Water-Responsive *Bombyx Mori* Silk for High-Energy Actuators

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Water-responsive (WR) materials mechanically swell and shrink in response to changes in relative humidity, and have demonstrated the capability to exert high actuation energy per unit volume than conventional actuators and artificial muscles. As a result, WR materials have recently gained attention as potential high-energy actuating components for various engineering applications, including robotics, shape morphing, and smart structures. Despite the growing interest in this emerging category of WR materials, the fundamental WR mechanism of their significant performance is still not fully understood, limiting any rational design. In our previous studies, it was found that by increasing the silk's mechanical stiffness or adding stiff silica nanoparticles, *Bombyx (B.) mori* silk's WR actuation energy density can be dramatically increased from 0.2 to 1.6 MJ m^{-3}, surpassing that of all known natural muscles. Moreover, our recent study has identified the critical role of nanoporous structures in silk's WR actuation, and the possibility of controlling and enhancing silk's WR strain and energy density by tuning nanoporosity. Our findings revealed that while water adsorption and WR strain of silk increased with porosity, there exists a specific range of porosities that yield optimal WR actuation energy density of 3.1 MJ m^{-3}. These findings suggest that mechanical stiffness and pore structure-dependent water properties could play a crucial role in silk's WR performance. The availability and processability of *B. mori* silk offer possibilities for simple and scalable modification and production of high-energy WR actuators.