【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Chemistry)

Title of Project : Utilizing the Sacrificial Bonding Principle to Create Soft-Hard Composites with Toughness that Surpasses Metals and Novel Functions

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Research Area : Polymer Science
Keyword : Composite, Polymeric Materials, Soft Matter, Gel, High Toughness

【Purpose and Background of the Research】

Our group has proposed a "sacrificial bonding (s-bond) principle" for toughening gels and elastomers, which has enabled the production of unique materials such as double network hydrogels, which contain 90% water but are mechanically comparable to robust industrial rubbers. However, many materials which require high strength rely on stiff reinforcements, resulting in materials like fiber-reinforced plastics (FRP) which are strong and light-weight materials. Recently, we have observed that soft/hard composites whose soft phase is composed of tough, soft materials based on the s-bond principle possess extremely high toughness (tougher than metal) due to the synergetic combination of the two phases. Based on this preliminary result, in this project we will adopt the s-bond principle to soft/hard composites to create a new field of composite materials whose toughness dramatically exceeds that of conventional tough hard materials such as metals and FRPs. Through these studies, we will attempt to establish a scientific model to understand and optimize toughening of soft/hard composite materials.

【Research Methods】

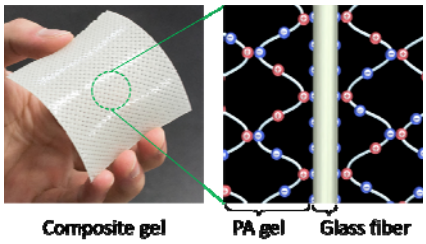

Figure 1. An example of a tough soft/hard composite whose soft phase works as s-bonds.

Our research plan is to fabricate tough soft/hard composites through the following two methods: 1. combining specially-designed, s-bond containing soft phases with conventional hard materials such as glass fibers and metal; 2. combining specially-designed hard phases working as s-bonds with compliant soft phases. Examples of both approaches are shown in Figures 1 and 2.

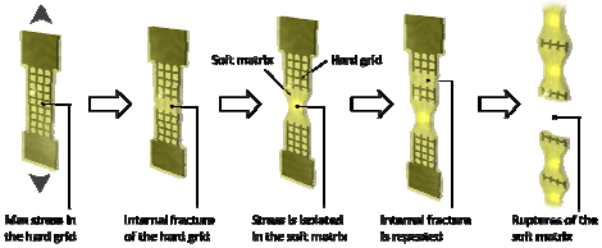

Figure 2. A design of a tough soft/hard composite whose hard phase works as s-bonds.

The effect of sacrificial bonds on the mechanical properties of the composites will be investigated by measuring the energy dissipation during deformation and fracture.

【Expected Research Achievements and Scientific Significance】

Previous research on conventional hard/hard composites has concentrated on their mechanical properties at small strain, such as modulus. In contrast, in this project we will focus on energy dissipation upon large deformation, which plays an important role for toughening of soft materials. This study will lead to a general understanding of soft/hard composites, which may possess properties which greatly surpass current structural materials.

【Publications Relevant to the Project】

Y. Huang, D. R. King, T. L. Sun, T. Nonoyama, T. Kurokawa, T. Nakajima, J. P. Gong, *Adv. Funct. Mater.*, 27(9), 1605350 (2017).

D. R. King, T. L. Sun, Y. Huang, T. Kurokawa, T. Nonoyama, A. J. Crosby, J. P. Gong, *Mater. Horiz.*, 2(6), 584-591 (2015).

【Term of Project】 FY2017-2021

【Budget Allocation】 157,000 Thousand Yen

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