

Reply to Commentary on: 'Mechanical Properties of Mono-domain Side Chain Nematic Elastomers' by O. Stenull and T.C. Lubensky

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Abstract. We point out that all samples we have studied experimentally are beyond the critical point and that all experimental results on mechanical properties obtained for nematic sidechain elastomers can be interpreted without ever using the concepts of 'soft' or 'semi-soft' elasticity.

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In the preceding commentary [1] on our paper [2] Stenull and Lubensky (SL) give a theory of the dynamics of nematic elastomers including hydrodynamic and non-hydrodynamic aspects. It is not the place here to deal in

detail with this theory or its extended version [3]. We only want to make a few remarks that are pertinent to [2].

1) All our samples are 'above the mechanical critical point', i.e. they show a certain mechanical anisotropy even in the isotropic phase. This is corroborated by NMR

measurements [4, 5] and consistent with the concept of frozen-in nematic order proposed and analysed a decade ago in [6]. This is a clear indication that there is no spontaneous breaking of rotational symmetry due to a spontaneous shape anisotropy at the isotropic to nematic phase transition. Thus, concepts of 'soft' or 'semi-soft elasticity' are not applicable.

2) SL discuss two scenarios for the dynamic shear elastic response, one with an extra dip in G''_{\parallel} and a plateau in G'_{\parallel} due to dynamic (semi-)softness (Fig. 1a), and another without these features (Fig. 1b). The scenario of Fig.1a can clearly be excluded for our samples. First, as we discuss thoroughly in our reply [7] to the commentary by Terentjew and Warner [8], the times τ_n and τ_R are of the same order of magnitude and by no means different by three orders of magnitude as assumed in Fig. 1a. Second, the extra plateau above, and the subsequent drop of G'_{\parallel} at $\omega = \tau_n^{-1} = 10^2 s^{-1}$ is clearly ruled out by our measurements that were performed down to $\omega \sim 1 s^{-1}$ (Figs. 9 and 10 in [2]) and to $\omega \sim 0.1 s^{-1}$ (Fig.1 in [7]). Fig. 1b is the scenario that resembles the experimental results. The fact that this behavior is the classical behavior observed for any typical elastomer indicates that the concept of soft elasticity has no consequences, when τ_n is of the order of τ_R , for the classical description of a nematic elastomer using the Rouse-type picture pioneered in ref [2]. On the other hand it should be noted that Fig.1a associated with $\tau_n = 10^3 \tau_R$ shows that the value of C_5^R does not correspond to a soft or semi-soft value.

3) The remark in [1] that 'the data obtained by the two groups are qualitatively if not quantitatively similar' only applies to the dip in $G'_{\parallel}/G'_{\perp}$. The scaling exponent n and the low frequency behaviour of the mechanical response are in fact completely different, as discussed in [7]. The fact that the samples of the two groups show the same dip in $G'_{\parallel}/G'_{\perp}$ indicates again that the concept of soft or semi-soft elasticity is not playing a role.

4) Finally, all the nematic elastomers we have studied experimentally can be described as uniaxial rubber network with a small mechanical anisotropy in the hydrodynamic regime, and a Rouse-like frequency dependence in the viscoelastic region. Since the shear rigidity modulus has the same order of magnitude as that of a conventional silicon elastomer, there is no reason to call these elastomers 'semi-soft elastomers'.

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References

1. O. Stenull and T.C. Lubensky, *Eur. Phys. J. E*, preceding comment (2004).
2. P. Martinoty, P. Stein, H. Finkelmann, H. Pleiner, and H.R. Brand, *Eur. Phys. J. E*, this issue (2004).
3. O. Stenull and T.C. Lubensky, to appear in *Phys.Rev. E* (cond-mat/0311464).

4. S. Disch, C. Schmidt, and H. Finkelmann, *Macromol. Rapid Commun.* **15**, 303 (1994).
5. B. Zalar, T. Apih, A. Lebar, M. Vilfan, S. Zumer, and H. Finkelmann, paper presented at the *Second International Workshop on Liquid Crystalline Elastomers*, Bleibach im Elztal, Germany, Sept.25-27, 2003; and to be published.
6. H.R. Brand and K. Kawasaki, *Macromol. Rapid Commun.* **15**, 251 (1994).
7. P. Martinoty, P. Stein, H. Finkelmann, H. Pleiner, and H.R. Brand, *Eur. Phys. J. E*, reply to [8] (2004).
8. E.M. Terentjev and M. Warner, *Eur. Phys. J. E*, preceding comment (2004).