Polymer 44 (2003) 909–910

polymer

www.elsevier.com/locate/polymer

Polymer Communication

The crystal modulus of silk (*Bombyx mori*)

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Received 20 September 2002; received in revised form 30 September 2002; accepted 4 October 2002

Abstract

It is shown that experimentally determined values of the crystal modulus of *Bombyx mori* silk agree reasonably well with the computationally determined values, if account is taken of the stress relaxation, which occurs during the experimental measurements. The experimental are 16–22 GPa depending on the sample and the computational are 13 or 16 GPa depending on the method of analysis.

Keywords: Bombyx mori; Stress relaxation; Nanofibril

1. Introduction

The crystal modulus of *Bombyx mori* silk has been reported for computational and experimental determinations [1]. The former yielded values of 13 and 16 GPa, but the latter yielded 20–28 GPa. Several possible causes of the discrepancy were discussed. One is the structural and associated stress relaxations that occur during the time period of the measurements which were made at a fixed macroscopic strain of the fibers. The relaxation after the initial application of the strain was compensated for by a further increase in applied strain before the X-ray measurements were begun [1]. This note briefly reports the results of an examination of whether further significant stress relaxation occurred after the compensation.

2. Methods

The experimental measurements were carried out in a manner similar to that described previously [1]. However, the decrease of stress as a result of the further stress relaxation after the initial compensation was determined.

3. Results and discussion

The further relaxation did indeed take place and taking account of the effect led to an approximately 20% reduction in the value of the crystal modulus. As a result, the range of the experimentally and computationally determined values is now in closer agreement as shown in Table 1.

The data in Table 1 confirm again that the various helical and pleated contracted conformations lead to relatively low values of crystal modulus [9,10]. It is this lower modulus of silk coupled with the relatively small nanofibril diameter [16] which contributes to the flexibility of silk fibers and their ability to undergo rather sharp bending without failing by either kinking or tensile failure [16–19].

4. Conclusion

Taking account of the stress relaxation after the initial compensation, leads to experimental values of the crystal

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PII: S0032-3861(02)00729-2

Table 1
The crystal modulus values of silk and other polymers

Crystal modulus (GPa)				
Materials	Reference	Computational	Experimental	Structural contraction (%)
Silk (extended)	[2]	150	–	0
Silk (β-pleated)	[1, This work]	13, 16	16–22	6
Nylon 6 α-form (extended)	[3–5]	244, 263, 312	183	0
Nylon 6 γ form (pleated)	[6]	54	21	3
Poly-L-glycine I (extended)	[7]	147	–	0
[i]Poly-L-glycine II (pleated)	[8]	12	–	–
Poly-L-alanine (extended)	[6]	160	–	0
Poly-L-alanine (α helical)	[6]	60	–	53
Poly-L-alanine (β-pleated)	[9,10]	–	16–17, 20	4
Collagen (0% RH) (triple helical)	[11–13]	–	21.5	22
Poly-γbenzyl-l-glutamate (α helical)	[14,15]	34	37–47	–

modulus in fairly good agreement with the computed values.

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