Novel Design of Nano-Silica Network in Polypropylene Using Sol-Gel Method with Supercritical Carbon Dioxide

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Properties of polymer based nanocomposites have been dramatically influenced by the introduction of a network structure, which are usually made by either polymer-filler or filler-filler interaction. However, the aploar nature of polypropylene (PP) makes it extremely difficult to construct a network structure, where inorganic fillers tend to severely agglomerate in the PP matrix. In this study, the impregnation of silica precursors using supercritical carbon dioxide (sc-CO_2) and the sol-gel method were combined to overcome this difficulty. The process is composed by two steps: (1) impregnation of the silica precursor in PP amorphous region using sc-CO_2, (2) sol-gel reaction of the precursors in the matrix (Figure 1). Since the silica precursor is only impregnated in the amorphous region, it is expected that a filler network forms in continuous amorphous phase as a template.

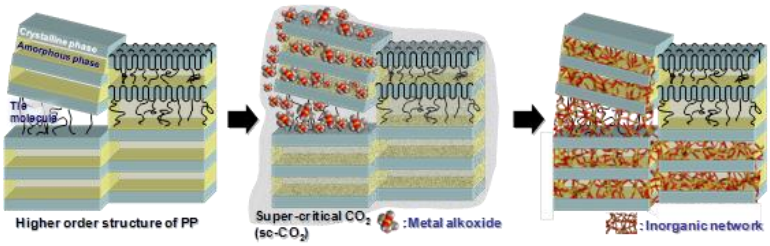

Figure 1. Synthetic images

The silica was synthesized in confined amorphous region of PP, which results in the generation of nano-scale silica, and the establishment of relationship between the structure of formed silica and properties of resultant nanocomposites was tried by changing conditions of sol-gel reaction. Silica network structures were successfully constructed in PP at low silica loading. The relationship between the structure of formed silica network and properties of nanocomposites was established, where formation of silica showing lower mass fractal dimension led to high reinforcement both in solid state and in molten state.

Since silica is synthesized in only PP amorphous region, it was expected that the morphology of synthesized silica is controlled by the amorphous region as a template. Silica was also synthesized in PP with different higher structure. The size and shape of silica was controlled by amorphous region of PP also due to confinement by PP amorphous region. Sol-gel template synthesis using amorphous region of PP was newly proposed as new method to control morphology of silica synthesized through sol-gel method combined with template approach.

As a final attempt, mimicking nacre structure was performed. Nacre has a hierarchical structure, which induce far excellent mechanical properties in contrast to artificial mixture of their component. To mimic nacre structure, BOPP films were laminated, and then sol-gel reaction was performed after impregnation of BOPP with silicon alkoxide. The drastic reinforcement was obtained by incorporating silica not only into amorphous part of BOPP and interface between laminated thin BOPP films.

It was believed that obtained results contribute not only to academic but also to industrial field. Since the method led to effective network formation, it is expected that various properties such as electro or thermal conductivity are added by incorporating other oxide materials such as tin or alumina oxide. In addition, the films after processing is possible to reinforce by incorporating filler using sol-gel method combined with the impregnation.

Key Words: Polypropylene, Nanocomposite, Sol-gel method, Supercritical carbon dioxide, Network structure