Development of Dynamic Bionanostructures Based on Peptides

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Peptides are useful building blocks for the development of nanostructures that mimic, control, and transcend naturally occurring biological supramolecules because of the target recognition and self-assembly capability by rational design.[1] We developed and controlled the dynamic functions of bionanostructures based on peptide chemistry. Firstly, a peptide that binds to the inner surface of microtubules was constructed to encapsulate nanostructures into microtubules. Secondly, propulsion systems driven by light-induced peptide nanofiber growth were developed.

1. Modulation of microtubules by molecular encapsulation using a Tau-derived peptide

Microtubules are hollow cytoskeletons (15 nm inner diameter) composed of tubulin proteins. By combining with motor proteins, microtubules are utilized as components of dynamic materials such as active matters. Although the functionalization of the "outer" surface of microtubules has been established, the "inner" space has not been focused and there was no method to introduce molecules inside microtubules. We developed a Tau-derived peptide (TP) from a Tau protein as a binding motif to the inner surface of microtubules (Fig. 1a).[2] By using TP, various nanostructures were introduced inside microtubules to modulate their structures and functions (Fig. 1b).[3] We found that GFP can be encapsulated to microtubules by linking TPs and that the GFP-encapsulated microtubules showed increased length, rigidity, stability, and velocity.[4] Also, we succeeded in constructing "magnetic microtubules" that aligned in response to weak magnetic fields with increased velocity by the formation of magnetic CoPt nanoparticles inside microtubules using TP.[5] In addition, TP-based cyclic peptides were shown to stabilize the microtubule structures by stronger binding to microtubules than TP.[6] We also discovered that TP binds to microtubules in living cells.[7] Through these researches, we developed new design

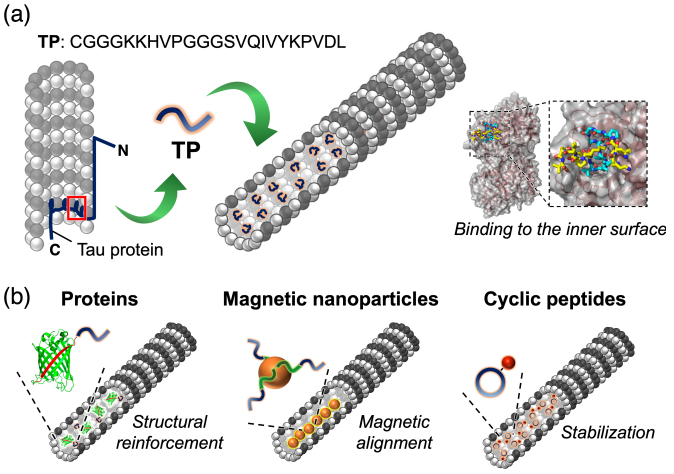

Fig. 1. (a) Tau-derived peptide (TP). (b) Encapsulation of nanomaterials inside microtubules by using TP

guidelines for modulation of microtubules from their inside by using TP. In the future, we expect the development of microtubule-based materials such as nanodevices and molecular robots, as well as cell manipulation by controlling intracellular microtubules.

2. Development of propulsion systems driven by light-induced peptide nanofiber growth

Controlling the movement of micrometer-sized particles by light has attracted attention in the field of nanoscience. Inspired by bacteria that use actin filament formation for their intracellular movement, we developed propulsion systems driven by light-induced peptide nanofiber growth. UV light irradiation to the DNA-peptide conjugate which consists of a nanofiber-forming peptide and DNA connected by a photocleavage amino acid results in the release of the peptide and subsequent formation of nanofibers. By introducing the DNA-peptide conjugate into one side of phase-separated giant liposomes, UV light irradiation induced the local formation of nanofibers on the surface to promote the propulsion of the liposomes (Fig. 2a).[8] The directional propulsion of DNA microspheres (nucleospheres) composed of DNA three-way junctions was also achieved. In this system, the filled structures of nucleospheres were utilized to promote local nanofiber growth on the light-irradiated side, resulting in the propulsion with negative phototaxis (Fig. 2b).[9]

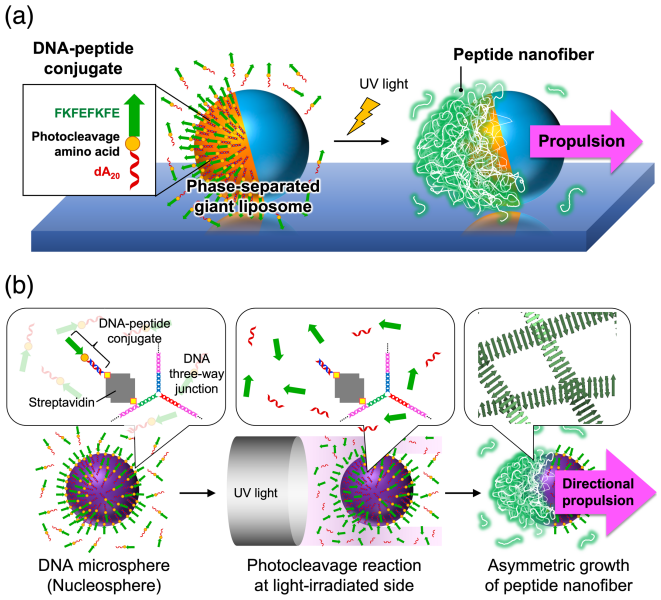

Fig. 2. Propulsion of (a) giant liposome and (b) nucleosphere by light-induced peptide nanofiber growth.

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