

Improving the Poling Efficiency of Electro-Optic Polymers Through the Use of Charge Insulating Layers

Presented by

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Motivation

- Terahertz Imaging and Spectroscopy (10^{12} Hz)

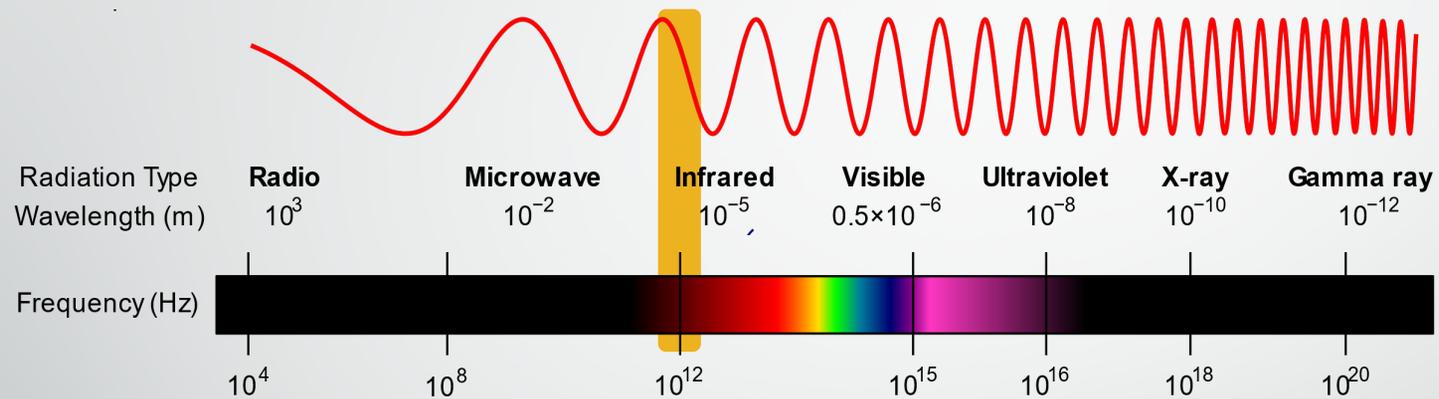


Image of Electromagnetic Spectrum

- Applications are available in electronic device inspection, materials science, and medical diagnostics.¹

¹ A.M. Sinyukov and L.M. Hayden, *Optics Letters* **27**, 55 (2002).

Application

- Biomedical Applications
 - Noninvasive, Nonionizing, Strong Spatial Resolution.²

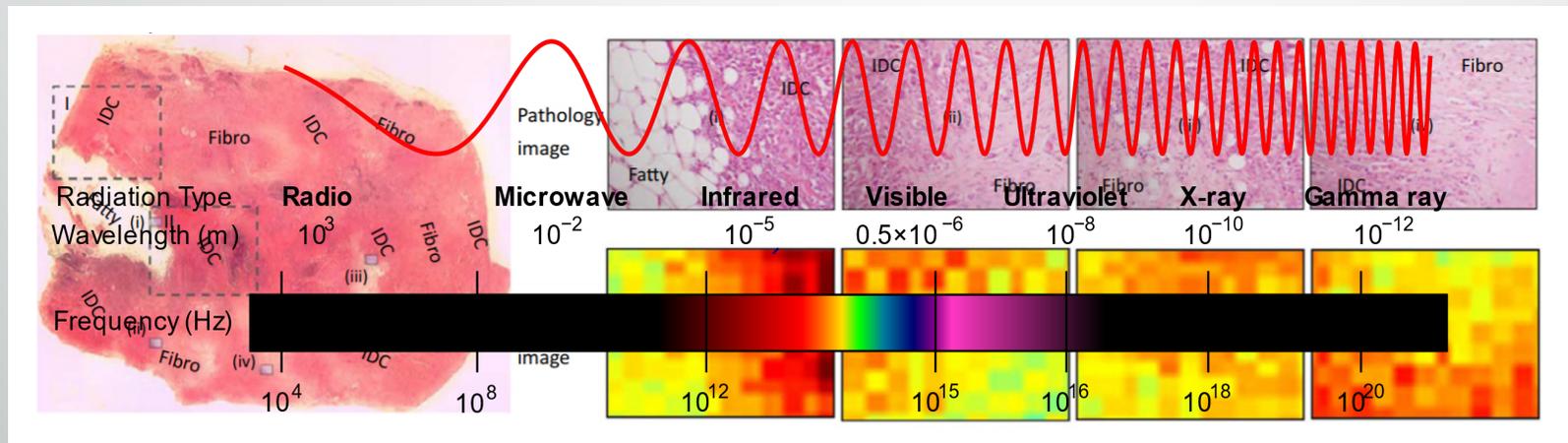


Image of breast cancer cell along with comparison shots of Pathology image versus Terahertz image.²

- Integration of THz Imaging into medicine is has been halted due to low THz signal strength and expensive materials.

² X. Yang, X. Zhao, K. Yang, Y. Liu, Y. Liu, W. Fu, and Y. Luo, *Trends in Biotechnology* **34**, 810 (2016).

Electro-Optic Polymers

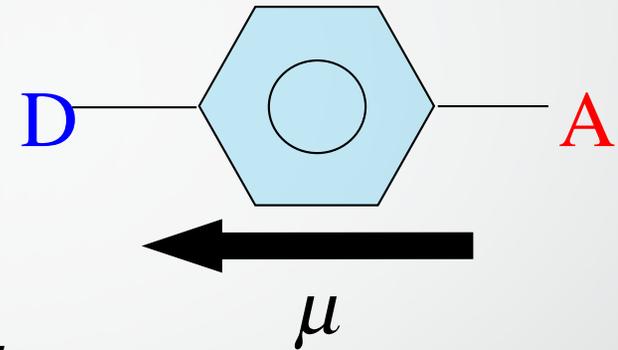
- Electro-Optic (EO) Polymers are organic materials constructed typically of a host polymer and chromophore dye molecule that change their index of refraction (n) under the influence of an electric field.

Inorganic Crystal (ZnTe)	EO Polymer
$r_{33} \sim 4 \text{ pm/V}^1$	$r_{33} > 120 \text{ pm/V}^1$

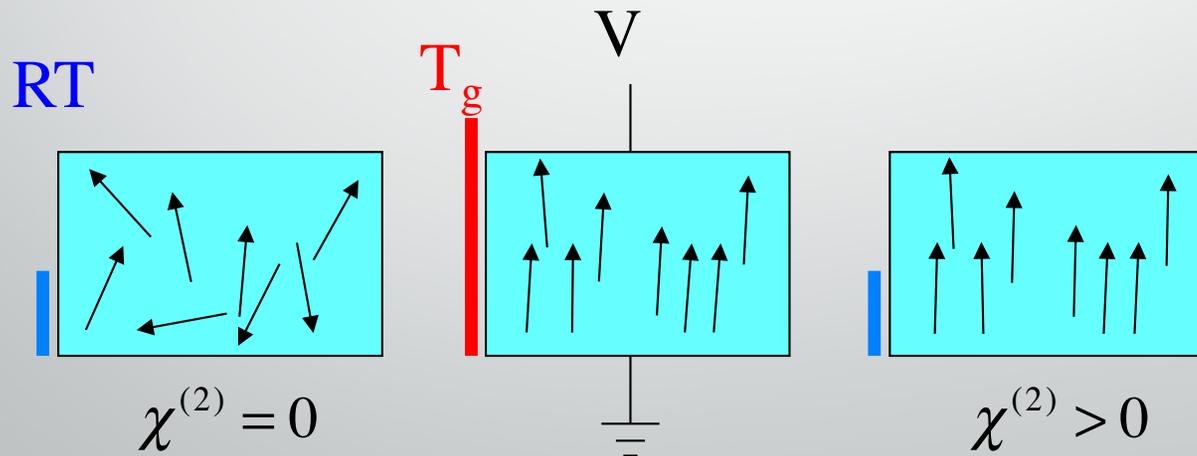
¹ A.M. Sinyukov and L.M. Hayden, *Optics Letters* **27**, 55 (2002).

Electro-Optic Poling

- Nonlinear optical properties arise from the orientation of the chromophore that occurs during poling.³



$$P_I = P_I + \chi_{IJ}^{(1)} E_J + \chi_{IJK}^{(2)} E_J E_K + \chi_{IJKL}^{(3)} E_J E_K E_L + \dots$$



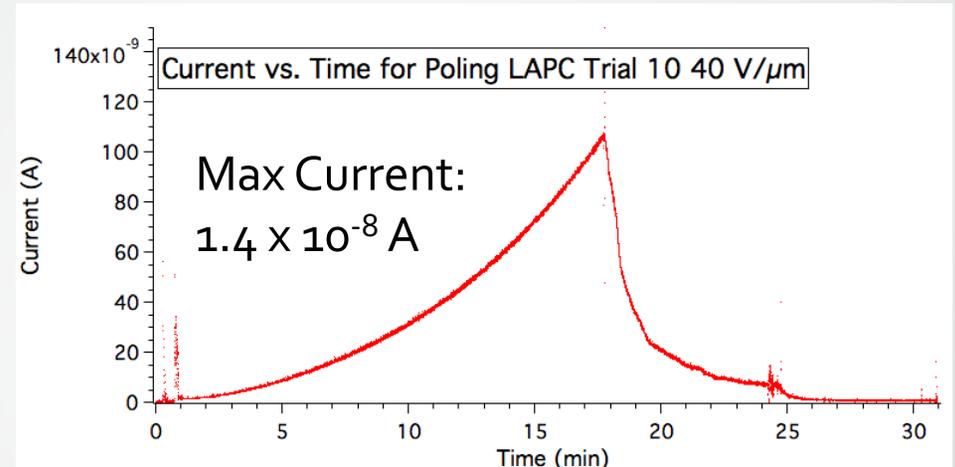
³ P.N. Prasad and D.J. Williams, *Introduction to Nonlinear Optical Effects in Molecules and Polymers* (New York : Wiley, c1991., 1991).

Dielectric Breakdown

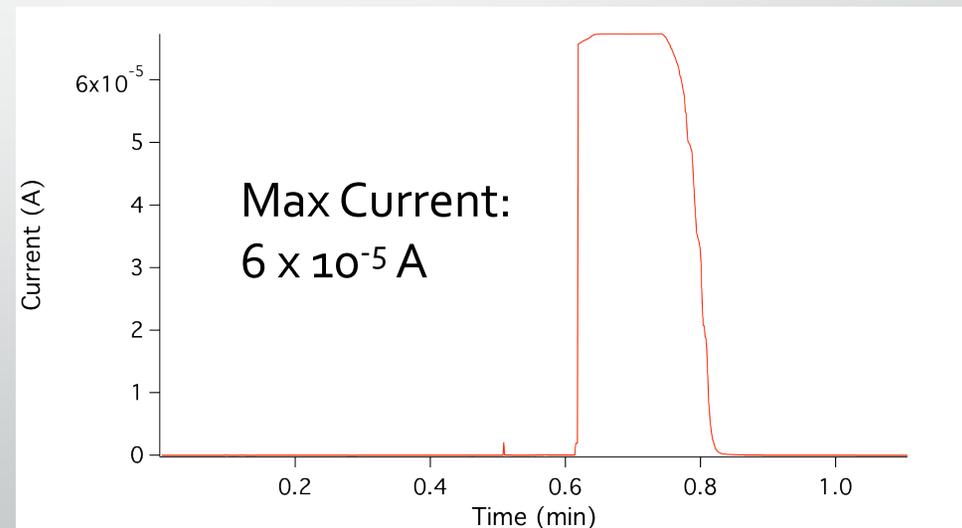
- Applying high voltage across the system will result in large currents that will lead to breaking of the material.



Image of broken samples during poling process.



Current of a sample being poled.



Current of a sample breaking.

Objective

- The addition of layers of barrier layers has shown to assist in postponing dielectric breakdown.⁴
- Try introducing a layer of SiO₂ to limit charge flow through polymer while allowing for large electric fields to still be applied.
- Hope to offset when dielectric breakdown will occur.
 - Test this by poling polymers at various field strengths and measuring the corresponding EO coefficient.

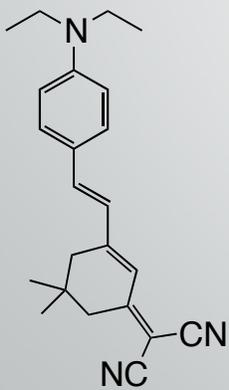
⁴ Su Huang, Jingdong Luo, Zhian Jin, Xing-Hua Zhou, Zhengwei Shi, and A.K.-Y. Jen, *J of Materials Chemistry* **22**, 20353 (2012).

Materials

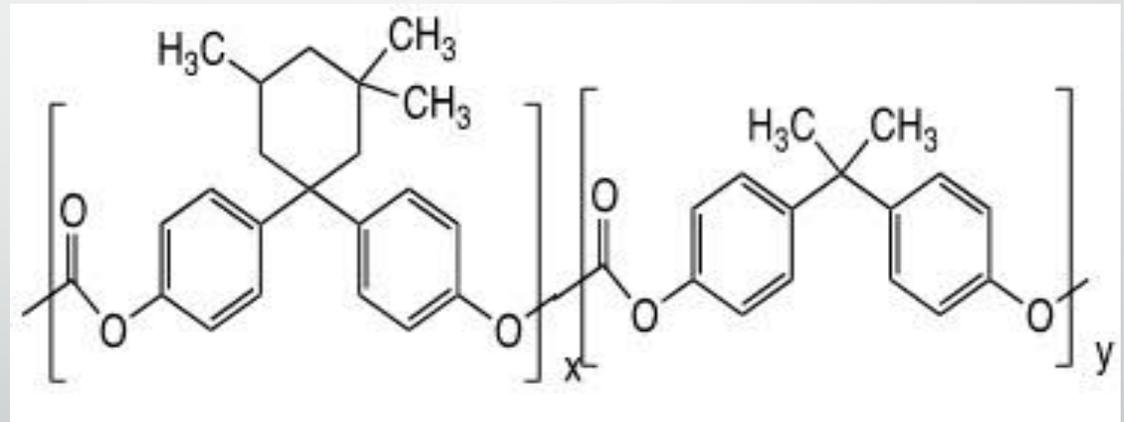
Lemke-e

Poly[Bisphenol A carbonate-co-4-4'-(3,3,5-trimethylcyclohexylidene)diphenol carbonate] (APC)
Dichloroethane (DCE)

Lemke-e $\mu = 8.3$ Debye



APC

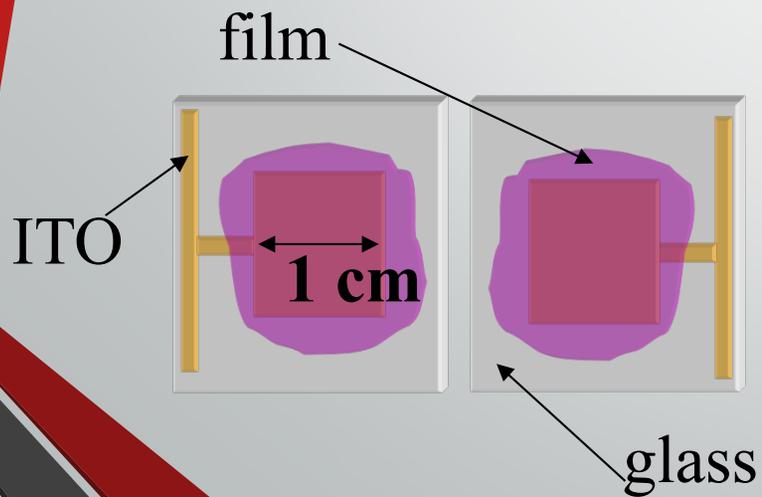
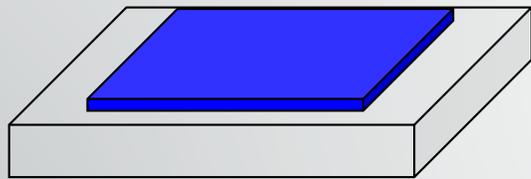


LAPC: 40% Lemke-e
60% APC

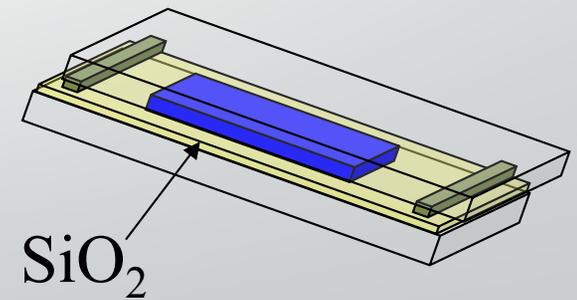
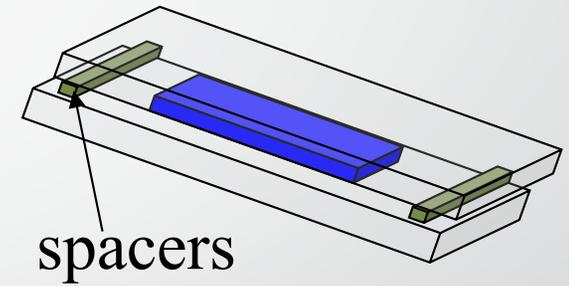
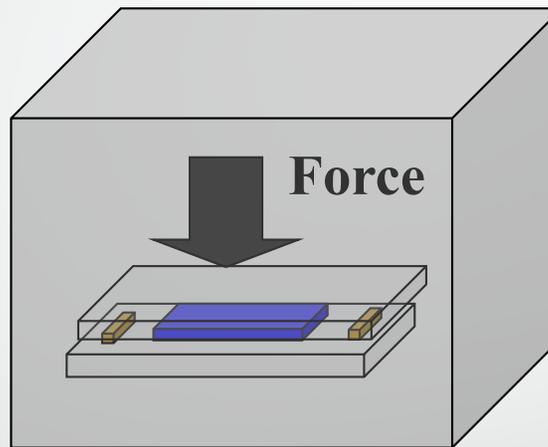
10% LAPC in DCE

Sample Preparation

- Casting

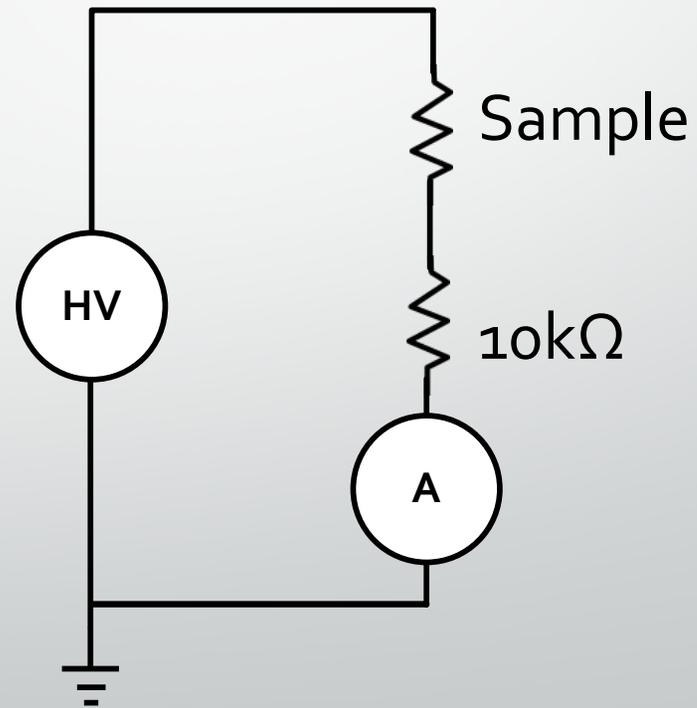
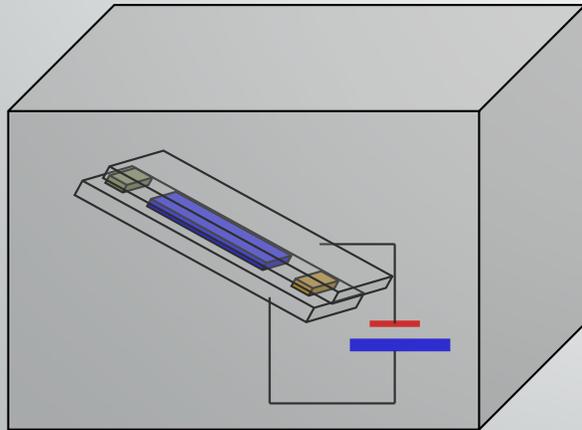


- Pressing



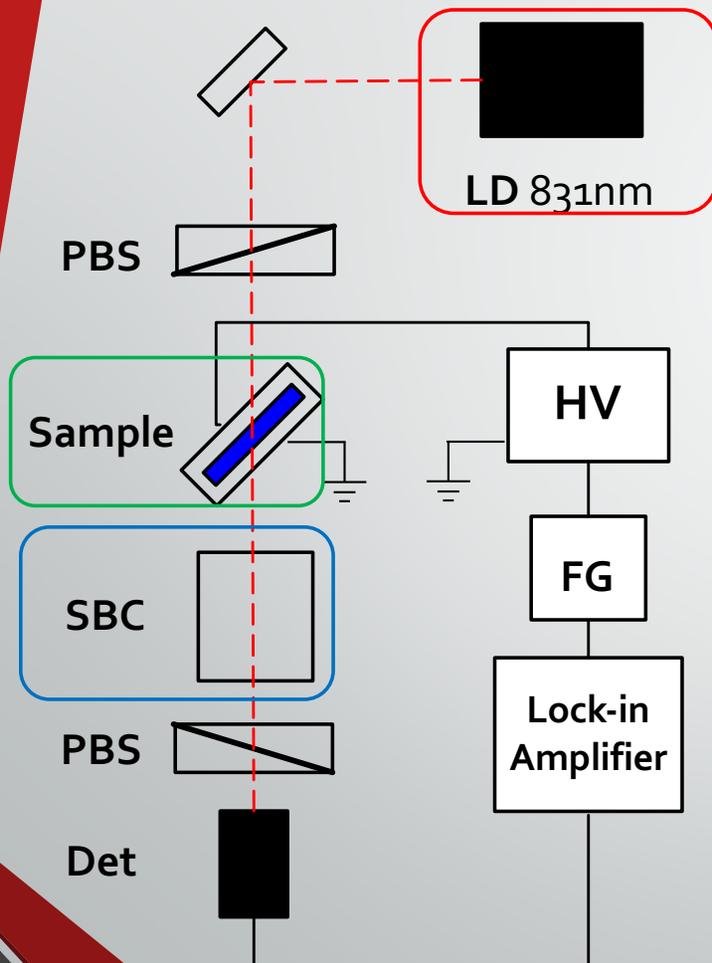
Poling

- Using the measured current, voltage applied across the sample can be determined.

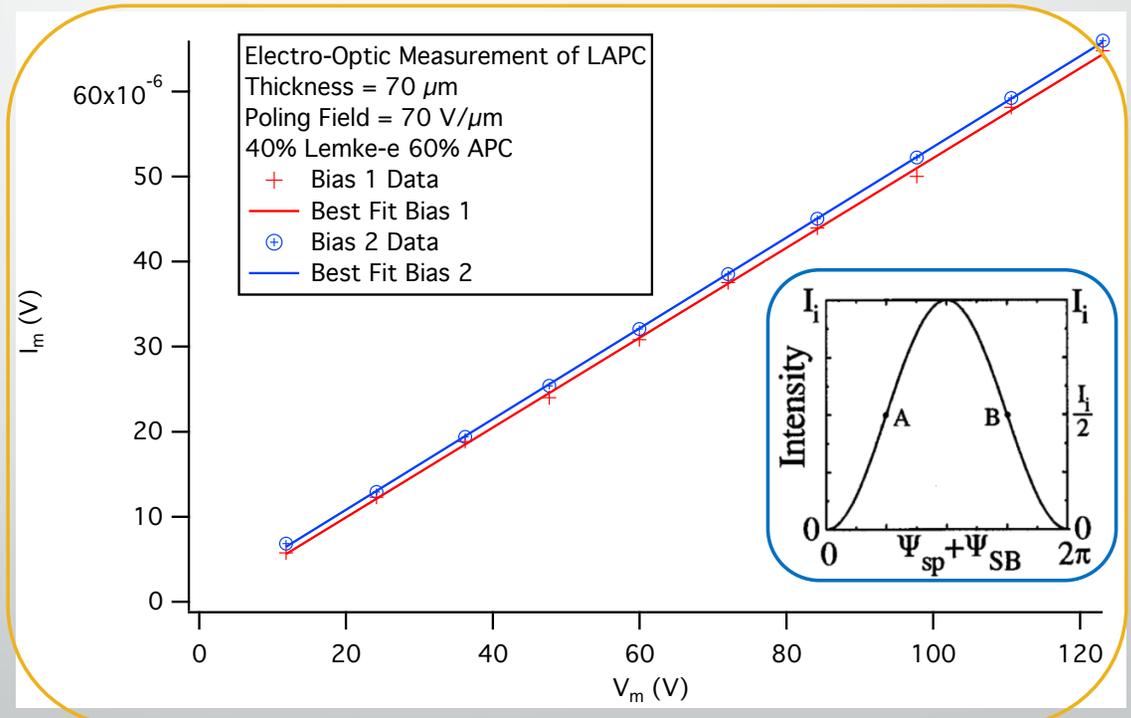


EO Experiment

- Ellipsometric Technique⁶

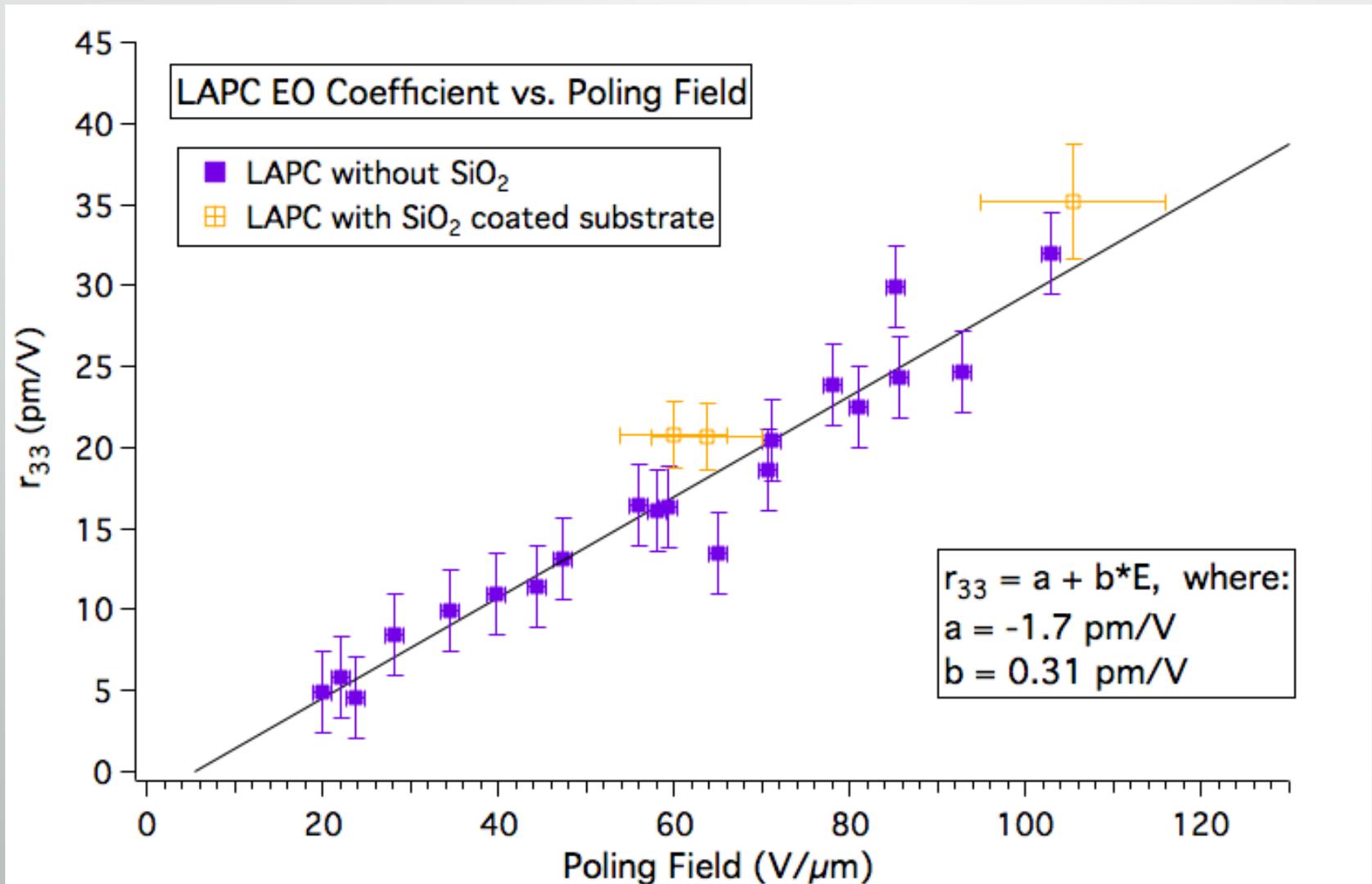


$$r_{33} = \left(\frac{3\lambda}{\pi} \right) \left(\frac{\sqrt{n^2 - \sin^2 \theta}}{n^2 \sin^2 \theta} \right) \left(\frac{\frac{dI_m}{dV_m}}{I_{\max} - I_{\min}} \right)^5$$



⁵ Sandalphon, B. Kippelen, K. Meerholz, and N. Peyghambarian, *Appl. Opt.*, **35**, 2346 (1996).

Results



Future Implications

- Poling technique of using barrier layers could be applied to other polymers with better properties.
- Films poled with this technique can be used in THz applications.
- International collaboration.

References

- ¹ A.M. Sinyukov and L.M. Hayden, *Optics Letters* **27**, 55 (2002).
- ² X. Yang, X. Zhao, K. Yang, Y. Liu, Y. Liu, W. Fu, and Y. Luo, *Trends in Biotechnology* **34**, 810 (2016).
- ³ P.N. Prasad and D.J. Williams, *Introduction to Nonlinear Optical Effects in Molecules and Polymers* (New York : Wiley, c1991., 1991).
- ⁴ Su Huang, Jingdong Luo, Zhian Jin, Xing-Hua Zhou, Zhengwei Shi, and A.K.-Y. Jen, *J of Materials Chemistry* **22**, 20353 (2012).
- ⁵ Sandalphon, B. Kippelen, K. Meerholz, and N. Peyghambarian, *Appl. Opt.*, **35**, 2346 (1996).
- ⁶ J.G. Grote, J.S. Zetts, R.L. Nelson, F.K. Hopkins, L.R. Dalton, Cheng Zhang, and W.H. Steier, *Optical Engineering* **40**, 2464 (2001).

Acknowledgements

- I would like to thank:
 - Dr. L. Michael Hayden, Faculty Mentor
 - Physics Department, UMBC
 - UMBC McNair Summer Research Institute

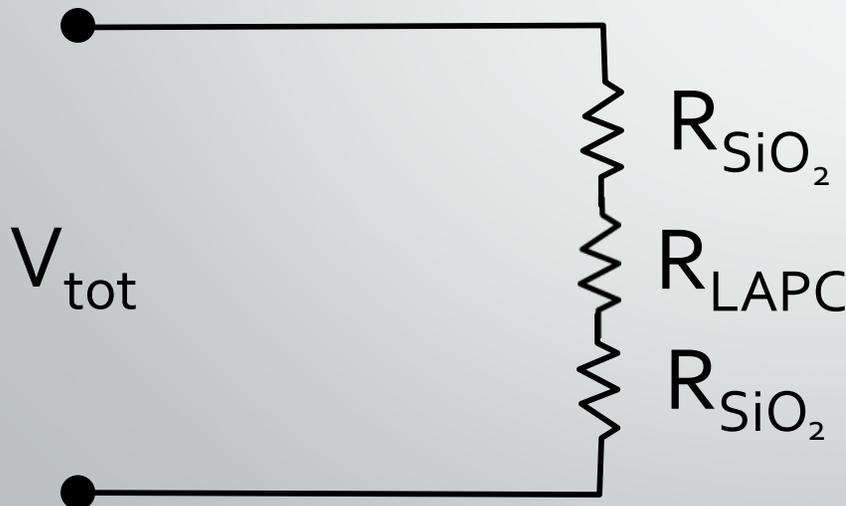
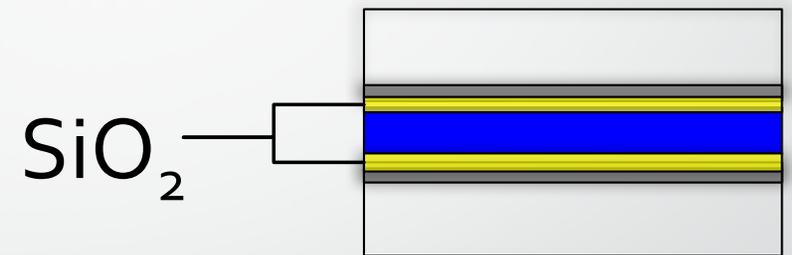
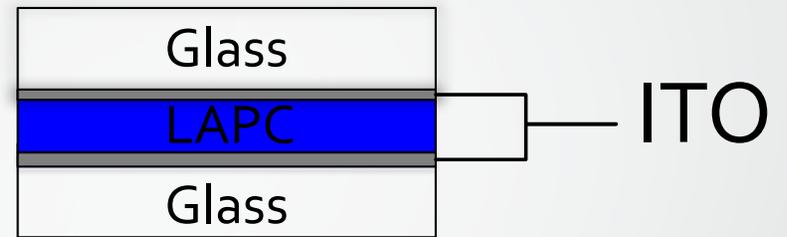




Questions?

Correction of Measurements

- Measurements during poling and EO experiment are done between ITO electrodes, and would not account for the added layers of SiO_2



$$V_{LAPC} = V_{tot} \frac{1}{1 + 2 \left(\frac{\rho_{\text{SiO}_2} l_{\text{SiO}_2}}{\rho_{\text{LAPC}} l_{\text{LAPC}}} \right)} \cdot^6$$

⁶ J.G. Grote, J.S. Zetts, R.L. Nelson, F.K. Hopkins, L.R. Dalton, Cheng Zhang, and W.H. Steier, *Optical Engineering* **40**, 2464 (2001).