

Design of ionic solvents for production of man-made cellulose and silk fibers

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Introduction

The making man-made fibers, mainly based on wood pulp, started since the late 19th century. Their industrial production, reaching a maximum in the middle of the twentieth century, was later gradually declining. Due to ecological restrictions the fiber industry began to use the new technology Lyocell instead of the viscose process. In this technology, to solve cellulose, hydrogen sulphide is replaced by N-methylmorpholine-N-oxide (NMMO). Lyocell fiber has higher tensile strength (until 0,55GPa) and elastic modulus (until 25GPa) with respect to the viscose fiber (until 0,40и 10GPa, respectively). However, using NMMO as a direct solvent is dangerous. In fact, already at a temperature slightly above 140°C NMMO begins to decompose with the formation of N-methylmorpholine, morpholine and the release of oxygen. This effect leads to formation of explosive mixtures.^{1,2}

Therefore, the attention of researchers was attracted by ionic liquids (ILs)-these solvents are thermostable up to 300°C and higher, and they are able to dissolve wood pulp well. Being organic salts with a melting point up to 100°C, ILs practically do not have vapor pressure, and therefore do not pollute the atmosphere. To obtain concentrated cellulose solutions suitable for spinning, the researchers have tried to use ILs based for example on imidazolium, pyridinium and ammonium cations.³ At the beginning of the 21st century a new Ioncell process was developed for the processing of wood pulp with the help of ILs.⁴ According to the first information, the properties of new man-made fibers exceed all previously known ones, namely, their tensile strength reaches 0.7-0.8GPa and elastic modulus approaches to 30GPa. Another promising area of ionic liquids using is the production of new fibers based on silk fibroin. Recycling waste of silk industry, one can create artificial polypeptide fibers with excellent consumer properties.⁵

Ionic liquids have a great advantage with respect to other solvents. It is possible to vary their important technological properties (melting point, thermostability, and dissolving power), which depend on the cation and anion.⁶⁻⁹ Note that, on the one hand, during the synthesis of ILs we must provide a technologically justified melting point that can be achieved by increasing the volume of the cation. We can change the number, the mutual position and the length of the substituents of the heterogeneous ring of the cation. On the other hand, an increase in the number and the length of alkyl substituents in the ring implies a decrease in the dissolving power of IL. The choice of the anion is also an important stage in the design of the solvent with the desired properties. When choosing an anion, we should take into account that higher charges on its electron-donor center cause a greater dissolving power of the ionic solvent with respect to natural polymers. This property can be observed experimentally when one measures the Camlet-Taft basicity of the solvent.

We can conclude that the targeted design of the ion pairs allows us to regulate the most important properties of solvents required in

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the process of dissolving cellulose and silk fibroin. This fact reveals new perspectives in creating innovative fibers based on fiber-forming polysaccharides, polypeptides and their mixtures.

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Conflicts of interest

Author declares there is no conflict of interest in publishing the article.

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