Physicochemical Properties of Polypropylene Surfaces and Their Biomedical Application

Naoshi Kawamoto[1]
Supervised by Prof. Dr. Minoru Terano
School of Materials Science, Japan Advanced Institure of Science and Technology

keywords polypropylene, surface, crystalline-amorphous microstructure, crystallinity, orientation, blood, protein, platelet, sorbed water

1 Abstract

The present dissertation describes a basis of the surface physics and chemistry of polypropylene, and blood-contacting properties of their surfaces. Polypropylene molded articles as sheets and films with various crystalline-amorphous microstructures were prepared by compression-molding and/or drawing using a series of polypropylene having several comonomer contents as starting materials. Physicochemical evaluation by way of spectroscopic, morphological, crystallographic, viscoelastic and mechanical methods, and biomedical evaluation in terms of protein adsorption and platelet activation were performed on the molded articles in order to clarify the crystalline structure at their surfaces.

[1]**Note:**The author was delegated fromCHISSO CORPORATION.
2-7-3 Marunouchi, Chiyoda, Tokyo 100, Japan

Crystallinity of the surface layer for the compression-molded polypropylene sheets was significantly lower compared with that of the bulk. Differences in crystallinity between the bulk and the surface layer were enhanced by increasing comonomer content of polypropylene as a starting material. Polypropylene formed into the monoclinic α crystal form even at the outermost surfaces. Remarkable lattice distortion of crystal unit-cell occurred at surfaces during compression molding. The distortion was ascribed to residual stress during processing. Aggregation state was quite different in the continuity of amorphous phase between the bulk and the surface layer for the sheets. Mechanical strength such as tensile and flexural strengths decreased drastically with decreasing surface layer crystallinity. Even at the outermost surfaces, c-axis orientation of crystallites parallel to the machine direction was proceeded in similar to the bulk by uniaxial drawing. The orientation of crystalline part was comparable to that of the amorphous part at the surfaces.

Protein adsorption onto polypropylene surfaces and platelet activation that were coming in contact with the surfaces changed with the variation of crystalline-amorphous microstructure such as crystallinity, long period, and orientation, resulting in improving blood-contacting properties at the surface with a particular microstructure. Adhesiveness of polypropylene surfaces and the structure of sorbed water into polypropylene were evaluated by peel test and IR spectroscopy, respectively. The blood-contacting properties were affected significantly by the macromolecular interaction, that is a probability in interaction between proteins and amorphous chains at polypropylene surfaces, and by the hydrophobic interaction in terms of structure of sorbed water. Excellent blood-contacting properties were achieved by the reduction in these interactions via optimizing the crystallinity and the orientation.

2 List of Publication and Patents

2.1 Original Articles

1. N. Kawamoto, H. Mori, K. Nitta, N. Yui and M. Terano, Characterization of the differences in the crystallinity from surface to bulk of compression-molded polypropene sheets using attenuated total reflection Fourier-transform IR spectroscopy, *Macromolecular Chemistry and Physics*, **197**, 3523-3530 (1996).

2. N. Kawamoto, H. Mori, N. Yui, K. Nitta and M. Terano, Effects of surface crystallinity on dynamic mechanical properties for compression-molded polypropene sheets, *Die Angewandte Makromolekulare Chemie*, **243**, 87-98 (1996).

3. N. Kawamoto, H. Mori, N. Yui, K. Nitta and M. Terano, Tensile and flexural behavior of polypropene sheets with different crystallinities of surface layer, *Die Angewandte Makromolekulare Chemie*, in press (1998).

4. N. Kawamoto, H. Mori, K. Nitta, S. Sasaki, N. Yui and M. Terano, Microstructural characterization of polypropene surfaces using grazing incidence X-ray diffraction, *Macromolecular Chemistry and Physics*, in press (1998).

5. N. Kawamoto, H. Mori, M. Terano and N. Yui, Blood compatibility of polypropylene surfaces in relation to crystalline-amorphous microstructure, *Journal of Biomaterials Science, Polymer Edition*, **8**, 859-877 (1997).

6. N. Kawamoto, H. Mori, K. Nitta, N. Yui and M. Terano, Crystalline structure at surfaces of uniaxially drawn polypropylene films, *Die Angewandte Makromolekulare Chemie*, in press (1998).

7. N. Kawamoto, H. Mori, N. Yui and M. Terano, Mechanistic aspects on blood-contacting properties of polypropylene surfaces-from the viewpoint of macromolecular entanglement and hydrophobic interaction via water molecules, *Journal of Biomaterials Science, Polymer Edition*, in press (1998).

8. N. Kawamoto, M. Terano and N. Yui, Blood-contacting properties of polypropylene surfaces, *Journal of Artificial Organs*, submitted (1998).

2.2 Reviews

1. N. Kawamoto, H. Mori, K. Nitta, N. Yui and M. Terano, Estimation of surface crystallinity for compression-molded polypropylene films using ATR-FT-IR Technique, *Surface Science of Crystalline Polymers*, N. Yui and M. Terano Eds., Kodansha Scientific, Tokyo 1996, p.45-50.

2. N. Kawamoto, H. Mori, N. Yui, K. Nitta and M. Terano, Characterization of surface layer in compression-molded polypropylene films using dynamic mechanical spectroscopy, *Surface Science of Crystalline Polymers*, N. Yui and M. Terano Eds., Kodansha Scientific, Tokyo 1996, p.61-68.

3. N. Yui, N. Kawamoto and M. Terano, Design of blood compatible polypropylene surfaces by controlling crystalline-amorphous microstructure, *Advances in Polymeric Biomaterials Science*, T. Akaike, T. Okano, M. Akashi, M. Terano, and N. Yui Eds., CMC, Tokyo 1997, p.15-32.

4. N. Kawamoto, H. Mori, N. Yui and M. Terano, Recent research tendency of the polypropylene surface properties, *Fine Chemicals*, **25**, 5-13 (1996).

5. N. Kawamoto, H. Mori, N. Yui and M. Terano, Feasibility of blood compatible polypropylene surfaces, *Function & Materials*, **17**, 41-53 (1997).

2.3 Patent Application

1. JP 8-219286 (Application Number)
   N. Kawamoto, M. Terano
   (patent rights for Chisso Corporation)

2. JP 8-219287 (Application Number)
   N. Kawamoto, M. Terano
   (patent rights for Chisso Corporation)

3. JP 8-277476 (Application Number)
   N. Kawamoto, N. Yui, M. Terano
   (patent rights for Chisso Corporation and Terumo Corporation)

4. JP 9-123205 (Application Number)
   N. Kawamoto, Y. Shiraishi, N. Yui, M. Terano
   (patent rights for Chisso Corporation and Terumo Corporation)

5. JP 9-264892 (Application Number)
   N. Kawamoto, Y. Shiraishi, N. Yui, M. Terano
   (patent rights for Chisso Corporation and Terumo Corporation)

February 20, 1998