Letters

Influence of molecular weight on the tensile properties of nearly monodisperse polystyrenes

There have been relatively few studies of the influence of molecular weight upon the tensile properties of glassy polymers[1]. It is generally accepted, however, that both tensile strength and rupture elongation increase as the molecular weight increases up to a certain value and remain nearly constant thereafter. Some results on polystyrene have been reported by Merz *et al.*[2], McCormick *et al.*[3], Wyman *et al.*[4] and by Thomas and Hagan[5]. From the excellent review paper of Martin *et al.*[1] it can be gathered that in many instances the influence of molecular weight has been confused with that of the molecular weight distribution. In the present investigation nearly monodisperse polystyrenes were used, purchased from Pressure Chemical Co., Pittsburgh, Pa.

The test specimens were made by Maxwell's[6] miniature mixing and injection moulding machine manufactured by Custom Scientific Instruments, Inc., Whippany, NJ. These specimens were very small (about 0.2 g) and in a usual 'dumb-bell' shape with an overall length of 3/4 in. and a 1/16 in. diameter by 5/16 in. long test section. The same standard procedure was followed for the preparation of all the specimens before testing. Moulding temperatures were in the range of 170°–200°C and after a mixing time of about 2 min the specimens were allowed to cool in air at room temperature.

Table 1 Tensile properties of nearly monodisperse polystyrenes at room temperature. Elongation rate: 1.5×10^{-3} sec^{-1}

$\bar{M}_w$	$\bar{M}_w/\bar{M}_n$	Tensile strength (kPa)	Rupture elongation (%)
51 000	<1.06	18 750	
97 200	<1.06	26 200	2.48
200 000	<1.06	46 200	4.70
411 000	<1.15	51 020	5.62
498 000	<1.20	52 920	6.37
670 000	<1.15	49 640	5.97
860 000	<1.15	50 050	5.66
2 000 000	<1.20	54 670	5.87

The measurements were performed on a Mini Max tensile tester also made by Custom Scientific Instruments, Inc. Fifteen specimens from each polystyrene sample were tested and the results are shown in *Table 1*. Deviations as high as 15% from the average values given were observed in certain samples.

From *Table 1* it can be gathered that the tensile strength increases with molecular weight up to a value of $\bar{M}_w$ between 300 000 and 400 000. This result is fully in agreement with Bondurant's data[7] which show that the tensile strength of polystyrene fractions does not become constant until $\bar{M}_w$ = 350 000. Our results show that the rupture elongation also increases with molecular weight and becomes constant at about M_w = 400 000. It should also be noted that, except for the samples of the two lower molecular weights, the specimens exhibited a 'yield point' before rupture.

Acknowledgement

Financial assistance from the National Research Council of Canada is gratefully acknowledged.

References

1 Martin, J. R., Johnson, J. F. and Cooper, A. R. *J. Macromol. Sci. (C)* 1972, **8**, 57
2 Merz, E. H., Nielsen, L. E. and Buchdahl, R. *Ind. Eng. Chem.* 1951, **43**, 1396
3 McCormick, H. W., Brower, F. M. and Kin, L. *J. Polym. Sci.* 1959, **39**, 87
4 Wyman, D. P., Elyash, L. J. and Frazer, W. J. *J. Polym. Sci. (A)* 1965, **3**, 681
5 Thomas, D. P. and Hagan, R. S. *Polym. Eng. Sci.* 1969, **9**, 164
6 Maxwell, B. *SPE J.* 1972, **28**, 24
7 Bondurant, C. W. *PhD Thesis* Virginia Polytechnic Institute (1960)

J. Vlachopoulos, N. Hadjis and A. E. Hamielec
Department of Chemical Engineering, McMaster University, Hamilton, Ontario L8S 4L7, Canada
(Received 28 August 1977; revised 12 September 1977)

Incorporation of spin probes into polynucleotides by enzymatic polymerization

Spin labelling is an effective tool for studying the structure–function relationships present in various complex biological systems. A variety of biological systems have been investigated by the spin label method, but nucleic acids thus far have received little attention. This is essentially due to the known difficulty of achieving site-specific chemical modifications of nucleic acids. For the past several years, one of us has used non-site-specifically spin labelled polynucleotides ('first generation spin labelled nucleic acids') for characterizing conformational transitions of nucleic acids, and nucleic acid–nucleic acid or nucleic acid–protein interactions[1]. The spin label experiments were carried out with probes tumbling in the 'motionally narrowing region'[2]. It was, therefore, hypothesized that it is not essential to achieve site specific labelling of nucleic acids, since the probe cannot be very sensitive to detailed structural features in that motion range: i.e., probes linked to different sites of the nucleic acid residue would give rise to similar e.s.r. spectra. However, perturbation of the probe region by formation of an inter–intramolecular association would cause e.s.r. spectra which are significantly different from those of unperturbed systems.