Water-free process for natural polymer aerogel

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Polymers widely found in nature such cellulose, chitin, polypeptide, rubber are of great interests as source of bioplastics that are promising alternative materials of petrochemical polymers. Especially their nano-scaled products such nanofiber, nanowhisker and nanoparticle have unique features so called "Nano effects" that come up from extremely large surface area of the nanomaterials. A representative application of the Nano effects is to enhance mechanical properties of base plastics by assembling with the nano substances. In order to obtain a new filler material for lighter and stronger composite, we have attempted to prepare sponge-like cellulose aerogel that is the lightest three-dimensional sustainable biopolymer, using chemical treatment and supercritical fluid extraction for the last decade. The process basically consists of (1) preparation of cellulose solvent-gel using strong hydrogen bond acceptor, tetrabuthyl ammonium fluoride, (2) substitution of the solvent with alcohol that is easily removed by supercritical CO_2, and (3) extraction of the alcohol in gel by supercritical CO_2 that is well-used as a non-aqueous medium having significantly low surface tension to maintain porous aerogel structure. We optimized the experimental conditions and obtained a cellulose aerogel having 30-40 mg/cm^3 of density and 0.8-3.1 kPa of compressive modulus depending on cellulose dose by this process [1].

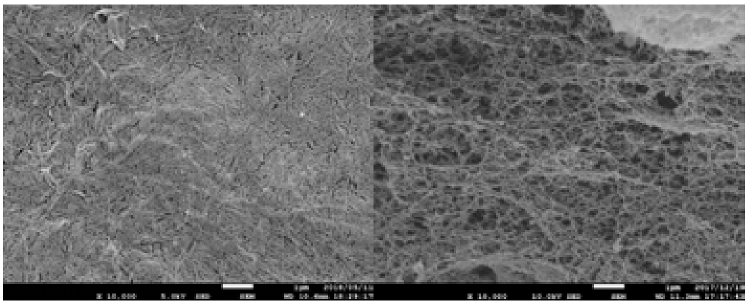

Figure 1. SEM images of cellulose nanofibers disintegrated by mechanical treatment in water with (left) and without (right) sericin after supercritical CO_2 extraction

Recently, the process above was simplified by skipping substitution process (2). This improvement not only saved time for whole process but also reduced the shrinkage of the gel, resulting in more uniform and smaller pores of the aerogel [2]. The process set with (1) and (3) was also undertaken for cellulose nanofiber disintegrated by mechanical treatment without any chemicals and dispersed in water taking medical applications into account. Any sponge-like material was not obtained from the cellulose nanofiber dispersed in water, although a sheet-like material was found in a high pressure-vessel after supercritical CO_2 extraction. On the other hands, adding a silk protein, sericin into the aqueous solution containing cellulose nanofiber promoted its gelation and the bulky aerogel was prepared as their scanning electron microscopic images are shown in Figure 1 [2].

At present, we have been preparing an aerogel of another silk protein, fibroin from the nanofiber disintegrated in water by mechanical treatment followed by supercritical CO_2 extraction. The fibroin aerogel is going to be tested for tissue scaffold, and influences of the aerogel morphology e.g. pore size, pore volume, specific surface area on the formation of new viable tissue will be investigated.

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References

[1] Y. Koyama, "Preparation of nonligneous cellulosic aerogel using high pressure CO_2", *Master Thesis at Graduate School of Science and Technology, Kyoto Institute of Technology*, 2013.

[2] S. Ueeda, Y. Okahisa, E. Kotani, S. Okubayashi, "Preparation of natural polymer aerogel using supercritical carbon dioxide", *Proceedings of the 71st Annual Meeting at The Textile Machinery Society of Japan*, p65, 2018.