Researchers develop bioinspired Bouligand structure for enhanced mechanical properties

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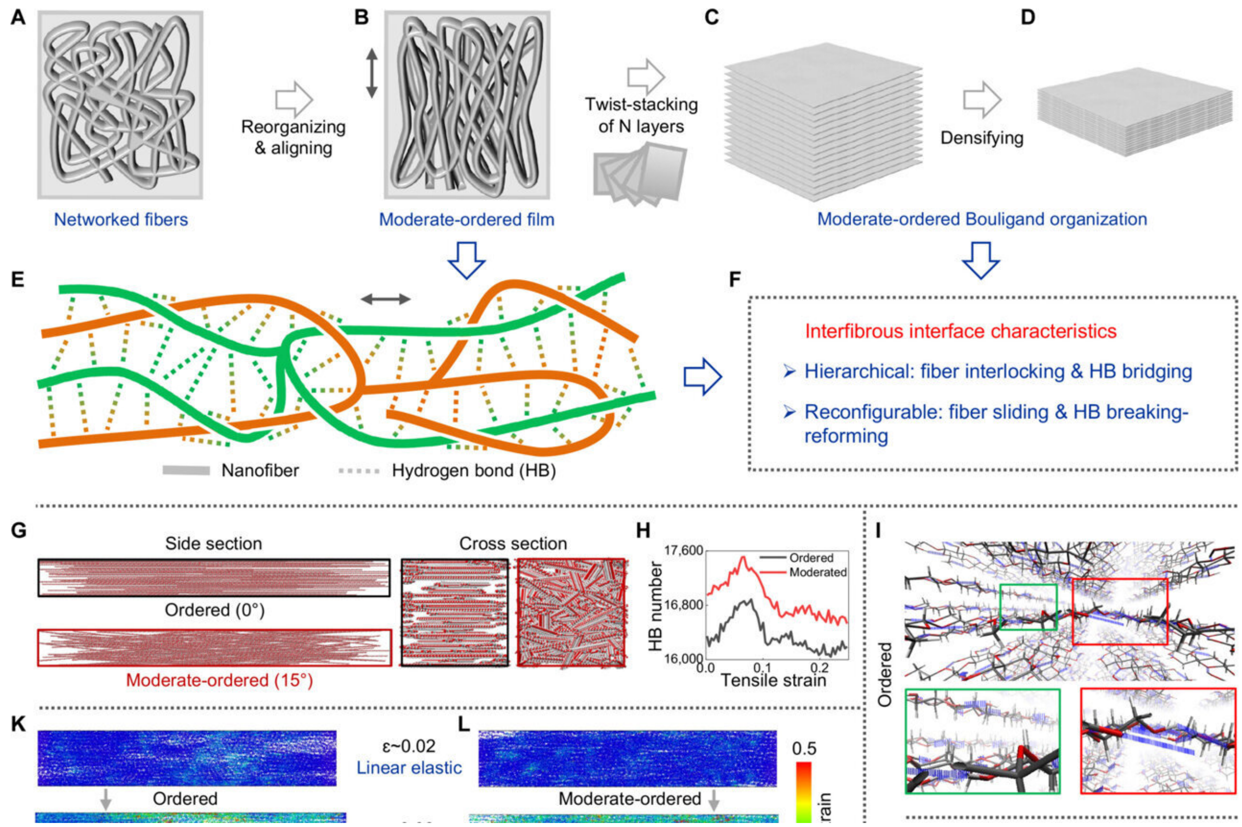

Hierarchical and reconfigurable interfibrous interface of bioinspired Bouligand structure enabled by moderate orderliness. (A to D) Schematic of fabricating moderate-ordered bioinspired Bouligand structure based on networked nanofibers. (E and F) Hierarchical and reconfigurable interfibrous interface of the moderate-ordered bioinspired Bouligand structure. (G) Side-sectional and cross-sectional snapshots of the initial simulated ordered (0° orientation angle) and moderate-ordered (15° orientation angle) models assembled by cellulose chains. (H) Number and evolution of HBs as the function of tensile strain. (I and

J) 3D snapshots of the initial simulated ordered model and moderate-ordered model, showing the more stereoscopic HB (blue line) network bridging within the latter. (K and L) Snapshots of the ordered and moderate-ordered models at three typical deformation stages. The shear strain distribution indicates the relative sliding of cellulose chains at the plastic stage and the stronger failure-resistant capability of the moderate-ordered model. Enlarged snapshots show chain interlocking within the moderate-ordered model and chain separation within the ordered model. Credit: *Science Advances* (2024). DOI: 10.1126/sciadv.adl1884

Bouligand structures, found in natural materials like fish scales, lobster peritoneum and bones, are known for providing exceptional mechanical properties to biomaterials. While progress has been made in creating bioinspired materials, most research has focused on putting the fibers together. A deeper understanding of how the fibers interact to enhance the mechanical functions is needed now.

A research team led by academician Yu Shuhong of the University of Science and Technology of China (USTC) of the Chinese Academy of Sciences (CAS) has introduced a bioinspired Bouligand structure with a hierarchical and reconfigurable interfibrous interface that significantly boosts mechanical strength and toughness through dynamic load transfer and energy dissipation, offering a new strategy for creating advanced structural materials.

The paper is published in the journal *Science Advances*.

The team had initially used bacterial cellulose nanofibers as a model matrix but struggled to understand how nanofiber orientation influenced micromechanical behavior. To tackle this problem, they conducted large-scale molecular dynamics simulations with different orientation angles.

The results revealed that optimizing the hydrogen-bonding network dimension through cross-linking structures improved load transfer capacity and damage resistance.

Moreover, the team observed that excessive orientation angles weakened load transfer efficiency and interchain hydrogen bond density, resulting in decreased mechanical properties. This highlighted the importance of moderate orderliness for optimal interfacial interaction.

Moderate orderliness integrated microstructure and hydrogen bonding, outperforming high structural orderliness due to tradeoffs among structural orientation, fiber interlocking and hydrogen bonding network dimensions.

In addition, the team identified a large shadow zone around cracks, and revealed micro-motion of nanofiber primitives. Cross-polarizing light was used to monitor this micro-motion within the membrane layer, enabling the preparation of bioinspired Bouligand structural materials with multiscale coupling through helical stacking and hot-press densification.

USTC's bioinspired Bouligand structure enabled by moderate orderliness exhibits outstanding mechanical properties and dimensional stability, and may have applications in biomedical fields such as fibrocartilage tissue repair and replacement.

More information: Si-Ming Chen et al, Hierarchical and reconfigurable interfibrous interface of bioinspired Bouligand structure enabled by moderate orderliness, *Science Advances* (2024). DOI: 10.1126/sciadv.adl1884