PHYSICAL REVIEW E **68**, 023702 (2003)

Reply to "Comment on 'Optical determination of flexoelectric coefficients and surface polarization in a hybrid aligned nematic cell' "

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(Received 27 February 2003; published 28 August 2003)

In their Comment [G. Barbero and L. R. Evangelista, Phys. Rev. E **68**, 023701] on our paper [A. Mazzulla, F. Ciuchi, and J. R. Sambles, Phys. Rev. E **64**, 021708 (2001)], Barbero and Evangelista conclude that the procedure followed by us to fit the reflectivity data from the half leaky guided mode technique is questionable. In the absence of a model that is able to reproduce the experimentally obtained tilt angle profiles, their argument is unsubstantiated. To further refute their arguments, we also illustrate and discuss additional experimental data (that were not shown in our paper) that strongly support our conclusions.

DOI: 10.1103/PhysRevE.68.023702 PACS number(s): 61.30.Gd, 42.70.Df

The Comment by Barbero and Evangelista states that it provides an alternative interpretation of the results of our work on the flexoelectric effect in hybrid aligned nematic (HAN) cells. This suggestion, that ion diffusion within the cells may explain the reported optical behavior, had occurred to us also. Indeed, for HAN cells having rubbed polyimide surface layers there is clear evidence for such an effect as seen in the optical response of the cells to square pulses, where, after a few tens of milliseconds, the applied field is largely canceled by mobile ion drift. However, we looked for and saw no such effects within the cells prepared with a silicon oxide aligning layer. The number of ions may be higher when polyimide is used as a surface layer instead of SiO, although there is no evidence that the ionic relaxation changes by three orders of magnitude, as Barbero claims. Furthermore, the slow relaxation (tens of seconds) that is observed may be due to low mobile ions or to liquid crystal decomposition or desorption of adsorbed ions.

To substantiate our interpretation and refute the interpretation presented by Barbero and Evangelista, we present here details of the ''data not shown'' as referred to in our paper in the third line of the first column of page 5. Optical results were obtained from simple transmission measurements through the cell, oriented at 45° from the planar alignment direction, between crossed polarizers.

Preliminary measurements under ac (1 kHz) applied voltage [Fig. 1(a) shows the transmitted intensity] allows a simple evaluation of the birefringence Δn [Fig. 1(b)] which is estimated from $\Delta n = (\lambda \arcsin\sqrt{I/I_0})/\pi d$, where λ is the wavelength of the incoming light, d the thickness of the sample, and I_0 and I the incident and the transmitted intensities, respectively.

Measurements under a fixed dc voltage (2 V) have also been taken. The intensity value (and hence the birefringence) reached after the initial fast transient [due to liquid crystal (LC) reorientation] is nearly the same as that found for the ac field case at the same rms voltage; the small difference arises from the slightly different tilt angle profiles (see the tilt profiles in our paper). Looking at Fig. 2, it is clear that the intensity (and the birefringence also) does not change noticeably during a time scale of the order of 1 s, i.e., the time during which we took the data shown in our paper (the time scale in Fig. 2 is 500 ms/division).

For the sake of completeness, to illustrate the long-time effects in these highly insulating cells, we also show the very-long-time behavior (Fig. 3), where the intensity (and the birefringence) returns to the zero-voltage value after hundreds of seconds. This clearly shows that there are charges accumulated onto the surfaces, which eventually screen the external voltage after about 350 s. This is strongly at variance with Barbero and Evangelista's suggestion of a time scale of 100 ms (the time scale in Fig. 3 is 5.0 s/division). They suggest that the field is completely screened in the bulk

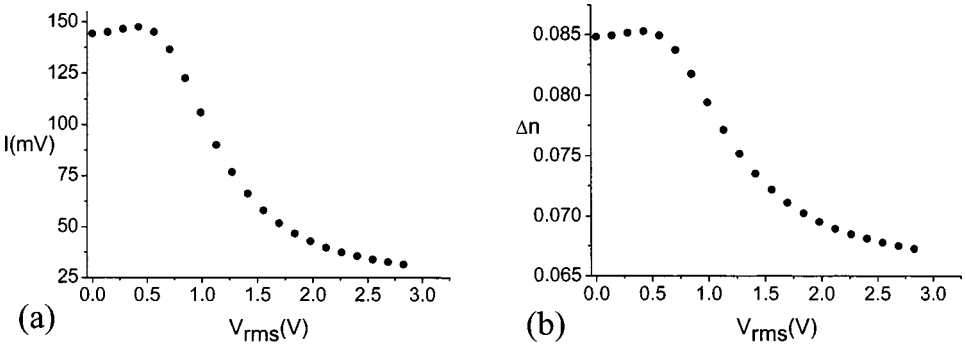

FIG. 1. (a) Transmitted intensity through the HAN cell, oriented at 45° from the planar alignment direction between crossed polarizers, versus the applied voltage. (b) Birefringence Δn of the HAN cell versus the applied voltage.

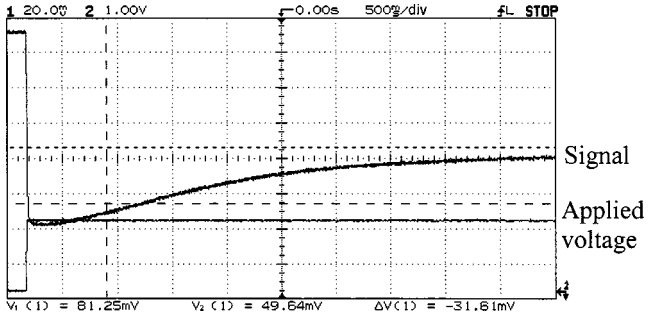

FIG. 2. Transmitted intensity through the cell on applying a 2 V dc voltage versus time, during the first seconds.

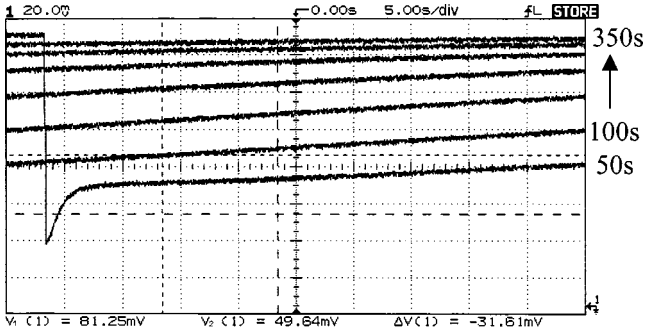

FIG. 3. Transmitted intensity through the cell on applying a 2 V dc voltage versus time on a longer scale.

over a very short time (the first time), the ions being collected near the electrodes screening the field and then being adsorbed at the interface over a much longer time scale. What we actually see instead is that the electrooptical response does not change noticeably in hundreds of milliseconds and relaxes slowly to the no-field configuration in minutes. For this reason we do not understand their sentence ''the screening effect takes place after the first time, when the ions are collected near the electrode.'' The long-time response does indeed show the influence of ion motion with a time constant of order 150 s, following a faster but smaller effect with a time constant of order 1.5 s. There is no evidence for any strong effect of the type suggested occurring within the first tens of milliseconds.

From the experimental evidence therefore we contend that our measurements are not significantly affected by the ionic screening.

In conclusion, we think that the criticism raised by Barbero and Evangelista cannot be substantiated. If those authors do not agree with our evaluation, we invite them to produce a paper in which their theory is used to reproduce the tilt angle profiles we obtain experimentally. Specifically, we note their assertion that ''the electric field distribution is mainly localized close to the bounding surfaces'' has no meaning. This is rather important. If they mean the gradient of the electric field is strongest near the boundaries then they should say so and give a model. This model has then to accord with our data. If indeed the fields were strongest near the boundaries then the director profiles we determined would have reflected this. Thus if such an effect occurs it is below our sensitivity. They must quantify what they claim. Note that in contrast to their unsubstantiated suggestions our work is completely self-consistent and fully interprets all the data obtained.