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14. ABSTRACT

This research focuses on:: (1) Organic electro-optic materials with the objective of realizing materials characterizec by electro-optic coefficients greater than 300 pm/V at telecommunication wavelengths and which pass Telecordia standards. New processing techniques were developed for fabrication 3-D devices and circuits and for achieving low insertion loss electro-optic devices including active wavelength division multiplexing (WDM) transmitter/receiver systems. During this period of time, the Dalton research group served as the national resource for state-of-the-art electro-optic materials providing materials to DoD laboratories, DoE labs, NIST researchers industry, and academic researchers. (2) Metal core dendrimer materials were developed for applications as sensors organic light emitting diodes, and light harvesting solar cell coatings. Materials were designed for improvec emission properties and photochemical stability both by systematic design of the chelated metal and by design of the surrounding dendrimer structure. Materials were provided to DoD and NASA laboratories and to industry.

15. SUBJECT TERMS

Organic electro-optic materials, Monte Carlo calculations, nanostructured materials, electro-optic devices, light emitting materials

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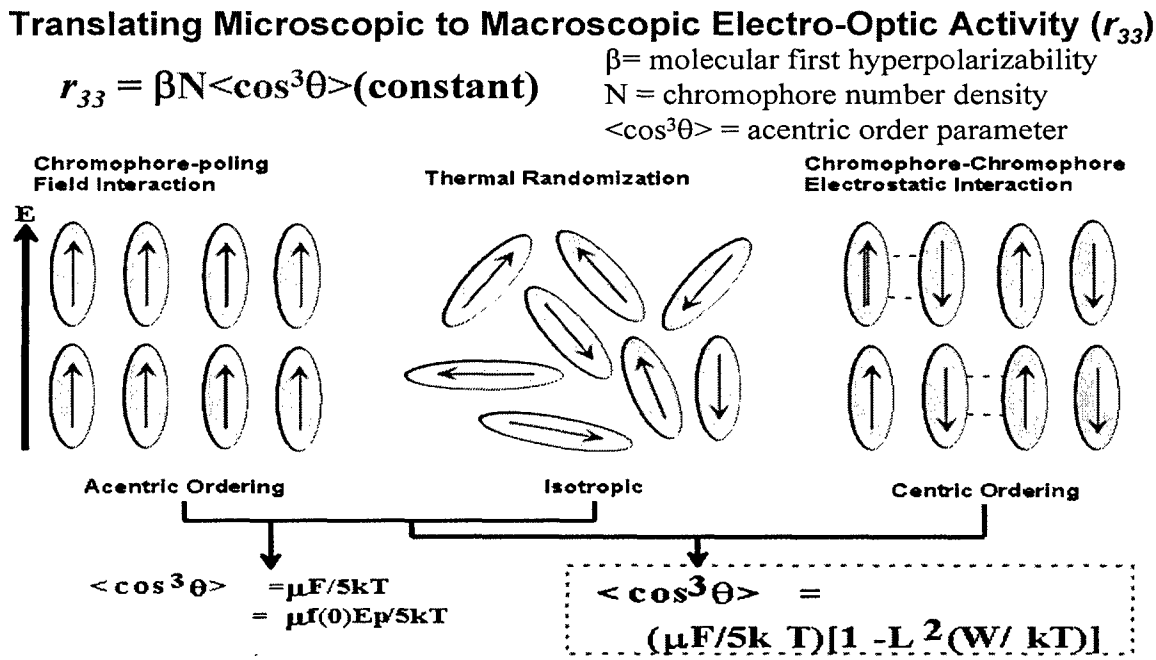
Technical Report

While the development of new state-of-the-art materials for the implementation of new device technologies, relevant to Department of Defense, needs has always been an important component of our research, the more critical and transformative achievement has been the advancement of the understanding of the forces that control the development of various types of nanoscopic order over macroscopic dimensions. While this general pursuit has been an on-going theme in polymer science (e.g., the work of Flory and others), our research has been the first to address the role played by very large (greater than 10 Deybe) electronic dipole-dipole interactions that are associated with extended conjugation π-electron chromophores. Moreover, our research is the first research to address in a systematic way the effect of anisotropic ordering potentials on single and multi-chromophore component systems (e.g., binary and higher order organic glasses). Our research was initially motivated by a request from Dr. Charles Lee to define and rationalize the variation of electro-optic activity with chromophore concentration for electro-optic chromophore/polymer composites. This request, and the subsequent discussion of our early results and conclusions, led in a natural way to a new and rational design paradigm for generating robust macromolecular (ultimately polymeric, optical-quality glasses) organic materials exhibiting exceptional photonic and electronic properties. The practical consequence has been a substantial success story marked by the generation of substantial intellectual property; the formation and development of new companies Lumera and AES; the launching of new sponsored research programs by DARPA and NRO; and enhanced research collaborations with AFRL (including theory as well as device development), Boeing, Lockheed Martin, and Intel. While Federal and private support for the applications of this research has grown dramatically during the period 2003-2006, this research award has provided the key support for basic research necessary to enable new material and device implementation.

In this section we present a brief overview of the research accomplishments of the past (2003-2006) period of support from AFOSR. Space limitations do not permit an exhaustive discussion of detail or of all applications; for such information, the reader is referred to cited (in print) publications (1-63). Our objective will be to provide a comprehensible review of the design paradigm that has guided research and of our most important accomplishments. To that end, we start with a review of theoretical methods that have been used to guide design of materials to be synthesized.

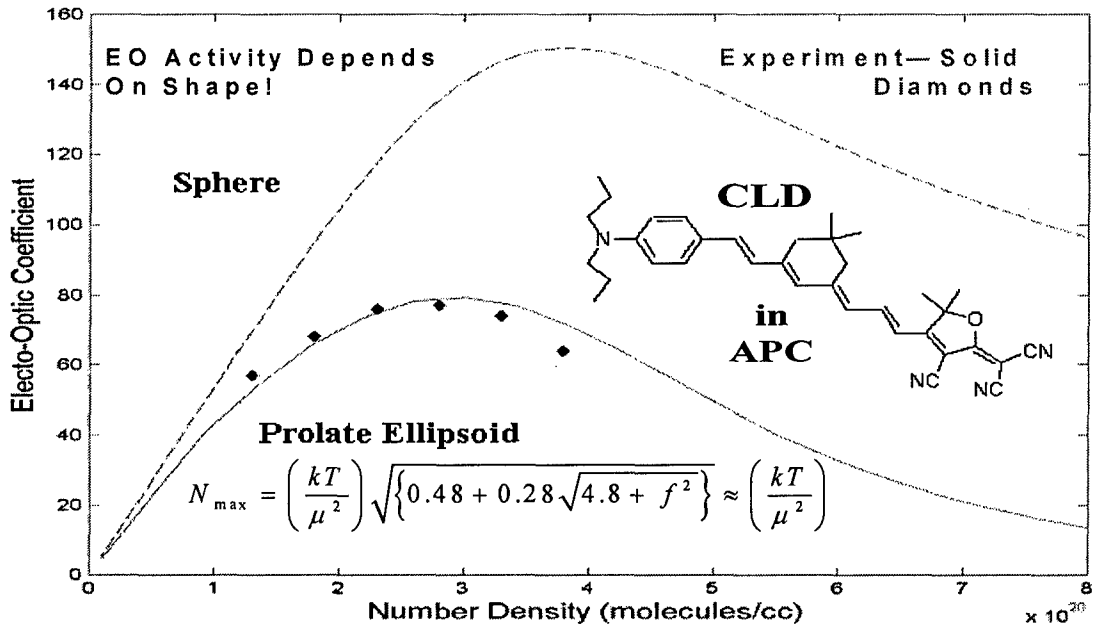
A critical initial objective was to understand the nano- and microscopic organization of high dipole moment chromophores in the presence of an applied electric poling field. Chromophores may be incorporated into a polymer host (which is poled near the glass transition temperature, T_g, of the composite material) or into dendritic structures that exist as organic glasses. Electro-optic activity, r_{33}, is both a technologically important quantity and an excellent measure of macroscopic noncentrosymmetric order. The cartoon shown below illustrates key features:



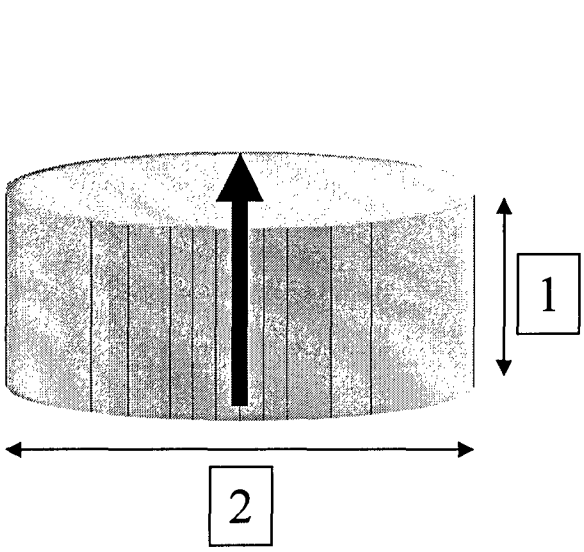
L = Langevin Function; W = Intermolecular Electrostatic Potential; k = Boltzmann constant; E_p is applied poling field; F is poling field felt by chromophore

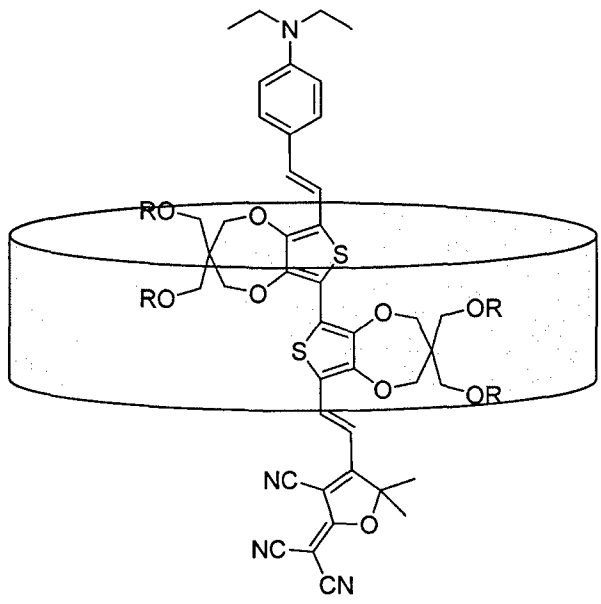
In the absence of intermolecular electrostatic interactions, the simple result is that the acentric order parameter $\langle \cos^3\theta \rangle$ depends upon the ratio of poling energy to 5 x (thermal energy, kT) and is independent of chromophore loading (number density, N). Our first approach to the problem of treating strong intermolecular interactions was to derive an analytical potential function describing the field felt by a reference chromophore (dipole) from an ensemble of surrounding dipoles; this potential function can also be defined numerically by Monte Carlo calculations [1,2,20,37,61,64-66, and references contained therein]. If chromophores are treated as point dipoles, the intermolecular electronic electrostatic interaction (W) leads to an attenuation of poling-induced order given by $L^2(W/kT)$ where L is the Langevin function. To quantitatively simulate data for chromophore/polymer composite materials, the shape (nuclear

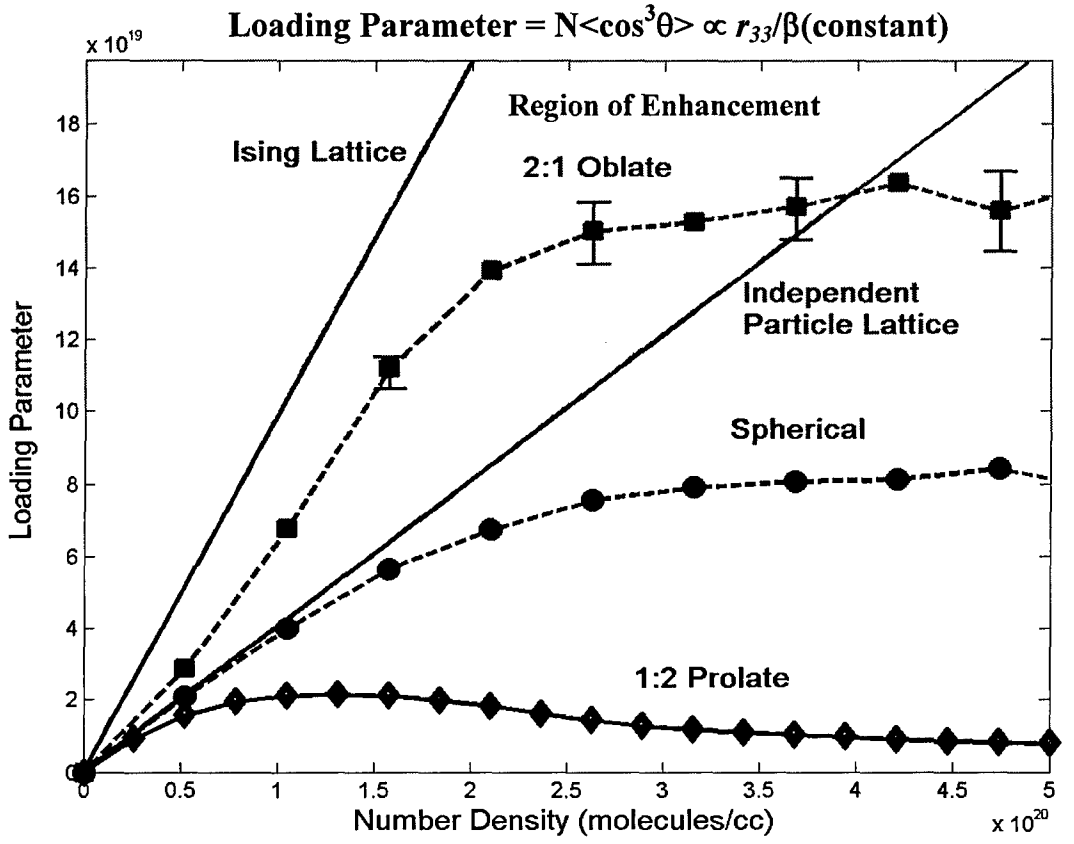
repulsive intermolecular electrostatic or steric interactions) of chromophores must be taken into account. We have developed highly efficient methods for evaluating the many complex integrals over the appropriate orientational variables and have described these in various publications [1,20,61,66, and references contained therein]. Shape effects can be treated approximately by modifying limits of integration over certain orientational variables [1,64,66]. Typical agreement between theory and experiment is shown below (for data at 1.06 microns wavelength):



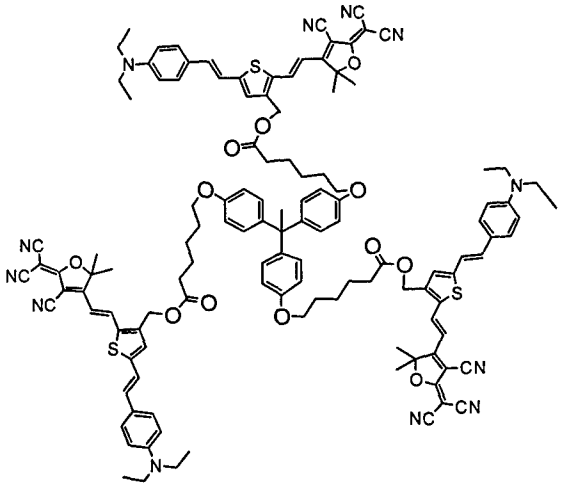
In the above example, we have treated chromophores as rigid (hard shell) objects with quantum-mechanically-defined, embedded electron distributions. Moreover, Van der Waals interactions beyond dipole-dipole interactions have been neglected. The above simulation was performed without adjustable parameters. Even with the neglect of detailed treatment of all Van der Waals interactions and a "hard shell" treatment of nuclear repulsive interactions, nearly quantitative agreement with experimental data is achieved. Highly quantitative agreement can be achieved by use of r^{-12} repulsive potentials and by full consideration of Van der Waals interactions, but even the above more approximate treatment illustrates the influence of chromophore shape upon electro-optic activity and the influence of chromophore dipole moment, μ, upon maximum achievable electro-optic activity. Shape modification can be systematically achieved by employing a sequential dendritic synthesis scheme as is illustrated in the next figure. Even simple modification (which fails to achieve the desired 1:2 oblate ellipsoidal structure shown) results in a factor of 3-4 improvement in measured electro-optic activity [57,61,62]. The practical consequence of this result is that discotic shaped chromophores yield electro-optic activity coefficients in the range of 150-250 pm/V (at telecommunication wavelengths) even when our vintage "1999-2001" chromophores (FTC, CLD) are used. This result is better illustrated in following figure which shows theoretically-computed values of $N\langle\cos^3\theta\rangle$ vs. N as a function of chromophore shape. This figure has the advantage of being a "universal" curve for understanding the role of chromophore shape in defining electro-optic activity.



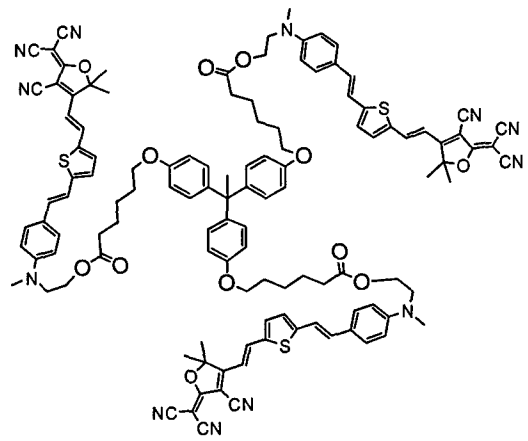




It is clear from the above figure, that intermolecular electrostatic interactions augment poling-induced order for discotic shaped chromophores. The situation becomes even more favorable (intriguing) when different chromophores are mixed together or when chromophores are incorporated into multi-chromophore-containing dendrimers such as shown below: In such cases, potential functions associated with covalent bonds and full treatment of Van der Waals interactions must be considered. This requires use of pseudo-atomistic Monte Carlo/molecular dynamics calculations. By "pseudo-atomistic", we mean that π-electron segments (e.g.,

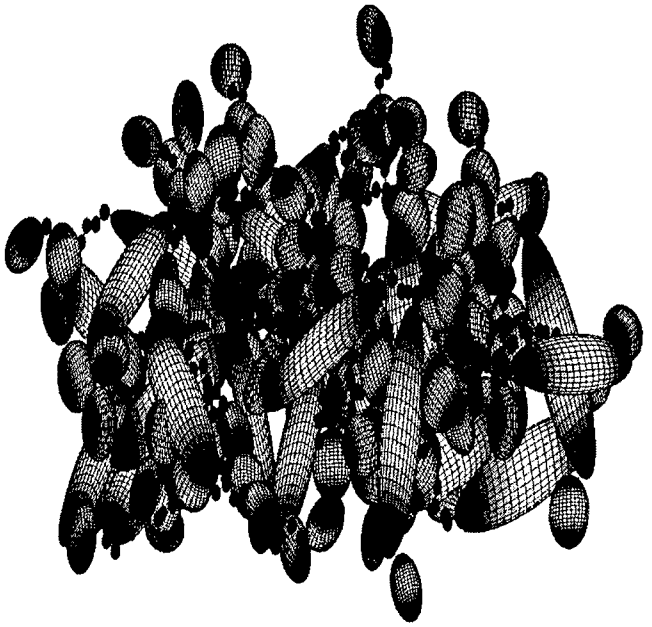


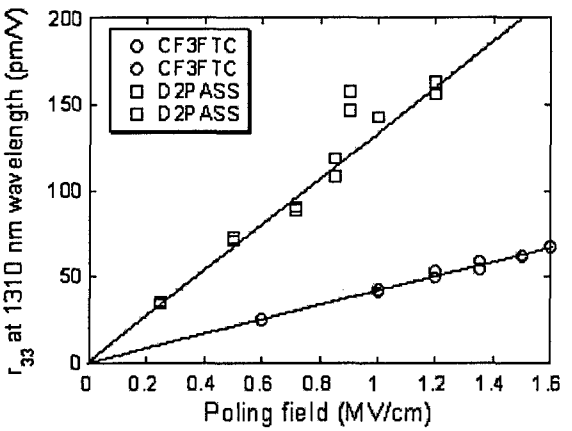
Side-on
D2.PAS.31
IV

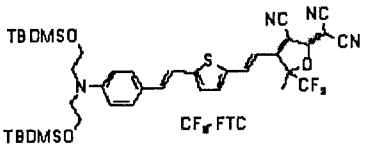


End-on
AALD-1104
V

chromophores, phenyl rings) are treated in the United Atom Approximation while σ-electron segments are treated atomistically using potentials derived from quantum mechanics. An example of simulation of the PAS dendrimer is shown below: Monte Carlo simulations illustrate

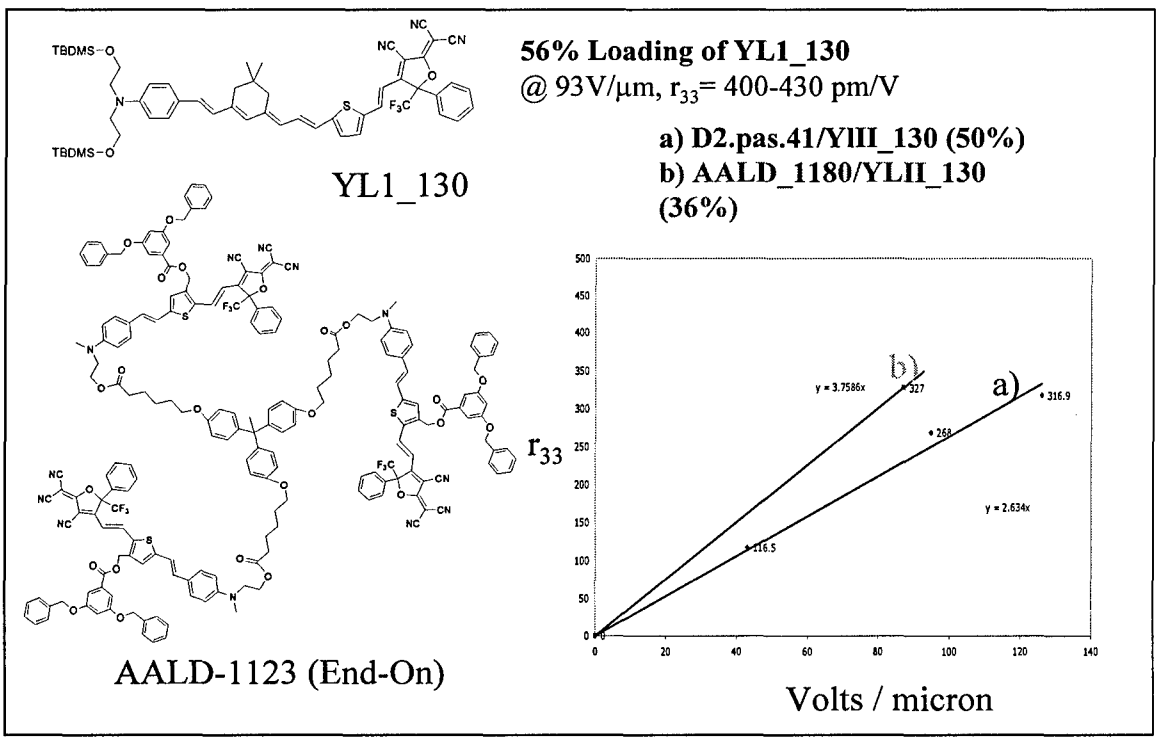






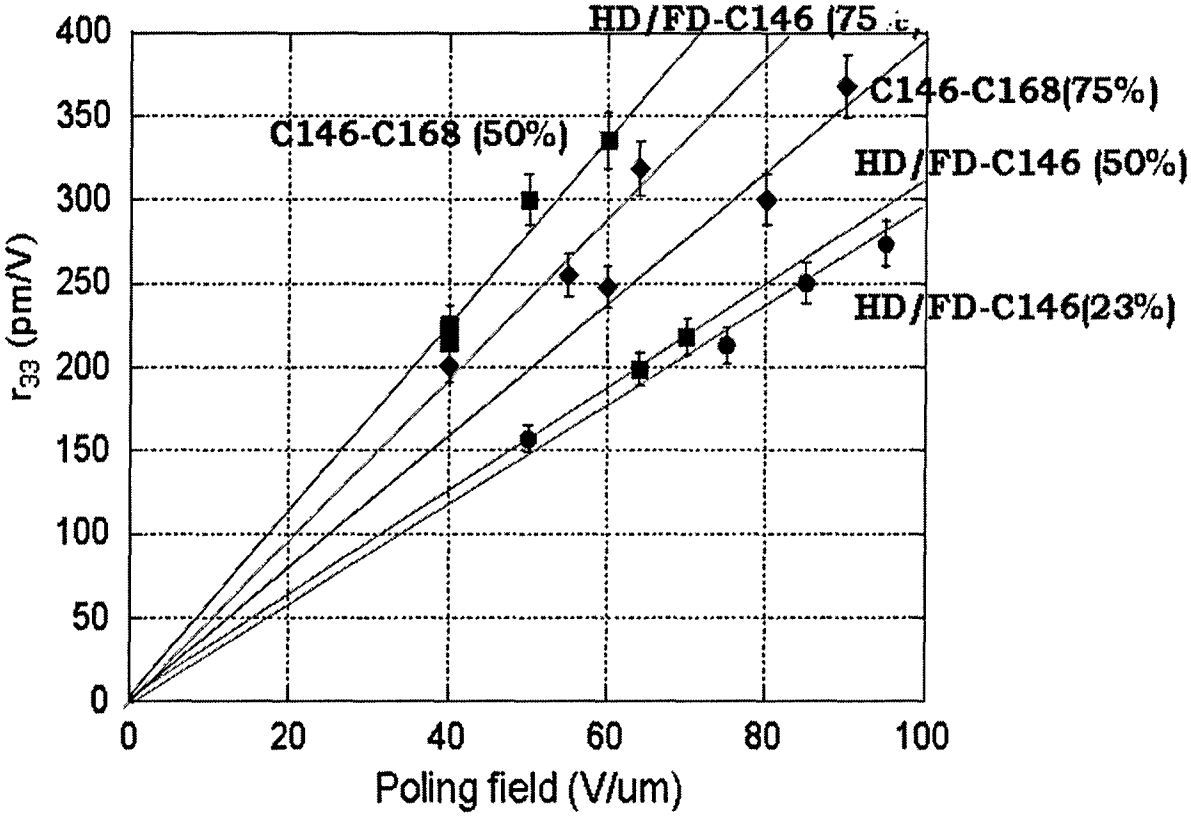
that the order parameter increases from 0.15 at low loading to greater than 0.25 at high loading (see above left). Close consideration of the ordering of chromophores illustrates that covalent bond restrictions and Van der Waals interactions play critical roles in defining the resultant order. Experimentally, a factor of somewhat greater than 3 improvement in electro-optic activity is realized for the PAS dendrimer relative to the best values that can be obtained for the same chromophore in polymer composite materials (see above right). In some cases (not shown), covalent bond restrictions and Van der Waals interactions led to a case where the acentric component of the intermolecular dipole-dipole potential function dominates; Monte Carlo calculations suggest that, for such materials, chromophores are organized in a head-to-tail manner with chromophores in adjacent chains displaced by a distances that results in a relative "magic angle" (no dipole-dipole interaction) relationship between chromophores in adjacent chains. Of course, many chromophore variants are possible leading to an array of intriguing results.

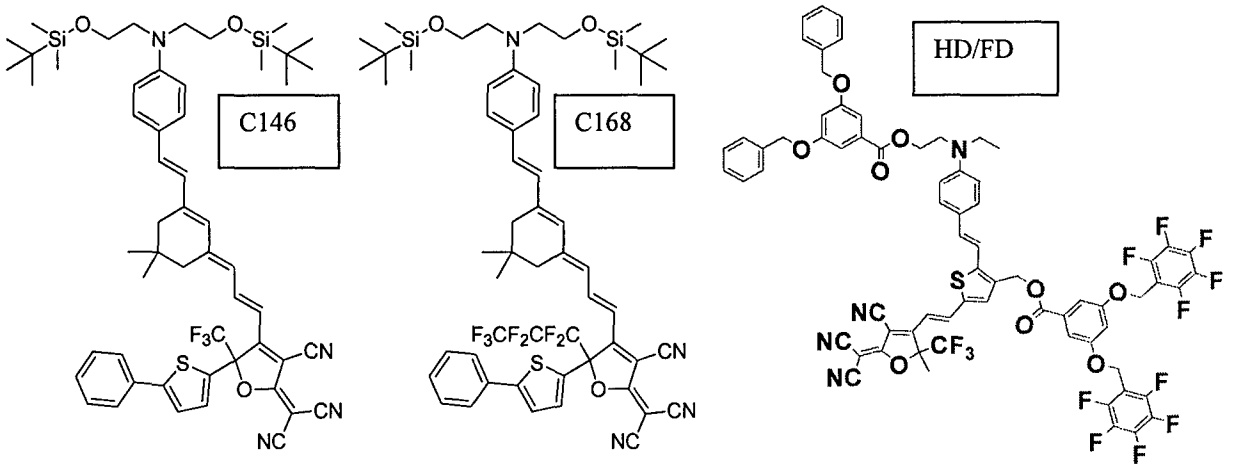
Even more interesting results are shown for blends of organic EO chromophores and multi-chromophore-containing dendrimers in the figure below.



Such materials start to approach Ising lattice behavior. Hydrogen bonding can play an important role in enhancing poling-induced order for dendrimer materials containing strategically positioned hydrogens and fluorines (see HD/FD results in the following figure); however, subtle interplay of dipole-dipole, steric, and Van der Waals interactions define the experimentally-observed results. In these binary systems, it is clear that entropy is playing an important role in defining the interactions of the components. Because each chromophoric species can be ordered under the poling field, each species acts to enhance the order of the other. In a crude way

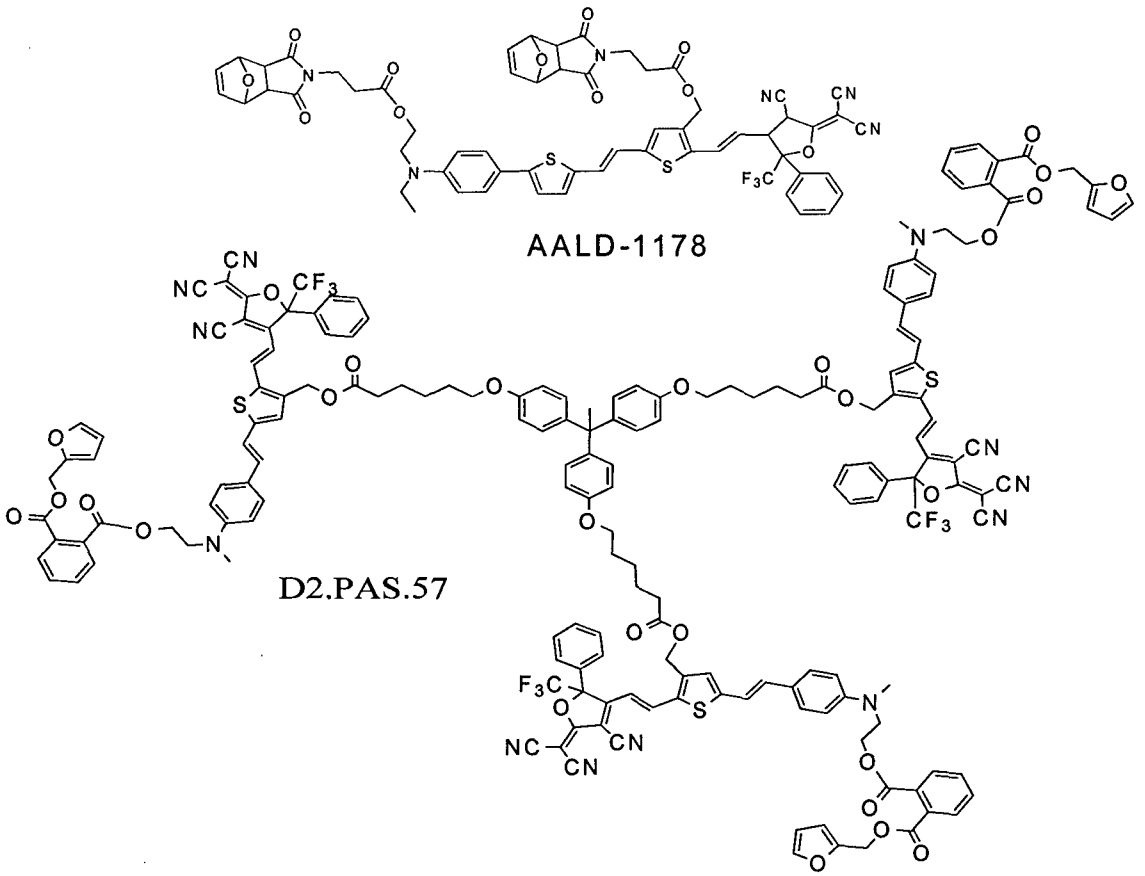
this can be thought of as each order species acting to provide an Ising-like potential for the other. While the components must be different to realize an entropy enhancement, our preliminary experiments indicate that the difference can be realized in





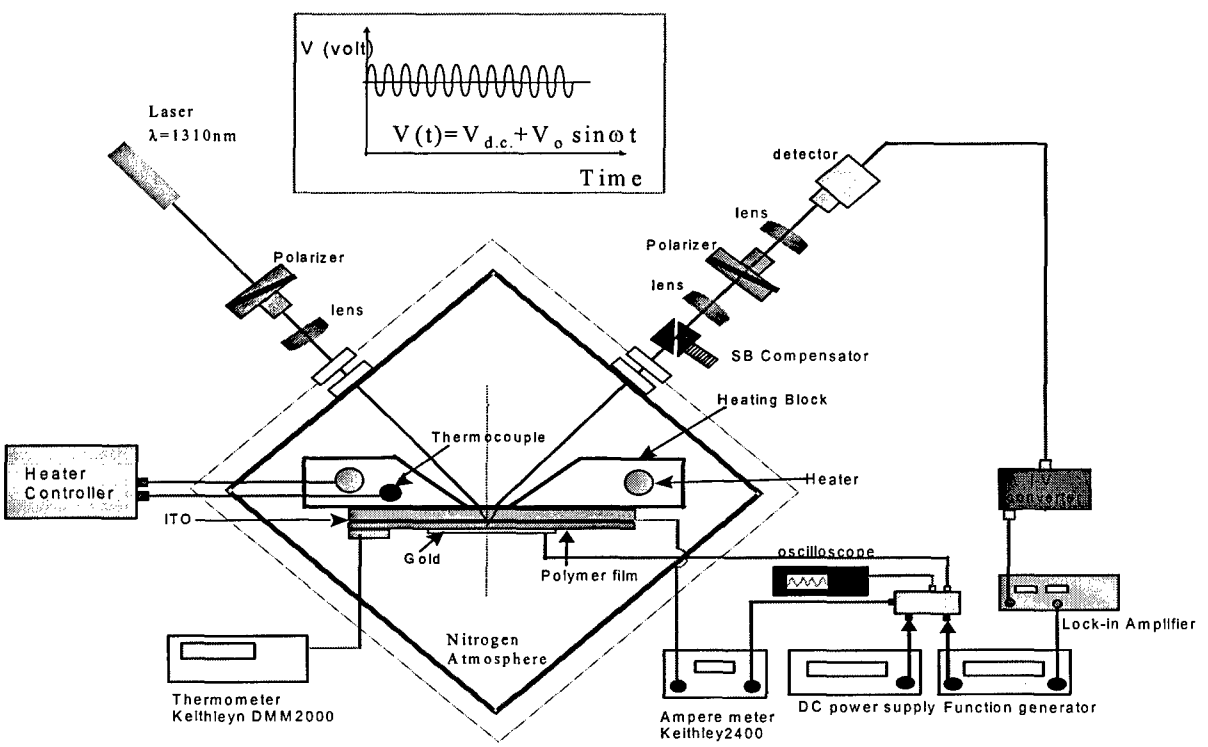
various ways: Disparity in length, disparity in structure/composition, disparity in isotopic composition. It is also interesting to note the relatively low poling voltages used for poling some dendritic glasses. Electrical conductivity limits achievable poling voltage; and when the donor and acceptor ends of chromophores are positioned in close proximity in some organic glass lattices, high conductivity is observed. Steric bulk around the donor and acceptor ends attenuates such conductivity leading to enhanced electro-optic activity. Organic glasses also yield improved auxiliary material properties relative to chromophore-polymer composite materials. Photostability (in the presence of oxygen) is improved by 1-2 orders of magnitude, probably reflecting the dense material lattices of organic glasses. Thermal stability, for uncrosslinked materials, is determined by the molecular weights of components but is much higher than might be expected for relatively low molecular weight dendritic materials. This likely reflects the fact that in organic glasses cooperative motion of the chromophores is required for relaxation of poling-induced order (The Ising potential effect). Optical loss of organic glasses is comparable to that of polymer composite materials but loss is often observed to decrease during electric field poling. This may reflect the annealing of micro-domains existing in unpoled materials.

To fabricate useful devices, it is critical to control the glass transition temperatures (Tg) of organic glasses at various processing stages and in the final device materials. This is effectively accomplished by using reversible Diels-Alder chemistry. By changing the dienes and dienophiles used to effect crosslinking, crosslinking temperatures can be varied from 120°C to greater than 200°C. An example is given in the following figure.

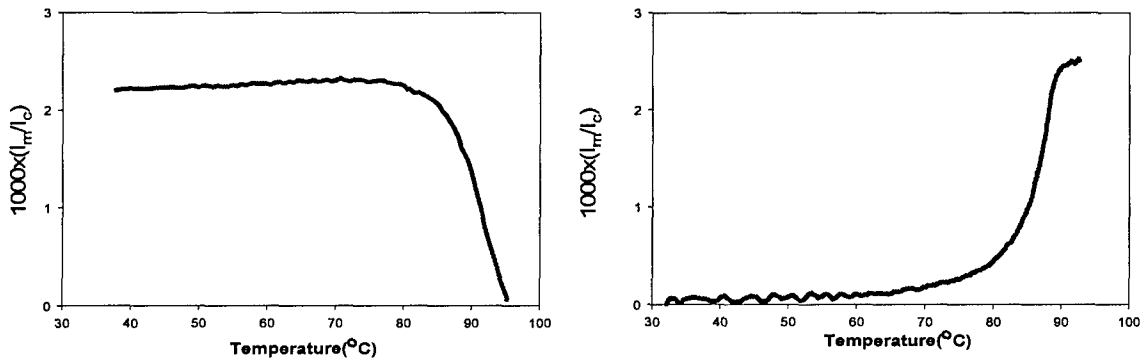


By use of both reversible Diels-Alder crosslinking and use of the fluorovinyl ether crosslinking group, we have realized materials with final glass transition temperatures of 200°C. Realization of such high glass transition temperatures requires electric field poling above 200°C and this can create problems for chromophore stability and likely should not be pursued except for those device applications where such high thermal stability is required. Glass transition temperatures of 140-160°C are more than adequate to surpass Telcordia Standards.

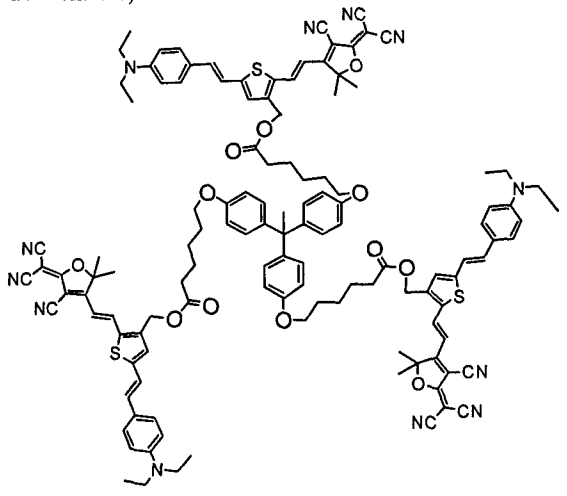
In order to optimize electric field poling efficiency and to define the thermal stability of materials before final device fabrication we have developed various test beds for measurement of second order optical nonlinearity (electro-optic activity and second harmonic generation) equipped with heating stages. For example, we have modified the Teng-Man simple reflection method of measuring electro-optic activity for *in situ* studies (see below).



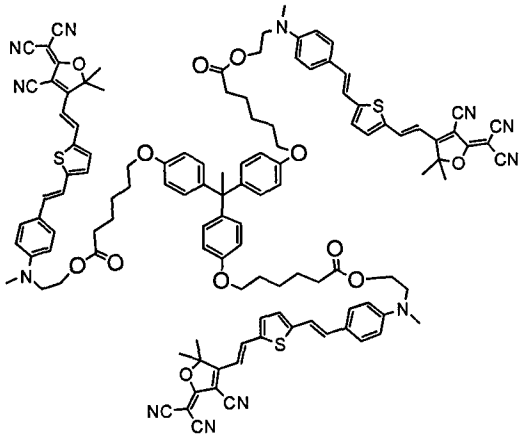
SIDE-ON w/ 56% YL I 124



On the right, we monitor the induction of electro-optic activity for a doped organic dendritic glass; and on the left, the relaxation of electro-optic activity after the poling field is turned off is shown. In addition to dynamic assays shown above, we also use the test beds to carry out temporal kinetic studies. For example, we have used such studies to define the difference in temporal stability for chromophores attached to a dendritic core either by "end-on" or "side-on" attachment (see accompanying figures for dendrimer structures and the analysis of temporal data using stretched exponential fitting). Studies on uncrosslinked multi-chromophore-dendrimers,



Side-on
D2.PAS.31
IV



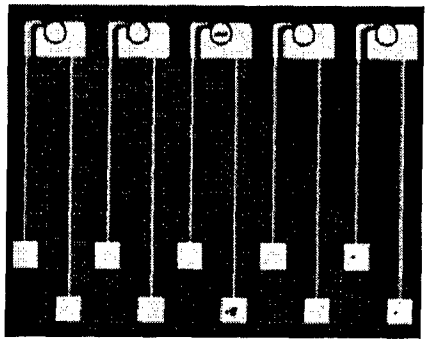
End-on
AALD-1104
V

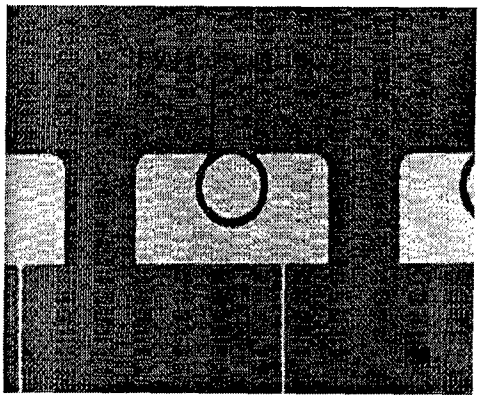
	HE-End-on V			HE-Side-on IV		
	τ(s)	$\langle\tau\rangle$(s)	β	τ(s)	$\langle\tau\rangle$(s)	β
118°C	47.39	817.54	0.337	133.37	666.57	0.3506
114°C	67.66	1369.50	0.300	454.55	14354.25	0.227
109°C	409.33	32669.02	0.256	2327.21	6037700.72	0.150
E_a (kcal/mole)	124.57			302.84		

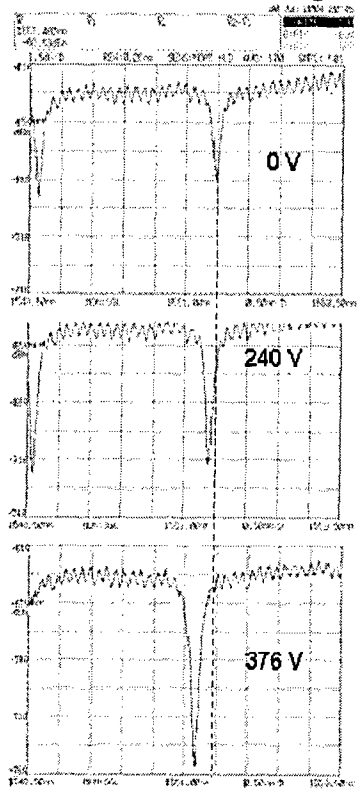
chromophore-doped uncrosslinked multi-chormophore dendrimers, and crosslinked dendrimers permit detailed insight into the effects of plastization and crosslinking on thermal stability. Note that control of glass transition temperatures is critical to the use of nano-imprint lithography.

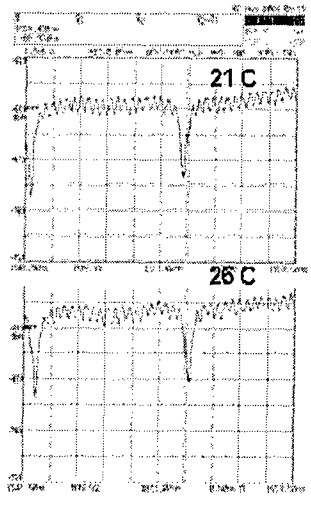
A number of novel devices have been fabricated from the materials produced with AFOSR support, including devices involving stripline, cascaded prism, and ring microresonator structures. Ring microresonator voltage-controlled optical filters (switches) and wavelength division multiplexing (WDM) transmitter receiver devices have been fabricated [6,8,14,20,21,30,39,48,50,58,60-63,67,68], including by soft lithography (nano-imprint lithography) techniques [30,39,48,58,60-63]. Organic EO glass materials have also been incorporated into silicon photonic circuitry [48,60-63] and a collaborative evaluation of devices have been undertaken with Intel and Boeing Corporations. Conformal and flexible device structures have been fabricated and exhibit exceptional performance [14,20,21,30,39,48,50,58,60-63,67,68]. Direct integration of photonics with semiconductor VLSI electronics has been demonstrated [46,69,70]. Terahertz signal generation and detection has been demonstrated [42]. An example of the performance of our initial organic EO/silicon photonic ring microresonator circuitry is shown below. Performance has been subsequently improved by a factor of 5 (research carried out in collaboration with Boeing and Cal Tech).

Voltage and Thermally Tuned CLD-PSDA/Si Ring Resonator (8/18/04)









Thermally Tuned
"Red Shift"

Our research in the previous funding periods has also produced significant advances in organic light emitting device [4,5,18,38,71-78], carbon nanotube based device technologies including actuators (MEMS devices) and photovoltaics [25,79-81], organic electronics [35,44], and sensor materials [11,13,22,26,38,52,59]. Space limitations prohibit detailed review of these activities in this proposal and the reader is referred to cited literature for detailed descriptions of the research.

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Nanostructured Materials Annual Report (period 03/01/03 – 2/28/06) Statistics:

Personnel Supported:

Number of PI(s) and Co-PI(s) Involved: 1
Number of Post Docs Supported: 1
Number of Graduate Students Support: 8
Other Researchers Supported: 2

Postdoctoral Fellows Supported (Partial Support)
Jeremiah Miller

Graduate Students Supported (Partial Support)
Haishan Sun
Dinesh Patel
Roni Kopelman
Scott Gable
Nicholas Buker
Steven Bowles
Carla McDowell
Benjamin Olbricht

Other Researchers Support:
Joseph Amend
Cyrus Anderson

Publications:

Number of Publications in Refereed Journals: 102
Number of Publications Which Acknowledge AFOSR Support: 63

Publications Which Acknowledge AFOSR Support

1. L. R. Dalton, B. H. Robinson, A. K. Y. Jen, W. H. Steier, and R. Nielsen "Systematic Development of High Bandwidth, Low Drive Voltage Organic Electro-Optic Devices and Their Applications," Opt. Mater., 21, 19-28 (2003).
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Participation/Presentations: (From January 1, 2003 to end of grant period)

***Conference*--January 16-17, 2003**--NSF Workshop on Technological Challenges for Flexible, Light-weight, Low-cost and Scalable Organic Electronics and Photonics. Arlington Hilton Hotel & Towers, Arlington, VA--Invited Presentation: Organic Electro-Optic Materials: Present and Future.

January 24, 2003—DoD DDR&E Review of Polymeric Smart Skin Materials, Seattle, WA. Presentation: "An Overview of Polymeric Smart Skins Materials Research".

***Conference*--January 30, 2003**—Photonics West Symposium on Organic Photonic Materials and Devices VI, San Jose, CA. Invited Lecture: "Organic Electro Optics: Exploiting the Best of Electronics and Photonics".

February 13, 2003—Florida International University, Miami, FL, Invited Lecture: "Technology for the 21st Century: Exploiting Best of Photonics and Electronics".

February 14, 2003—Department of Chemistry, University of Miami, Miami, FL, Invited Lecture: "Information Technology for the 21st Century: Exploiting the Best of Photonics and Electronics".

***Conference*—March 31-April 3, 2003**—Government Microcircuitry Applications & Critical Technology (GOMAC)-03 Conference, Tampa, Florida, Invited Lecture: "New Organic Electro-Optic Materials for Time and Wavelength Division Multiplexing Applications".

April 8, 2003—University of Washington Science Forum Lecture (Televised), Seattle, WA, Invited Lecture: "Lighting the Way in the New Information Technology Age".

April 23, 2003—DARPA/MTO CS-WDM Nanophotonics for Mobile Platforms Review, Boeing Phantom Works, Seattle, WA, Invited Lecture: "Electro-Optic Polymers: Roadmap".

***Conference*—June 18-25, 2003**--ACS PRF Workshop on the Chemistry of Information Technology and Conference on the Electrical, Magnetic, and Photonic Properties of Organic and Hybrid Materials, Seattle, WA, Invited Lecture: "Introduction to the Chemistry of Information Technology".

***Conference*—June 18-25, 2003**--ACS PRF Workshop on the Chemistry of Information Technology and Conference on the Electrical, Magnetic, and Photonic Properties of Organic and Hybrid Materials, Seattle, WA, Invited Lecture: "Electro-Optics"

***Conference*—August 10-15, 2003**—39th IUPAC Congress and 86th Conference of the Canadian Society of Chemistry, Symposium MSO5-Polymers in Electronics and Photonics, Ottawa, Canada, Invited Lecture: "Organic Electro-Optic Materials".

***Conference*—September 21-25, 2003**—29th European Conference on Optical Communication/14th International Conference on Integrated Optics and Optical Fibre Communication, Rimini, Italy, Invited Lecture: Novel Polymer-Based, High-Speed Electro-Optic Devices".

***Conference*—October 18-25, 2003**—The Enrico Fermi and Galieo Galliei Celebrations, International School of Quantum Electronics, Erice, Sicily, Invited Lecture: "Microresonators as Building Blocks for VLSI Photonics".

November 4, 2003—Eastman Endowed Lectureship, University of Akron, Invited Lecture: "The Chemistry of Information Technology".

***Conference*—January 27-29, 2004**—NNI Interagency Workshop: Instrumentation and Metrology for Nanotechnology Grand Challenges Workshop, Gaithersburg, Maryland, Invited Lecture: "Rational Design and Characterization of Nanostructured Ferroelectric Lattices".

February 14, 2004—University of Miami, Miami, FL. Invited Seminar: "Technology for the 21st Century: Exploiting the Best of Photonics and Electronics".

***Conference*—February 12-16, 2004**, American Association for the Advancement of Science Annual Meeting, Seattle, WA, Invited Lecture: "An Overview of 21st Century Photonics".

***Conference*—February 12-16, 2004**, American Association for the Advancement of Science Annual Meeting, Seattle, WA, Invited Topical Lecture: "Electro-Optics for Next Generation Information Technology, Sensing, and Defense Applications".

***Conference*—March 15-18, 2004**—GOMACTech-04: Transformational Technologies, Hyatt Regency, Monterey, CA, Invited Lecture: "Toward Practical Sub 1-Volt, High Bandwidth, Stable Electro-Optic Modulators".

***Conference*—April 15, 2004**—Materials Research Society National Meeting, Symposium L: New Materials for Microphotonics, San Francisco, CA, Invited Lecture: "Integrated Optics/Electronics Using Electro-Optic Polymers".

April 27, 2004—Chemistry Department, University of California at Irvine, Irvine, Ca, Invited Lecture: "The Chemistry of Information Technology: New Materials by Rational Design".

***Conference*—May 20-24, 2004**—Fragrant Hill Symposium, Beijing, People's Republic of China, Invited Lecture: "The Role of Electro-Optics in the Information Technology Revolution".

***Conference*—June 27-July 2, 2004**—2004 Integrated Photonics Research—Optical Society of America, San Francisco, CA, Invited Lecture: Electro-Optic Materials and Devices for Integrated Photonics".

April 21-23, 2004—DARPA Molecular Photonics (MORPH) Review, China Lake Naval Weapons Center, Invited Lecture: "Organic Electro-optic Materials and Devices: An Overview".

May 31-June 4, 2004—Sensor Science and Technology, NSF Workshop, Alabama A&M University, Huntsville, AL, Invited Lectures: "Sensor Science and Sensor Technology".

***Conference*--June 7-10, 2004**—SPIE Midwest Regional Meeting, Cleveland, Ohio, Invited Lecture: "Next Generation Electro-Optic Materials by Rational Design".

June 9, 2004—GE Global Research, Niskayuna, New York, Invited Seminar: "Control of Energy, Charge, and Mass Transport in Nanostructured Materials".

June 9, 2004—GE Global Research, Niskayuna, New York, Invited Seminar: "Organic Electro-Optic Materials".

***Conference*—June 14-18, 2004**—6th International Symposium on Functional Pi-Electron Materials, Cornell University, Ithaca, NY, Invited Lecture: "Rational Design of Exceptional Organic Electro-Optic Materials".

***Conference*—August 22-26, 2004**, 228th ACS National Meeting, Philadelphia, Pennsylvania, Invited Lecture: Organic electro-optic materials for 21st century information technology".

***Conference*—September 22-24, 2004**—Frontiers of Polymer Science, Leuven, Belgium, Invited Lecture: "Organic Electro-Optic Materials at the Frontiers of Polymer Science".

September 29, 2004—Universite Pierre & Marie Curie, Paris, France, Invited Lecture: "Advances in Organic Photonic Materials".

October 21, 2004--AFRL Materials & Enabling Technologies Lecture Series/University of Dayton Nanotechnology Lecture Sereis, Nanotechnology Center, University of Dayton, Ohio, Invited Lecture: "Nanoscience/Nanotechnology and the Ration Design of Next Generation Electro-Optic Materials and Devices".

***Conference*—October 26-27, 2004**—SPIE European Symposium on Optics/Photonics in Security & Defense, IEE Building, Savoy Place, London, United Kingdom, Invited Lecture: "Organic Electro-Optic Materials".

***Conference*—November 5-7, 2004**—Tobinstock, Northwestern University, Evanston, Illinois, Invited Lecture: "Organic Electro

Optic Materials: Past, Present, and Future".

***Conference*—March 7-11, 2005**—International Conference on Organic Photonics and Electronics 2005 & 8th International Conference on Organic Nonlinear Optics, Matsushima, Miyagi, Japan, Invited Lecture: "Optimization of Organic Electro-Optic Materials".

***Conference*—March 13-17, 2005**—American Chemical Society National Meeting Symposium on Nanophotonics and Biophotonics, San Diego, CA, Invited Lecture: "Nanostructured Electro-Optic Materials: Theory, Synthesis, and Characterization".

***Conference*—April 1-2, 2005**—The Workshop on Physics and Chemistry of Switching in Condensed Matter, Materials Research Society Spring National Meeting, San Francisco, CA, Invited Lecture: "Advances in Organic Electro-Optic Materials".

***Conference*—May 14, 2005**—SPRC Organic Photonics Workshop, Stanford, CA, Invited Lecture: "Organic Electro-Optic Materials".

***Conference*--May 22-27, 2005**—CLEO/QELS, Baltimore, Maryland, Invited Lecture: "Reconfigurable Wavelength-Selective Reflector Consisting of Coupled Polymeric Microring Resonators".

***Conference*—May 22-27, 2005**—CLEO/QELS Tutorial Presentation on Optical Materials: Fabrication and Characterization, Baltimore, MD.

***Conference*—June 5-8, 2005**—Nanophotonics, Biophotonics, and Optoelectronic Polymer Systems—An ACS Polymer Division Symposium, Orlando, FL, Invited Lecture: "Rational Development of Next Generation Electro-Optic Materials".

***Conference*—July 11-15, 2005**—International Conference on Quantum Electronics 2005 and the Pacific Rim Conference on Lasers and Electro-Optics 2005, Tokyo, Japan, Invited Lecture: "Novel Organic Materials with large electro-Optic Coefficients for High Speed Modulators".

***Conference*—July 11-15, 2005**—2005 IEEE Conference on Nuclear and Space Radiation Effects (NSREC), Seattle, Washington, Invited Lecture: "Organic Electro-Optic Materials and Devices for Space Applications".

***Conference*—July 31-August 3, 2005**—SPIE Symposium on Optics and Photonics/Conference on Linear and Nonlinear Optics of Organic Materials V, San Diego, CA, Invited Lecture: "Electro-Optic Coefficients of 500 pm/V and Beyond for Organic Materials".

***Conference*—July 31-August 4, 2005**—Operational Characteristics and Crystal Growth of NLO Materials III, SPIE National Meeting, San Diego, CA, Invited Lecture: "Acentric Lattice Electro-Optic Materials by Rational Design".

***Conference*—July 31-August 4, 2005**—

September 24, 2005—The Dow/Karabatsos & Distinguished Alumni Lectureship, Michigan State University, East Lansing, MI, Invited Endowed Lecture: "Theoretically-Inspired Nano-engineering of Organic Materials with Exceptional Electronic and Photonics Properties".

***Conference*—September 26-29, 2005**—SPIE Defence Photonics Symposium, Bruges, Belgium, Invited Lecture: "Organic Electro Optic Materials".

***Conference*—October 4-6, 2005**—IEEE International Topical Conference on Microwave Photonics, Ogunquit, Maine, Invited Lecture: "Development and Exploitation of the Unique Properties of Organic Electro-Optic Materials and Devices".

***Conference*—November 7, 2005**—Symposium on Exploratory Research for Advanced Technology (ERATO)—Koike Photonics Polymer Project, Japan Science Technology Agency (JST), Tokyo, Japan, Invited Lecture: "Active Organic and Hybrid Photonic Circuitry: Electro-Optical and All-Optical Modulation to 10 THz with Small Electrical and Optical Fields".

***Conference*--October 23-26, 2005**—Optics East/ITCom, Boston, MA, Invited Lecture: "Organic Electro-Optic Materials and Waveguide Devices".

***Conference*—December 15-20, 2005**—PACIFICHEM 2005: Symposium on Macromolecules for Photonic Applications, Honolulu, Hawaii, Invited Lecture: "Rational Desing of Nanostructured Organic Electro-Optic Materials".

***Conference*—January 15-20, 2006**--Conference on Photoresponsive Organics and Polymers (ICPOP), Val Thorens, France, Invited Lecture: "Organic Electro-Optic Materials".

March 8, 2006—Intel Corporation (Corporation-wide by video conferencing), Portland, Oregon, Invited Lecture: "Exploiting the Best of Electronics and Photonics: Concepts and Applications to Telecommunications, Computing, Embedded Network Sensing and Defense Technologies".

March 13, 2006—Corning Corporation, Corning, New York, Invited Lecture: "Defining all structure/function relationships required for optimizing electro-optic activity, optical loss, and stability of organic EO materials".

March 14, 2006—CIBA Corporation, Tarrytown, NY, "Rational Design of Organic Opto-Electronic Materials and their Potential Technological Impact".

***Conference*—March 20-23, 2006**—Nanosensor Technology Tutorial/Government Microcircuits and Critical Technologies Conference (GOMAC '06), San Diego, CA, Invited Lecture: "Nano-Photonics and Organic/Hybrid Sensor Materials".

***Conference*—May 2-4, 2006**—7th International Symposium on Technology and the Mine Problem, Naval Postgraduate School, Monterey, CA, Invited Lecture: "Fiber Optic Sensor Based on Conjugated Molecules for IED Detection".

***Conference*—Junae 4-11, 2006**—Optical, Photonic & Electronic Materials ACS PRF Summer School, University of Central Florida, Orlando, FL, Invited Tutorial: "Electro-optic Materials & Applications".

***Conference*—June 16, 2006**—2006 IEEE MTT-S International Microwave Symposium Workshop on Low-Cost Microwave Component Technologies to Address Emerging Applications, San Francicso, CA, Invited Lecture: "High speed electro-optic modulators and other low-cost microwave photonic components in polymer materials".

Consultative/Advisory Functions:

•Member, Advisory Committee, Mathematical and Physical Science Directorate, National Science Foundation (2005-2008)
•Member, ACGPA (Advisory Committee for the Government Performance and Results Act (GPRA), National Science Foundation (2006-)
•Member, Advisory Group on Electron Devices (AGED), Office of the Undersecretary of Defense (2006-)
•Member, Committee of Visitors, Division of Materials Research, National Science Foundation (2005)
•Member, MPS/EHR Subcommittee on Broadening Participation, National Science Foundation (2005)
•Member, Engineering and Physical Sciences Research Council (EPSRC), England
•Chairman, Arizona Biomedical Research Commission (formerly, Arizona Disease Control Research Commission) Review Panel for Biomedical Engineering, Imaging, and Sensing (2005)
•Member, National Science Foundation Panel on the Technological Challenges of Organic Electronic and Photonic Materials (2004)
•Member, National Science Foundation Panel on Sensors and Sensor Systems (2003)
•Member, National Science Foundation Workshop on Chemical Bonding Centers (2003)
•Member, National Science Foundation "Grand Challenges Workshops" for the National Nanotechnology Initiative (2003)
•Member, Air Force Scientific Advisory Board, Review of the AFRL Materials and Manufacturing Directorate (2003)
•Member, Pacific Northwest National laboratory Peer Review Panel for the Energy Science and Technology Directorate (2003, 2004, 2005, 2006))
•Oversight Reviewer of the National Research Council Report on Implications of Emerging Micro- and Nanotechnologies
•Member, Pacific Northwest National Laboratory Peer Review Panel for the Nanotechnology Initiative (2002, 2003, 2004)
•Member, Editorial Board, Materials Today (2002-)
•Chairman/Member, External Advisory Committee, Center for Research and Education on Advanced Materials, Norfolk State University, (2002-)
•Member, External Advisory Committee, NSF RISE Center, Alabama A&M University (2005-)
•Member, *Scientific American 50* Awards Advisory Committee (2003)
•Board of Visitors, Chemistry Department, University of Alabama (98-2002)
•Guest Editor, Special Issue of the Journal of Physical Chemistry (2003-2004)
•Academic Technology Advisory Committee, University of Washington (2003-)
•Member, Board of Directors, Loker Hydrocarbon Research Institute, University of Southern California, Los Angeles, CA (2003-)

Interactions/Transitions:

Transition 1
a. Dalton, UW, b. Data for organic electro-optic materials, c. William Krug/Boeing Phantom Works., 253-657-8018 d. For a development of a research program for handling both digital and analog data exploiting WDM techniques and explicitly wavelength selective filter and beam steering concepts. 1x4x1 ROADM device delivered to NAVAIR (2006).

Transition 2
a. Dalton, UW, b. Data relating to polymeric electro-optic materials and processing protocols, c. Susan Ermer/Lockheed Martin Corporation, 650-424-3131 d. For prototyping high frequency, low drive voltage modulators.

Transition 3
a. Dalton, UW, b. Polymeric electro-optic materials and processing protocols, c. Abraham Gross/Microvision, 425-415-6642 d. For prototyping electro-optic modulator devices for telecommunication and display applications.

Transition 4
a. Dalton, UW, b. Polymeric electro-optic materials and processing protocols, c. Tom Mino/Lumera Corporation, 425-415-6616 d. For electro-optic device fabrication and consideration for establishing an electro-optic materials production facility.

Transition 5
a. Dalton, UW, b. Polymeric electro-optic materials and processing protocols, c. Ray Chen/UT-Austin Microelectronics Center and Radiant Photonics, 512-338-4942 d. For electro-optic device fabrication and evaluation.

Transition 6
a. Dalton, UW, b. Polymeric electro-optic materials and processing protocols, c. James G. Grote/AFRL/MLPO, 937-255-4474 ext 3263 d. For use with conducting cladding materials developed by AFRL.

Transition 7
a. Dalton, UW, b. Polymeric electro-optic materials and processing protocols, c. James Bechtel/TACAN Corporation, 760-438-1010 ext 3278 d. Polymeric electro-optic materials for device fabrication.

Transition 8
a. Dalton, UW, b. Polymeric electro-optic materials and processing protocols, c. G. A. Lindsey/ NAWCWD, 760-939-1396 d. Polymeric electro-optic materials for optical gyro development.

Transition 9
a. Dalton, UW, b. Polymeric electro-optic materials and processing protocols, c. Paul Ashley/Army Missile Command, Redstone Arsenal, 205-876-7484 d. Polymeric electro-optic materials for gyro development.

Transition 10
a. Dalton, UW, b. Polymeric electro-optic materials and processing protocols, c. Howard Katz/Bell Labs Lucent Technologies, 908-582-6968 d. Polymeric electro-optic materials for evaluation and to repeat syntheses.

Transition 11
a. Dalton, UW, b. Light harvesting solar cell coatings, c. Paul Hausgen/Kirtland AFB, paul.hausgen@kirtland.af.mil d. Improved solar cell technology.

Transition 12
a.Dalton, UW, b. Pressure sensitive paints, c. Rush Queen/Boeing, 206-655-7761;Tim Rieger/Boeing, 206-655-7769; Doug McLean/Boeing, 206-234-1106; John Harris/Boeing, 206-655-7794 d. Pressure sensitive paints for wind tunnel evaluation of airframes.

Transition 13
a. Dalton, UW, b. Light emitting materials and devices, c. Christopher Somogyi, 425-503-3658 d. light emitting devices for display applications.

New Discoveries, inventions, or patent disclosures:

Significant improvements have been made in organic electro-optic and light emitting materials and a new paradigm for developing materials with further improvement in properties has been validated.

Cyril, You will need to get patent disclosures from OIPTT.

Honors/Awards: (Lifetime)

•Fellow, American Association for the Advancement of Science (2006)
•QEM (Quality Education for Minorities)/MSE (Mathematics, Science, and Engineering) Network 2005 Giants in Science Award
•Dow/Karabatsos Lecture Series and the Alumni Distinguished Lectureship, Michigan State University, 2005
•AFRL Materials, Manufacturing & Enabling Technologies Lecture Series, Dayton, 2004
•2003 Chemistry of Materials Award of the American Chemical Society
•2003 Eastman Lecturer, University of Akron

•2002 Inaugural Lecturer of the National Science Foundation Distinguished Lecture Series
•Distinguished Alumni Award of Michigan State University (2000)
•1996 Richard C. Tolman Medal of the American Chemical Society, Southern California Section
•Paul C. Cross Lectureship, University of Washington, Seattle, WA (1996)
•NASA Lecturer, Fifty-Fourth Frontiers in Chemistry Lecture Series (1995), Case Western Reserve University
•The 1990 University of Southern California Associates Award for Creativity in Research and Scholarship
•1986 Burlington Northern Foundation Faculty Achievement Award
•NIH Research Career Development Awards (Two Awards, one at Stony Brook, one at Vanderbilt, 76-81)
•Camille and Henry Dreyfus Teacher-Scholar Award (75-77)
•Alfred P. Sloan Fellowship (74-77)

Awards Received by Graduate Students Working on This Project:

•Leonard Fifield, Pacific Northwest National Laboratory Fellowship
•Anna Pyayt, SPIE-International Society for Optical Engineering Fellowship
•Daniel Casmier, SPIE-International Society for Optical Engineering Fellowship
•Undergraduate Student Bjorn Miillard received a Mary Gates Endowment for Students Research Training Grant