protein. These nanowires are in fact functional, non-pathological amyloid fibres; they perform a biological function, namely recognition of the self and non-self of a filamentous fungus. With a diameter of 5 nm and an average length of 12  $\mu\text{m}$ , these nanowires, whose structure is known on an atomic scale, have a high aspect ratio **(1)**. What's more, hydrogels can be obtained in an easily controllable way **(2,3)**. Like all amyloid fibres, these nanowires have specific optical properties **(4)**, as well as very good intrinsic ionic/protonic conductivity **(2)**. Finally, the addition of a redox protein domain **(2)** or a redox chemical compound **(3)** on the prion domain gives them electronic conductivity. After self-assembly of the prion domains, these redox domains are aligned along the nanowire axes, enabling electronic conductivity by electron hopping.

Measurements of ionic and electronic conductivities will be described from the macroscopic scale (film) to the nanoscopic scale (single nanowire). Applications that take advantage of the various properties of these nanowires will be illustrated. For the first application, the ability to form a hydrogel and the ionic conductivity of nanowires make it possible to produce a biocompatible electrode coating for the primary culture of neurons over very long periods and to detect neuronal electrical activity. For a second application, in the field of sensors, electronically conductive nanowires, which can transport electrons over long distances, can be used as redox mediators between enzymes and glassy carbon electrodes **(2,3,5)**.

These results represent a first step towards innovative all-in-one materials for bioelectronics. Overall, we have observed that our nanowires formed by the self-assembly of a functional, non-pathological prion domain combine all the properties needed to bridge the gap between the world of biology and that of technology, particularly electronics.

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- (2) Altamura et al. A synthetic redox biofilm made from metalloprotein-prion domain chimera nanowires. *NATURE CHEMISTRY* **9**: 157-163 (2017)
- (3) Duraffourg et al. Hybrid Amyloid-Based Redox Hydrogel for Bioelectrocatalytic H<sub>2</sub> Oxidation. *Angew Chem Int Ed Engl.* **60**: 14488-14497 (2021)
- (4) Pansieri et al. Ultraviolet-visible-near-infrared optical properties of amyloid fibrils shed light on amyloidogenesis. *NATURE PHOTONICS* **13**: 473-479 (2019)
- (5) Rengaraj et al. Interprotein Electron Transfer between FeS-Protein Nanowires and Oxygen-Tolerant NiFe Hydrogenase. *Angew Chem Int Ed Engl.* **56**: 7774-7778 (2017)