Creation of a New Class of Cellulose Engineering Materials
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As petroleum prices increase, interest in renewable polymers, including cellulose, also increases. Successful use of this rapidly renewable, abundant and biodegradable material will depend on development of processing methods to produce materials with properties comparable to current engineering materials. These processing methods must also be economically and environmentally advantageous. Since cellulose does not melt, it must be spun from solution. Initially, we developed a rapid and efficient process for forming cellulose solutions in the ethylene diamine/salt solvent system and demonstrated that solution properties can be varied by varying salt concentration and cellulose molecular weight.

Earlier dissolution methods had relied on freezing and thawing mixtures to achieve uniform solutions. By chilling the solvent to decrease dissolution rate and increasing shear in mixing, we could prepare solutions rapidly and consistently without freezing [see process protocol above]. All cellulose samples investigated, including cotton batting, microcrystalline cellulose and wood pulps, dissolved easily in the solvent.

Varying the salt content of the solutions created conditions where flowing solutions or stiff gels formed. Decreasing the salt content resulted in cellulose precipitating out of solution [see figure at right]. Adding water stabilized solutions at higher temperatures (up to 60°C). Additionally, rheological studies indicated that solution viscosity decreased with increasing cellulose concentration [see chart below]. This behavior is commonly observed in liquid crystalline solutions from which high modulus fibers can be spun, e.g. Kevlar®.

We have prepared fibers and films from cellulose/ethylene diamine/salt solutions by electrospinning. Methanol and ethanol were used as coagulants in film casting, wet spinning and dry-jet wet spinning, but water was not a good coagulant.

In ongoing research we will focus on increased understanding of the dissolution process. Powerful NMR experiments should help to determine the specific interactions between the three solution components: cellulose, ethylene diamine and salt. These experiments are expected to lead to improved dissolution and processing of the system. Fiber and film formation will continue, and efforts will be made to improve fiber and film properties by controlling processing parameters and coagulation kinetics. Additionally, we will conduct preliminary explorations using the ethylene diamine/salt solvent system as a homogeneous reaction media for cellulose. In homogeneous reaction media, functional chemicals can be attached to the cellulose polymer to create new materials.

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