OVERLOOKED IONIC PHENOMENA AFFECTING THE ELECTRICAL CONDUCTIVITY OF LIQUID CRYSTALS

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ASEC 2021

Background

Characteristics of Nematic Liquid Crystals

- no positional molecular order
- anisometric molecules with orientational order
- dielectric material responsive to applied electric field

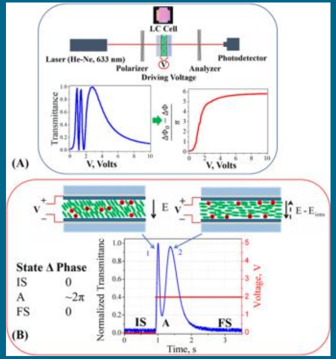
Ions in Liquid Crystals

- introduced in manufacture and handling
- introduced by contact with substrates
- diminish the effectiveness of applied electric field

Ions in molecular liquid crystals: screening caused side effects

- image sticking
- image flickering
- reduced voltage holding ratio
- slow display response

Typical laboratory setup with the ions effecting the applied field:



Model

Rate of change of ion concentration equals net sum of ion capturing and ion generation:

$$\frac{dn}{dt} = -k_a \frac{\sigma_s}{d} n(1-\theta_s) + k_d \frac{\sigma_s}{d}\theta_s$$

Conservation of ions after the influence of substrates:

$$n_0 + \frac{\sigma_s}{d} v_s = n + \frac{\sigma_s}{d}\theta_s$$

Ion concentration n can be determined by solving equations (1)-(2) and assuming steady-state conditions.

DC conductivity is a function of Ionic concentration:

$$\lambda_{DC} = q\mu n$$

Parameter values used in model:

Charge	$q = 1.6 \times 10^{-19}$ C
Charge mobility	$\mu = 10^{-10}$ m^2/V·s
Ion concentration	$n_0 = 6 \times 10^{18}$ m^{-3}
Surface density	$\sigma = 5 \times 10^{16}$ m^{-2}
Fraction sites occupied	$\nu_{s1} = 0$
	$\nu_{s2} = 10^{-3}$
Ion capturing/releasing	
	$K_1 = 10^{-21}$
	$K_2 = 10^{-22}$
	$K_3 = 10^{-23}$
	$K_4 = 10^{-21}$

Roles of the substrates

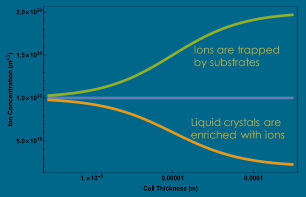
The substrates absorb some charged particles reducing ionic concentration of bulk:

Pre-existing ionic contamination of substrates enriches bulk with additional ions:

Single type of Dominant symmetrical ion:

Ion Concentration as a Function of Cell Thickness (Single Ion Type)

$\nu_s = 10^{-3}$

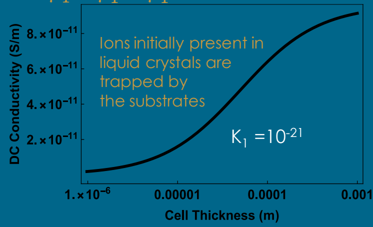


Two cases—each involving two types of dominant symmetrical ions:

1

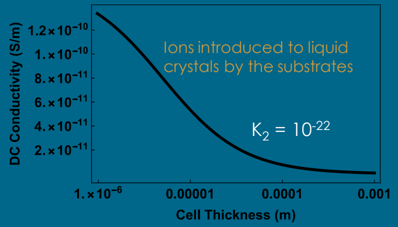
DC Conductivity λ_{DC1}

$\mu_1 = \mu_1^+ + \mu_1^-$



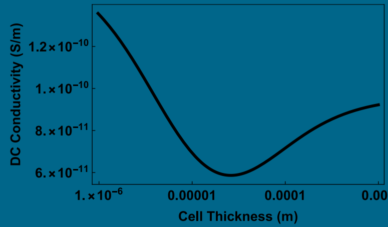
DC Conductivity λ_{DC2}

$\mu_2 = \mu_2^+ + \mu_2^-$



DC Conductivity $\lambda_{DC} = \lambda_{DC1} + \lambda_{DC2}$ as a Function of Cell Thickness

$\lambda_{DC} = q\mu_1 n_1 + q\mu_2 n_2$

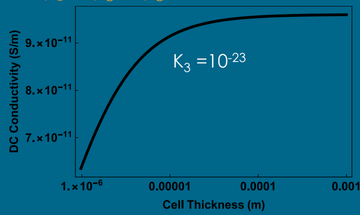


Using materials with values of K_1 and K_2 ($K = k_a/k_d$), λ_{DC1} and λ_{DC2} will combine to show a minimum.

2

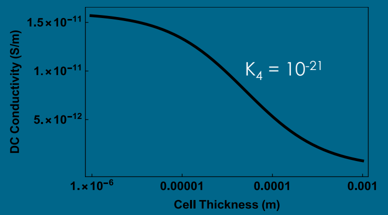
DC Conductivity λ_{DC3}

$\mu_3 = \mu_3^+ + \mu_3^-$

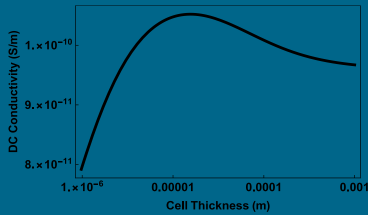


DC Conductivity λ_{DC4}

$\mu_4 = \mu_4^+ + \mu_4^-$



DC Conductivity $\lambda_{DC} = \lambda_{DC3} + \lambda_{DC4}$ as a Function of Cell Thickness



Using materials with values of K_3 and K_4 ($K = k_a/k_d$), λ_{DC3} and λ_{DC4} will combine to show a maximum.

Conclusions

- Measurements of ions in liquid crystals is a non-trivial process
- Substrates can alter DC conductivity both positively and negatively
- Ionic contamination of substrates can result in both monotonous and non-monotonous dependence of DC conductivity on the cell thickness
- Electrical conductivity of liquid crystals should be measured at a range the cell thicknesses

Acknowledgements

The authors would like to acknowledge the support provided by the CSU-AAUP Faculty Research Grant and by the Faculty – Student Research Grant.

References

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