

## The discovery of biaxial nematic phase in bent-core mesogens and possible technological applications

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The biaxial nematic phase had remained one of the most sought after phase of the past 34 years. The existence of biaxial nematic phase with  $D_{2h}$  symmetry had been predicted by Frieser a long time ago [1]. Several initial reports [2] of its existence in monomer thermotropic materials turned out to be [3] wrong. Numerous attempts to synthesize *biaxial* molecules or mixing rod and disk like molecules in the hope of realizing this phase did not succeed.

In the biaxial nematic phase, the mesogen's long and short transverse axes simultaneously orient along the two orthogonal directors denoted by two unit vectors,  $\mathbf{n}$  and  $\mathbf{m}$ , respectively. Evidently, such a nematic phase possesses three distinct indices of refraction along the three spatial directions. The nematic phases formed by three rigid bent-core mesogens [4] derived from 2,5-bis-(p-hydroxyphenyl)-1,3,4-oxadiazole and oxazole have been studied by x-ray diffraction and confirmed to be biaxial in nature [5-7]. Experimentally, the director  $\mathbf{n}$  was aligned by either an external magnetic field or by a rubbed polyimide coated substrate, and  $\mathbf{m}$  was reoriented by an electric field applied perpendicular to the substrate. The unique low-angle diffraction pattern, consisting of two pairs of peaks, in the nematic phases exhibited by these mesogens clearly reveals the biaxiality of these nematic phases. The experimental results can be readily reproduced from ab-initio calculations of molecular form factor and structure factor, assuming short-range (or, liquid-like) positional correlations in the nematic phase with the apex of the rigid cores aligned along the secondary director  $\mathbf{m}$ .

The biaxial nematic phase holds the potential of resulting in new type of displays and electro-optical devices. The current (uniaxial) liquid crystal devices which rely on reorientation of the director  $\mathbf{n}$ . The biaxial nematic devices can be function in a mode that required reorientation of  $\mathbf{m}$ . Reorientation of  $\mathbf{n}$  requires that molecules tumble, i.e., change their orientation from being horizontal to vertical in the middle of the device. On the other hand, the reorientation of  $\mathbf{m}$  will require that molecule rotate about their long axis by  $\sim 90^\circ$ . Since the molecules can rotate at low fields about their long axis much faster than they can tumble, the biaxial devices are likely to be much faster. Our preliminary measurements demonstrate that reorientation of  $\mathbf{m}$  is nearly 10 times faster than the response time of the uniaxial nematic devices. In addition to this evident advantage, other aspects that make biaxial nematic devices superior to conventional devices, will be discussed.

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- [1] M. J. Freiser, Phys. Rev. Lett. **24** 1041(1970).
- [2] S. Chandrasekhar, V.N. Raja, and B.K. Sadashiva, Mol. Cryst. Liq. Cryst. Lett. **7**, 65 (1990); J. Malthele et al., C.R. Acad.Sc. Paris **303**, 1073 (1986).
- [3] I.G. Shenouda, Y. Shi, and M. Neubert, Mol. Cryst. Liq. Cryst., **257**, 209 (1994); J. Hughes, et al., J. Chem. Phys. **107**, 9252 (1997).
- [4] T. J. Dingemans and E. T Samulski, Liq. Cryst. **27**, 131(2000).
- [5] B. R. Acharya, et al., Pramana **61**, 231 (2003).
- [6] B. R. Acharya, A. Primak, S. Kumar, **Invited Article**, Liquid Crystal Today, **13**, 1 (2004).
- [7] B.R. Acharya, A. Primak, and S. Kumar, Phys. Rev. Lett, **92**, 145506 (2004).