10G03

Development of High-Strength Poly(vinyl alcohol) Fibers

- mechanical properties of PVA films prepared from DMSO and/or water solutions -

Chang Seoul, Won-Jun Song, Se-Yeon Kim, Do-Hyon Kim, and Souk-Il Mah

Dept of Textile Engineering, Inha University, #253 Yonghyon-dong, Nam-gu, Inchon, 402-751, Korea.

1. Introduction

Poly(vinyl alcohol) has one of the highest theoretical modulus among the flexible-chain polymers. Therefore, PVA must be a good candidate for the high strength fibers.

Many preparation methods for the high-strength PVA fiber have been invented.

The necessary condition for the high-strength PVA fiber is first of all the high molecular weight of the PVA sample. A polymer assembly composed of longer linear chains with a critical entanglement density can change into high-strength fibers through the drawing process.

Gel spinning for the PVA spinning solution is one of the convenient methods in producing a high-strength PVA fiber.

PVA gels can be made from such solvents as, water, dimethyl sulfoxide(DMSO), DMSO+water mixture, glycerin(GC), ethylene glycol(EG), ethyleneurea, etc.

2. Experimental

PVA sample materials: The two PVA samples, Pn=1730 and 5000, were the product of Unitica, Japan. The degree of polymerization(Pn) of the samples were around 1730, 3500, and 5000, respectively and the degree of saponification around 99.9%, 99.9%, and 95%, respectively.

Solution preparation: PVA was dissolved in a mixture of DMSO and water. The mixing ratios of the solvent mixture were 100/0, 80/20, 60/40, and 0/100 by

weight.

Rheological properties measurement: Stactic and dynamic viscoelastic properties of the PVA/(DMSO/water) solutions were measured by an Weisenberg type rheometer (US 200, Paar Physica).

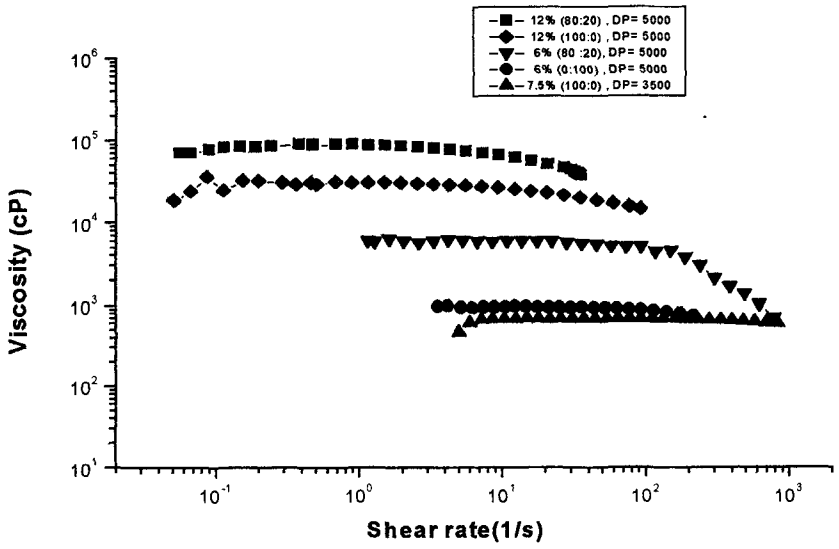
Film formation by solution casting: The PVA/(DMSO/water) solutions were poured into a polystyrene Petri dish and allowed to evaporate under a vacuum at 50 C.

Drawing: Tensile drawing was conducted with an Instron type machine at room temperature. The extension rate was 20mm/min.

Tensile tests: Tensile tests for the drawn samples were also conducted with the tensile machine with a gauge length of 20mm and the extension rate of 20 mm/min.

3. Results and discussion

According to Cha et al., the PVA fiber spun from 20 wt % PVA/(DMSO80/water 20) exihibited the highest maximum draw ratio in the any other DMSO/water solvent mixtures. The highest tensile strength and Young's modulus they obtained with Pn of 5000 were 2.8 GPa(21.7g/d) and 64 GPa(533g/d) respectively.



Figurel. The viscosity versus shear rate measured at 70℃ for the PVA solutions with different Pn , solvent composition, and concentration.

The overlap concentration can be estimated from the overlap concentration of the hydrodynamic radius like the radius of gyration of the polymer and by the reciprocal of intrinsic viscosity. The overlap concentration C* measured by Kajiyama was 1.25 g/dl for Pn=1640 and 0.725 g/dl for Pn=5430 PVA sample, respectively.

Cha et al. reported that the polymer concentration of 6wt% for the Pn=5000 is about the critical gelation concentration for the DMSO80/water 20 solvent mixture.

As can be seen in the Figure 1, the solutions made with DMSO80/water 20 mixture solvent has the highest viscosities among DMSO/water mixed solution. This means the DMSO80/water20 mixed solvent has the highest dissolution power for the PVA chains. This solvent mixture is suitable for the homogenization of the PVA solution and enhances the entanglement density of the polymer assembly by distributing the contact points evenly in the whole volume of the solution.

Table 1. The maximum draw ratios and moduli and stengths for the PVA films prepared from different molecular-weight samples, solvent constitutions, and polymer concentrations in the solvent system.

Degree of polymerization Pn	DMSO/ water wt/wt	P V A concentration	maximum draw ratio	modulus (GPa)	strength (GPa)
5000	100/0	6%	2.93	0.14	0.021
		12%			
	80/20	6%	5.87	0.10	0.015
		12%			
	60/40	6%	3.57	0.268	0.028
		12%			
	0/100	6%	2.6	0.198	0.038
		12%			
3500	100/0	7.5%	3.07	0.281	0.064
	80/20	7.5%			
1730	100/0	9%	4.6	0.050	0.021
	100/0	18%	1.86	0.361	0.011

The maximum draw ratios for the films prepared from different solvent constitutions and polymer concentrations, were shown in Table 1. With a higher water content in the precursor solution, the film has a higher strength. The film prepared with a higher molecular weight PVA sample possesses a higher strength. The highest strength of the drawn film made from Pn=3500 PVA with DMSO only were 0.064 GPa.

4. Conclusions

The solution cast PVA film made from Pn=5000 sample with DMSO80/water 20 solvent mixture exhibited the maximum draw ratio of 5.9 at room temperature. But the strength of the sample was not that high. Water is a good solvent for obtaining high-strength PVA films.

Acknowledgment

This work was supported by the Generic Industrial Technology Program(공업기반기술개발사업), Institute of Industrial Technology Policy(산업기술정책연구소). Ministry of Commerce, Industry & Energy(산업자원부).

5. References

1.W.-I. Cha, S.-H Hyon, and Y. Ikada, J.Polym.Polym.Phys.Ed.,32,297-304(1994)
2.M.Ohkura,T.Kanaya and K.Kaji, Polymer,33(17),3686-3690(1992)
3.T.Takigawa, H.Kashihara, K.Urayama, and T.Masuda, Polymer, 33(11) 2334 - 2339 (1992)
4.Chisako Hara and Masaru Matsuo, Polymer,36(3)603-609(1995)
5.M.Okazaki, Y.Miyasaka and S.Matsuzawa, Kobunshi Ronbunshu, 52(11) 710-717 (1995)
6.J.H.Choi, W.S.Lyoo,and Sohk Won Ko, Proceedings of the 4th Asian Textile Conference, June 24-26,1997,53-57