Fabrication of functional biomimetic materials by combination of different materials and properties

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【Introduction】

The material used by organisms are attracted attention not only its functions but also its sustainability. Whereas the human causes many problems such as marine pollution, the organisms achieves a complete natural circulation and generate multifunction using biodegradable materials[1]. In addition, superior functions of organisms are generated by the surface microstructure and the combination of different properties. Those functions can be realized by investigating the mechanism and the mimicking the microstructures[1]. In this thesis, as the development of low environmental load packaging materials, I have prepared cellulose nanocrystals (CNC) / chitosan composite films having and multi-functions. Furthermore, I have focused on clingfish having sucker, which has a mucus-covered nanofilaments, and investigated a new adhesive mechanism.

【Experiment Ⅰ】CNC / chitosan composite film having multi-functions.

CNC/ chitosan composite film has attracted attention as alternative materials for synthetic plastics, which cause marine pollution. The composite film has the characteristics required for packaging materials, such as high barrier properties, biodegradability, and antibacterial properties. However, this film lacks heat-sealing properties[2], which is an indispensable property for food packaging. In this study, imparting sealing properties to the film using hydrogen bonds between molecules (hornification[3]) are reported.

The CNC/chitosan mixed acetic acid aqueous solution (chitosan mixing ratio: 0% (CNC only), 25%, 50%, 75%, 100% (chitosan only)) were dropped on white kraft paper. After drying and removing acetic acid, the two same samples were stuck by using water or heat. The seal strength of sealed sample were measured by using a tensile tester.

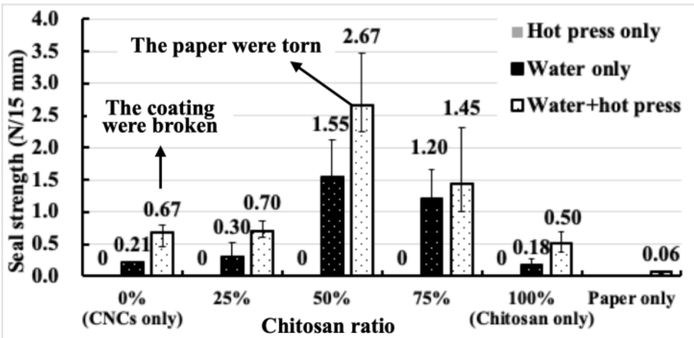

Fig. 1 Graph of seal strength

Fig. 1 shows the sealing strength of each sample. The film could not be sealed by hot press only, but its can be sealed by wetting the surface.

In addition, the rapid drying of moisture by hot press increased the sealing strength. These results indicated that the sealing were achieved by the hornification of CNC and chitosan. The samples with a weight ratio of 50% showed the strongest seal strength in all sealing conditions. We considered that the improvement of material strength increases the sealing strength.

【Experiment Ⅱ】A new adhesive mechanism learning from a clingfish surface microstructure

A clingfish sucker disc has the mucus-covered nanofilaments on the edges, and it is considered to affect adhesive strength[4]. However, these function was still obscure. We considered that important factor of adhesion; softness (Adhesion, increasing contact area) and hardness (Cohesion, resistance against peeling) are achieved by soft mucus and hard nanofilaments. This mechanism had been investigated by measuring the adhesive strength of the mimicked structure and finite element method simulation.

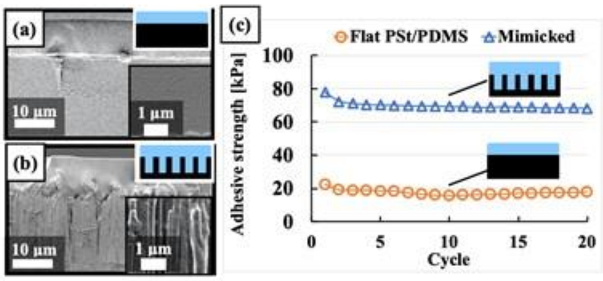

Fig. 2 Cross-sectional FE-SEM images of (a) the flat PSt/PDMS and (b) the mimicked structures. (c) Graph of the adhesive strength of the cycle test.

Fig. 2 show the FE-SEM images of flat PSt/PDMS structures (Fig. 2(a)) and mimicked structures in which the nanofilaments were filled by PDMS (Fig. 2(b)). The adhesive strength of mimicked structures were four times stronger than that of the flat PSt/PDMS, and the protection of nanofilaments by PDMS allowed repeated adhesions (Fig. 2(c)).

The simulation results were shown in Fig. 3 The deformation stress of the flat PSt/PDMS were concentrated on the edge of adhesive failure (red arrow in Fig. 3(b)), and its state leads easy peeling. On the other hand, the deformation stress of mimicked structures were not concentrated because the deformation stress were dispersed to the PSt filaments (Fig. 3(d)). According to the results, the nanofilaments enhance the adhesive strength due to deformation stress dispersion.

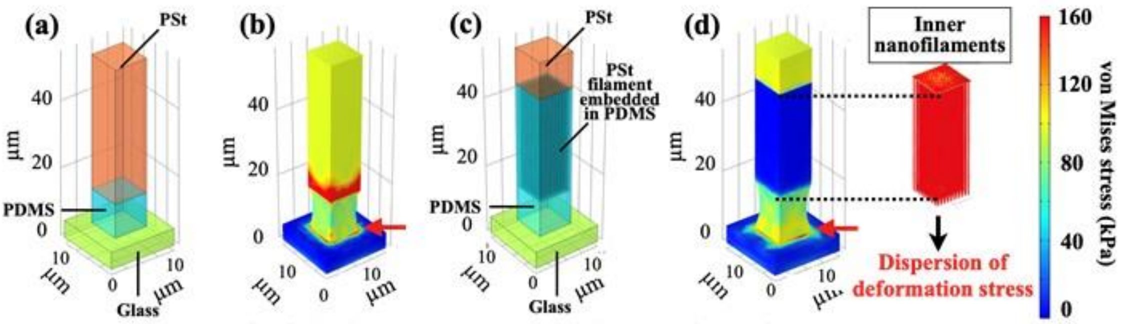

Fig. 3 (a, c) The models and (b, d) FEM simulation results of (a, b) the flat PSt/PDMS and (c, d) the mimicked structures.

【Reference】

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