Laboratory of Polymeric Materials

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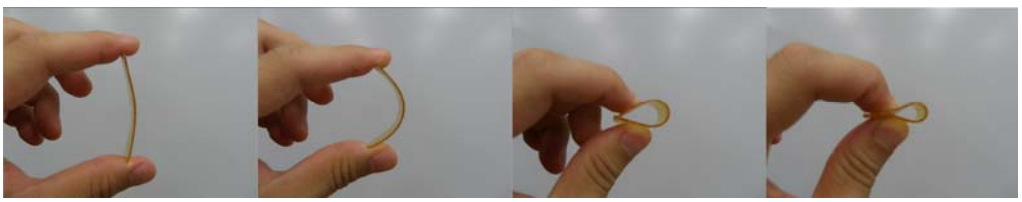
Plant Oil-Based Plastics

Recently, there has been great interest in bio-based polymeric materials, since usage of bioresources as starting substrate of polymeric materials halts greenhouse warming and contributes to global sustainability without depletion of scarce fossil resources. Natural oils are expected as an ideal alternative chemical feedstock, since oils, derived from both plant and animal sources, are found in abundance in the world. Inexpensive triglyceride plant oils have been used for production of valuable resins. However, these oil polymer-based materials do not show enough properties of rigidity and strength required for structural applications by themselves; oils have been used as a toughening agent to produce interpenetrating networks.

We have developed all bio-based polymer composites. The curing of epoxidized soybean oil (ESO) in the presence of electrospun PLLA nanofibers afforded the composite with relatively good transparency. The mechanical properties of the network polymer of ESO greatly improved by a combination of microfibrillated cellulose (MFC). The ESO / MFC composite exhibited the high storage modulus in the rubbery region of the ESO polymer, while the ESO polymer showed the enormous drop of storage modulus around its glass transition temperature. The tensile modulus and strength at break of the composites were much superior to those of the ESO polymer or the MFC sheet.

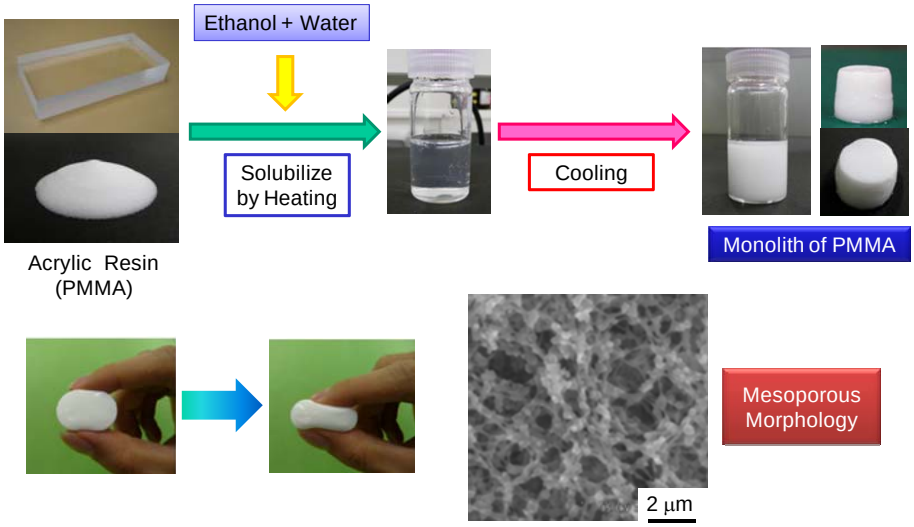
The curing of ESO in the presence of poly(caprolactone) (PCL) produced the composite with semi-IPN structure. The DSC and dynamic viscoelasticity analyses showed the good miscibility between the ESO polymer and PCL. The tensile modulus and stress as well as the elongation at break of the composite were much superior to those of the ESO polymer. This composite showed shape memory effect by utilizing the phase transition (melting) of PCL. By the addition of bio-based resin modifiers such as rosin derivatives to the ESO polymer, the resulting composite showed good bending strength; the composite did not crack even it folded back.



Functional Porous Polymer Monoliths

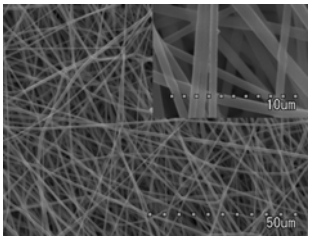
Porous polymer monoliths are a new category of materials developed during the last decade. The monolithic polymeric materials with well-defined pore properties and surfaces are suitable as chromatographic separation media, ion exchange resins, and catalyst supports. They are widely prepared by conventional radical polymerization in which phase separation or templating methods are utilized to tailor the meso- and macropore structure.

Poly(methyl methacrylate) (PMMA) is a conventional plastic, widely used as transparent organic glass. We have found that PMMA became soluble in a mixture of water and ethanol at 60 ^{o}C, although it is insoluble in both water and ethanol. The mesoporous PMMA monolith was formed by cooling the solution. This finding provides a new fabrication method of polymer monolith by the phase separation of PMMA from the solution. The porous structure could be controlled by the molecular weight of PMMA. From reactive methacrylate copolymers, functional polymeric monoliths were obtained, which have various applications in biomedical and analytical industries.



Nanofiber Technology for Bio-related Applications

Electrospinning is a convenient and straightforward process to fabricate non-woven mats of ultrafine fibrous polymers. The diameter of the electrospun fibers is often in the sub-micron range; in contrast, conventional polymer fibers are in the range of more than micron size in diameter. The small fiber diameter and non-woven morphology give rise to large specific surface area, which is advantageous in filter and biomedical applications.



We have fabricated nanofiber non-woven mats of polymer composites consisting of bioabsorbable gelatin and poly(L-lactic acid) (PLLA) via electrospinning. Mesenchymal stem cells well elongated and spread on the non-woven mats and the cells attached exhibited flat morphology, meaning that this non-woven mat has large potential for scaffold of tissue engineering. We have found that the electrospun nanofiber mat of biodegradable polymers was subjected to very fast enzymatic degradation, suggesting the nanofiber morphology is useful for evaluation of biodegradability of materials.