PHYSICAL PROCESSES AFFECTING THE ELECTRICAL CONDUCTIVITY OF LIQUID CRYSTALS

DAVID WEBB DR. YURIY GARBOVSKIY

DEPARTMENT OF PHYSICS AND ENGINEERING PHYSICS, CENTRAL CONNECTICUT STATE UNIVERSITY

DAVIDWEBB@MY.CCSU.EDU YGARBOVSKIY@CCSU.EDU

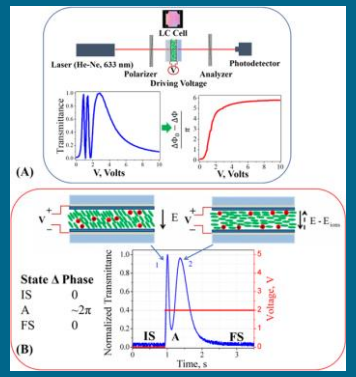
Background:

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:

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

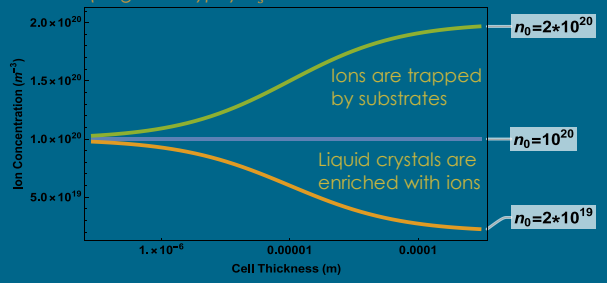
Ion concentration n can be determined by solving equations (1)-(2) and assuming steady-state.

DC conductivity is a function of Ionic concentration:

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

Single type of dominant symmetrical ion:

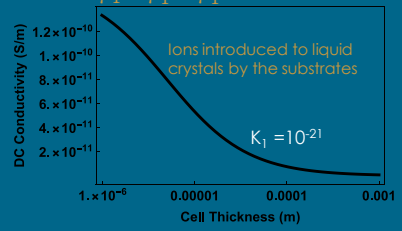
Ion Concentration as a Function of Cell Thickness (Single Ion Type) $v_s = 10^{-3}$



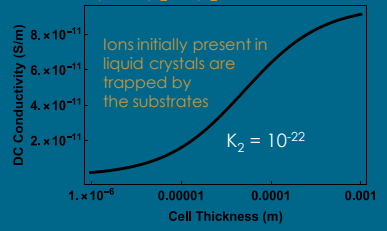
Two cases—each involving two types of dominant symmetrical ions:

1

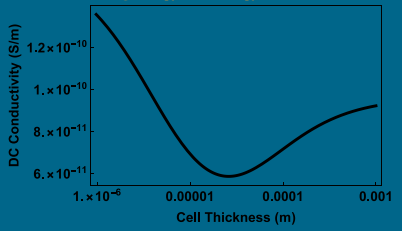
DC Conductivity λ_{DC1} $\mu_1 = \mu_1^+ + \mu_1^-$



DC Conductivity λ_{DC2} $\mu_2 = \mu_2^+ + \mu_2^-$



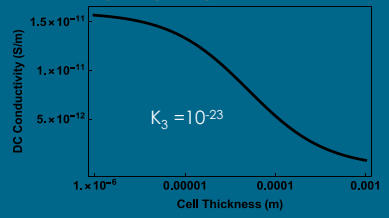
DC Conductivity $\lambda_{DC} = \lambda_{DC1} + \lambda_{DC2}$ *as a Function of Cell Thickness* $\lambda_{DC} = q\mu_1 n_1 + q\mu_2 n_2$



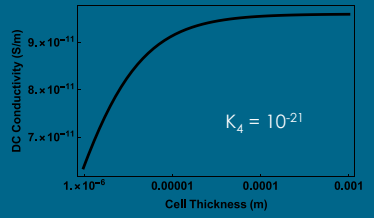
Using materials with values of K_1 and K_2 ($K = k_a / k_d$), λ_{DC1} and λ_{DC2} will combine to show a minimum.

2

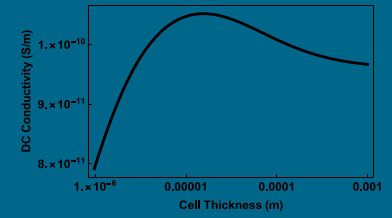
DC Conductivity λ_{DC3} $\mu_3 = \mu_3^+ + \mu_3^-$



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 the measured values of DC conductivity via interactions of ions with substrates
- Ionic contamination of substrates can result in both monotonous and non-monotonous dependence of DC conductivity on the cell thickness
- Electrical measurements of liquid crystals should be performed by varying the cell thickness

Acknowledgements

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References

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