Dynamic mechanical properties of nematic elastomers: Modified Rouse Model

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Nematic elastomers are rubbers whose constituent molecules are orientationally ordered. Due to their unique properties, nematic elastomers have a fascinating potential for technical applications (such as electro-optical display devices, piezoelectric and non-linear optical systems, actuators, and artificial muscles).[1, 2] Although the theory of phase transitions of nematic elastomers has been developed in detail, there are no microscopic theories in the literature which consider the effects of the chain dynamics on the mechanical relaxation properties of nematic elastomers.

We develop a microscopic theory of dynamic mechanical properties of nematic elastomers taking the chain structure of network strands explicitly into account. We use an approach in which the mobility of network strands is considered on scales larger than that of the chain fragments (subchains), whose statistics is Gaussian. In this approach, each network strand is modelled as a sequence of Gaussian subchains whose elasticity constants and friction coefficients are different for motions parallel and perpendicular to the LC director:[3] $K_{\parallel} \neq K_{\perp}$ and $\zeta_{\parallel} \neq \zeta_{\perp}$ (a modified Rouse model). Using a general network structure built from such anisotropic Rouse chains, we show that the dynamic modulus of an ordered nematic elastomer, $G^{*} = G' + iG''$, is determined by the eigenvalues of an isotropic network structure of the same topology. From this we draw the general conclusion that nematic elastomers should demonstrate a dynamic mechanical behaviour very similar to that of usual (non-ordered) rubbers; especially, they should display a frequency domain with a Rouse-like behaviour, $G' \cong G'' \sim \omega^{1/2}$, a feature which is confirmed by experiments.[2] In contrast to the usual rubbers, nematic elastomers are characterized by the anisotropy of the dynamic mechanical behaviour with respect to the LC director, $\mathbf{n}$. In agreement with experiment[2] we show that for prolate systems in the D-geometry (when $\mathbf{n}$ is parallel to the shear velocity) G'_D greatly decreases around the nematic isotropic phase transition, whereas in the V-geometry (when $\mathbf{n}$ is perpendicular to the shear plane) G'_V does not demonstrate such singularity. We discuss the predictions of our theory for oblate systems and for other geometries under shear deformation.

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(1) M. Hebert, R. Kant, P. G. de Gennes. *J. Phys. I* **1997**, *7*, 909.
(2) P. Martinoty, P. Stein, H. Finkelmann, H. Pleiner, H. R. Brand. *Eur. Phys. J. E* **2004**, *14*, 311.
(3) Yu. Ya. Gotlib, I. A. Torchinskii, V. P. Toshchevikov. *Macromol. Theory Simul.* **2002**, *11*, 898.