

YOSHIE LAB.

[Material Design Based on Polymer Dynamics Control]

Integrated Research Center for Sustainable Energy and Materials

Environment-Conscious Polymeric Materials Science

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We create new high-performance materials such as tough and self-healable elastomers and nano-patterned surface, by dynamically controlling hierarchical structure of polymeric materials spanning from molecular to mesoscopic scales.

Bio-inspired tough elastomer

The diagram illustrates the inspiration from mussel byssus. On the left, a photograph of a mussel and a scanning electron micrograph (SEM) of its byssus are shown. An arrow labeled "inspired" points to a schematic of a polymer network with dynamic crosslinks. Below this, a chemical structure shows "Dynamic crosslinks by quadruple hydrogen bonds" between polymer chains. To the right, a photograph shows a yellow elastomer being stretched and then returning to its original shape, labeled "Tough & Self-recoverable".

Mussels have a string-like tough organ called *byssus* to fix themselves to rocks. Inspired by the multiphase structure formed by dynamic crosslinks in byssus, we developed a new material with high toughness and excellent self-secoverability.

Seawater-assisted self-healable elastomer

The diagram shows a yellow elastomer being cut and then submerged in water. A schematic illustrates the "Cut then Hydrolysis" process, where the material is "Healed by Re-attachment". A photograph shows the healed material with a vertical seam. A circular inset shows a magnified view of the seam, labeled "High healing efficiency (~91%)".

Self-healing in polymeric materials assisted by water is gaining much attention. However, such a material is generally hydrophilic and hence its mechanical property decreases in water. Using hydrophobic dynamic bonds (boronic ester) we developed an elastomer that is stable and self-healable in sea water.

Functional materials by tuning dynamic structure

Rigid & water-proof organic/inorganic nanohybrid

The diagram shows the synthesis of a nanohybrid. It starts with "Surface modification" of a substrate, followed by "in situ polymerization" in a beaker containing a 50 g weight. The resulting material is shown as a layered structure.

Nacre in sea shells is an organic/inorganic nanohybrid consisting of alternating layers of plate-like minerals and organic polymers and is known for its high rigidity and low permeability. However, artificial nacre-mimetic materials are often water-sensitive because of high hydrophilicity of the inorganic component. We developed a rigid, water-proof nanohybrid by combining the surface modification and in situ polymerization techniques.

Nano-patterning by dynamic phase separation

The diagram illustrates the process of nano-patterning. It shows a "Solvent crystal" being used to pattern a surface. The resulting structure is a "poly(L-lactide)/poly(1-butene) Lamella in lamella structure", with a scale bar of 0.5 μm. The structure consists of alternating "secondary lamella" and "primary lamella".

Just like water and oil, a blend of two different polymers phase-separate and form poorly ordered structure. We discovered a method to fabricate highly ordered nano-patterns from simple polymer blends based on freezing of the directional phase separation process.