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Report on

Gordon Research Conference on
Liquid Crystal Polymers
July 9-13, 1984; New London, NH

Submitted to

Air Force Office of Scientific Research
National Science Foundation
Office of Naval Research

By

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September 15, 1984

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INTRODUCTION

The field of liquid crystal, LC, polymers is now almost thirty years old if it can be considered to have begun in 1956 with the theories of Flory on solutions of rigid-rod polymers and the observation of the lyotropic behavior of concentrated solutions of poly(benzyl-L-glutamate) in the laboratories of Courtaulds Ltd. in the same year. The observations of lyotropic behavior of solutions of aromatic polyamides in the du Pont laboratories in the late 1960s, which led to the development of the "Kevlar" fiber, undoubtedly provided the greatest stimulus to this field. While thermotropic aromatic polyesters were prepared in the laboratories of the ICI Company at about the same time, the potential for their application in fibers was probably not recognized until the early 1970s. At about that time, investigations on the application of aromatic polyesters for molded plastics, which were liquid crystalline in the melt state, were also begun at the Carborundum Co. and the Tennessee Eastman Co. Hence, the field of thermotropic polymers is only about ten years old, but in the last five years or so there has been an "explosion" in interest and the activity on such polymers.

This explosion can be readily seen from the number of conferences and symposia which have recently been devoted to this subject, including the following:

- (1) May 19-23, 1981 - Seminar on "Polymer Liquid Crystals: Science and Technology" at Santa Margherita Ligure, Italy, with 12 presentations.

- (2) March 25-April 2, 1982 - Symposium on "Liquid Crystals" including polymers, at the American Chemical Society meeting in Las Vegas, Nevada, with 12 talks on polymers.
- (3) July 12-16, 1983 - Min-symposium on "Rigid Rod Polymers" at the IUPAC Macromolecular Symposium in Amherst, Mass., with 35 talks on liquid crystal polymers.
- (4) August 28-September 2, 1983 - Symposium at the American Chemical Society meeting in Washington, D.C., on "Polymer Liquid Crystals" with 41 presentations.
- (5) September 12-14, 1983 - European Science Foundation Workshop on "Liquid Crystal Polymer Systems" in Copenhagen, Denmark, with 36 presentations.
- (6) July 16-20, 1983 - International Conference on Liquid Crystals in York, England, with several main lectures and numerous posters on liquid crystal polymers.

The large number of patents issuing from industrial laboratories is also indicative of this interest.

In spite of this degree of activity, there has been very little systematic information on such basic topics as the relationships between structure and type of liquid crystallinity, solution and solid state organization and morphology, degree of liquid crystallinity, phase transition behaviors and rates, degree of ordering, rheology, and so on. Indeed, there seems to be even little recognition of what areas of research should be initiated, and there appears to be almost no cooperation between the organic chemists, physical chemists, physicists and engineers on developing an approach to defining the important problems in this field. It was felt, therefore,

that a mechanism was needed for bringing these disciplines together, including individuals from both industry and university research laboratories, in an environment conducive to an intimate and free exchange of ideas and to the development of personal contacts. For this purpose, a proposal was submitted to the Gordon Research Conference organization, and approved by them, to hold a special conference on "Liquid Crystal Polymers." This conference was held at the Colby-Sawyer College in New London, NH, during the week of July 9-13, 1984.

CONFERENCE ORGANIZATION

Financial support for the Conference was received from the Gordon Research Conferences and in the form of grants from the Air Force Office of Scientific Research, the National Science Foundation, and the Office of Naval Research. The Conference was attended by 150 scientists from universities and industries from many different countries, as shown in the registration list in Table 1. Additional applications for attendance were also received, but the maximum number of participants which the Gordon Research Conferences will accept for any conference is 150. The distribution of attendees was approximately 70% from universities and government and 30% from industry.

The technical program of the Conference included 22 main lectures and 34 poster presentations. The speakers and titles of the main lectures were as follows:

1. S. L. Kwolek, E. I. du Pont Co., "Thermotropic LC Polyesters"
2. W. J. Jackson, Eastman Kodak Co., "LC Copolyesters"
3. A. C. Griffin, University of Southern Mississippi, "New Main Chain Polymer Liquid Crystals"

4. E. Chiellini, University of Pisa, Italy, "Optically Active Main Chain Thermotropic Polymers"
5. J.-I. Jin, Korea University, "Thermotropic Main Chain Polyesters with Flexible Spacers"
6. A. Blumstein, University of Lowell, "Structure-Property Correlations in Thermotropic Polyesters"
7. A. Sirigu, University of Naples, Italy, "Mesophasic Properties of Linear LC Copolymers"
8. J. Blackwell, Case Western Reserve University, "X-ray Studies of Thermotropic Aromatic Copolyesters"
9. C. Noel, ESPCI, France, "Characterization of Liquid Crystalline Mesophases"
10. G. Hardy, Research Institute for Plastics, Hungary, "Side Chain LC Polymers"
11. R. Zentel, Freiburg University, West Germany, "New Types of LC Polymers"
12. G. Strobl, University of Mainz, West Germany, "Dielectric Relaxation in Side Chain LC Polymers"
13. G. Kothe, University of Stuttgart, West Germany, "Nuclear Spinlabel Studies of LC Polymers"
14. W. R. Krigbaum, Duke University, "Phase Diagrams of Nematogen Systems"
15. E. T. Samulski, University of Connecticut, "Alkyl Chain Flexibility in Polymeric LCs"
16. H. Finkelmann, Clausthal University, West Germany, "Novel Physico-Chemical Investigations of LC Side Chain Polymers"
17. G. C. Berry, Carnegie-Mellon University, "Rheological Studies on Solutions of Mesogenic Rodlike Polymers"
18. T. Asada, Kyoto University, Japan, "Rheo-optical Studies on Lyotropic Polymer LCs"
19. P. Flory, Stanford University, "Concepts and Theories: Present in Retrospect"
20. L. Chapoy, Technical Institute of Denmark, "Prospects for Photoelectric LC Polymers"
21. B. Wunderlich, Rensselaer Polytechnic Institute, "Confirmation-Disordered (Condis) Polymer Crystals"
22. T. G. Ryan, ICI Co., "Applications of Thermotropic Polyesters"

The authors and titles of the poster presentations are listed in Table 2, and the complete mailing addresses for all speakers and chairpersons (discussion leaders) are given in Table 3.

The funds provided for the Conference by the agencies listed above were used only for the payment of the fixed fees (registration, room and meals) for all of the speakers and chairpersons, except those from industry, and also for specially invited participants. The latter were principally young faculty members and graduate students from American universities, including the following individuals:

R. J. Laub, San Diego State University (faculty)
S. I. Stupp, University of Illinois (faculty)
D. Behm, University of Massachusetts (student)
J. Tuttle, University of Massachusetts (student)
S. MacKenzie, University of Massachusetts (student)
C. Wu, Southeastern Massachusetts University (faculty)
H. Winter, University of Massachusetts (faculty)
S. Kantor, University of Massachusetts (faculty)
A. Tipton, University of Massachusetts (student)
E. George, University of Massachusetts (student)
W. Pawlowski, North Carolina State University (student)
B. Wood, University of Massachusetts (student)
F. Lonberg, Brandeis University (student)
S. Kumar, Lowell University (student)
Y. Ozcayir, Lowell University (student)
J. Mallon, University of Massachusetts (student)
M. C. Muir, University of Massachusetts (student)
P. Hann, University of Massachusetts (student)
P. Manson, University of Massachusetts (faculty)
E. Magat, Duke University (faculty)
E. Thomas, University of Massachusetts (faculty)
L.-P. Yu, University of Connecticut (student)
M. Poliks, University of Connecticut (student)
J. Adduci, Rochester Institute of Technology (faculty)
V. Subramanian, University of Louisville (student)

CONCLUSION

Virtually all of the participants agreed that the goal of the Conference of bringing together chemists, physicists and engineers to discuss the latest state of understanding and opportunities for applications of liquid crystal polymers and to help define the areas for future research and development was achieved. The program included lectures on subjects ranging from organic chemistry to applications and including theory and physics, synthesis, structure, physical properties, transitions, morphology, rheology, and viscoelastic and mechanical properties of both thermotropic and lyotropic polymers.

As a result of the success of this format and conference plan, and as indicated by the very large attendance and the enthusiastic response of the attendees, it is likely that a second Gordon Research Conference will be held in July 1985 with Prof. Roger S. Porter as its chairman.

Table 1

GORDON RESEARCH CONFERENCES

LIQUID CRYSTAL POLYMERS

July 9-13, 1984

Colby-Sawyer College, New London, NH

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Asrar, Jawed Monsanto Company 730 Worcester Street Indian Orchard, MA 01151	S 106	Blumstein, Rita University of Lowell Chemistry Dept. Lowell, MA 01854	C 203
Baird, Don Virginia Tech Dept. of Chemical Engineering Blacksburg, VA 24061	M 9	Boileau, Sylvie C. N. R. S. Collège de France 11 Place Marcelin Berthelot 75231 Paris, Cedex 05, FRANCE	C 106
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Table 2

Polymer Liquid Crystals

Gordon Research Conference

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Contributions to Poster Sessions

<u>Authors and Address</u>	<u>Title</u>
1	
I.C. Choy, M. Kojima and J.H. Magill	"Morphology and Properties of Polyphosphazenes"
Dept. of Metallurgical and Materials Engineering 858 Benedum Hall University of Pittsburgh Pittsburgh, PA 15261	
2	
F. Dowell	"Molecular Theory of Chain Flexibility Monomers"
Theoretical Div., T-4, MS-B212 Los Alamos National Laboratory Los Alamos, NM 87545	
3	
M.A. Apfel, H. Finkelmann, G.M. Janini, R.J. Laub,* B.-H. Luhmann, A. Price, W.L. Roberts, T.J. Shaw, and C.A. Smith	"Solute-Probe Study of Mesomorphic Polysiloxane (MEPSIL) Solvents by Gas-Liquid Chromatography"
Department of Chemistry San Diego State University San Diego, CA 92182	
4	
Bernhard Wunderlich and Janusz Grebowicz	"Conformationally Disordered Crystals (A Mesophase Type of Special Interest to Macromolecules)"
ATHAS Department of Chemistry Rensselaer Polytechnic Institute Troy, New York 12181	

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<u>Authors and Address</u>	<u>Title</u>
5 Richard D. Gilbert, D.L. Patel and Penelope A. Patton Dept. of Textile Chemistry Box 5666 North Carolina State University School of Textiles Raleigh, North Carolina 27650-5666	"Liquid Crystal Formation in Solutions of Cellulose and Cellulose Derivatives"
6 Tamotsu Yoshimura, Masahiko Nakamura and Atsushi Kasai Mitsubishi Chemical Industries, Ltd. Research Center 1,000 Kamoshida-cho, Midori-ku Yokohama-shi, Kanagawa-ken 227 JAPAN	"A Molecular Design and A Few Examples to Reduce the Mechanical Anisotropy of LCPs"
7 G. Viola and D.G. Baird Department of Chemical Engineering Virginia Polytechnic Institute and State University Blacksburg, Virginia 24061-6496	"Flow Induced Texture and Orientation in Thermotropic Copolyesters"
8 Yoshiko Uematsu, Munehiro Date, Katsuhisa Shibuya, and Ichitaro Uematsu Faculty of Engineering Tokyo Institute of Polytechnics Atsugi, Kanagawa, 243-02, JAPAN	"The Orientational Behavior of Polypeptide Liquid Crystals in an Electric Field"

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<u>Authors and Address</u>	<u>Title</u>
9	
John R. Evans and Robert A. Orwoll Department of Chemistry The College of William and Mary in Virginia Williamsburg, Virginia 23185	"Some Polyimides with Semiflexible Spacers"
10	
S.I. Stupp, P.G. Martin and B.M. Landreth Department of Ceramic Engineering 204 Ceramics Building University of Illinois at Urbana-Champaign Urbana, Illinois 61801	"Liquid Crystalline Polymers in Electric Fields: Orientational Dynamics, Crystal- lization and Electrical Memory"
11	
A.M. Donald Department of Physics Cavendish Laboratory University of Cambridge Madingley Road Cambridge CB3 0HE	"Transmission Electron Microscopy of Domains in Thermotropic Polymers"
12	
C. Boffel, R. Ebelhauser, T. Fahmy, U. Pschorn, and H.W. Spiess Makromolekulare Chemie II Universitat Bayreuth Universitätsstrasse 30 D-8508 Bayreuth, WEST GERMANY	"Deuteron NMR Study of Thermotropic and Lyotropic Liquid Crystalline Polymers"

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13	
Gerhard A. Kossmehl Fachbereich Chemie Institut für Organische Chemie (E02) Freie Universität Berlin FB Chemie, WE 02, Takustrasse 3, Berlin, WEST GERMANY	"Liquid Crystalline Polymers with 2.2'-Bithienyl Units"
14	
P.E. Hahn, R.W. Lenz, R.S. Stein, and X. Wang Dept. of Polymer Sci. & Eng. University of Massachusetts Amherst, MA 01003	"X-Ray and Light Scattering Studies of Thermotropic Liquid Crystalline Polymers"
15	
Per Lagerkvist, Bengt Lindsleed, Sören Halvarsson, and Per Flodin Department of Polymer Technology Chalmers University of Technology Fack S-412 96 Gothenburg, SWEDEN	"Physically Crosslinked Macroporous Gels"
16	
Franklin Lonberg and Robert B. Meyer Department of Physics Brandeis University Waltham, Massachusetts 02254	"Nonlinear Dynamics of a Fredericks Transition in a Nematic Polymer due to Elongational Flow Viscosity"

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<u>Authors and Address</u>	<u>Title</u>
17 Professor George Srajer and Robert B. Meyer Department of Physics Brandeis University Waltham, Massachusetts 02254	"Electric Field Induced Transient Periodic Structures in a Nematic Polymer"
18 Victor Taratuta and Robert B. Meyer Department of Physics Brandeis University Waltham, Massachusetts 02254	"Light Scattering Study of Orientation Fluctuations in a Nematic Polymer"
19 Barbara A. Wood and Edwin L. Thomas Department of Polymer Science and Engineering University of Massachusetts Amherst, Massachusetts 01003	"Microstructural Studies of Oriented Thermotropic Liquid Crystalline Polyesters with Flexible Spacers"
20 P. Sixou and J.M. Gilli Laboratoire de Physique de la Matiere Condensee (Lab. associe au C.N.R.S. No 190) Universite de Nice Parc Valrose 06034 Nice Cedex, FRANCE	"Electric and Magnetic Field Effects and Electrohydrodynamic Instabilities on Mesomorphic Polymers"

Liquid Crystal Polymers

<u>Authors and Address</u>	<u>Title</u>
21 Eric R. George and Roger S. Porter Materials Research Laboratory Department of Polymer Science and Engineering University of Massachusetts Amherst, Massachusetts 01003	"A New Approach for the Processing of Thermotropic Polyesters"
22 N. Hiramatsu and Frank E. Karasz Materials Research Laboratory Department of Polymer Science and Engineering University of Massachusetts Amherst, Massachusetts 01003	"Thermodynamic Parameters at Transitions in Poly(oxy-2,2'-dimethylazoxybenzene- 4,4'-diyloxydodecanedioyl)"
23 D.J. Sikkema Enka bv Research Institute Arnhem Velperweg 76 Arnhem, HOLLAND	"Thermotropic Aliphatic Polyether" ("Isomorphism of Rigid and Flexible Elements")
24 K.H. Ullrich, M. Eich and J.H. Wendorff Deutsches Kunststoff-Institut Schlossgartenstr. 6R 6100 Darmstadt WEST GERMANY	"Studies on the Local Orientational Order in Liquid Crystalline Polymers"

Liquid Crystal Polymers

<u>Authors and Address</u>	<u>Title</u>
25	
Amar H. Al-Dujaili, Aubrey D. Jenkins and David R.M. Walton	"Polyesters with Main-Chain Mesogenic Units"
School of Chemistry and Molecular Sciences University of Sussex Brighton BN1 9QJ Sussex, ENGLAND	
26	
Garo Khanarian and William MacKnight	"Dielectric Relaxation of Liquid Crystal Polymers"
Department of Polymer Science and Engineering University of Massachusetts Amherst, Massachusetts 01003	
27	
P. Nieri, J. Majnusz, and R.W. Lenz	"Poly(2-n-Alkyl-1, 4-Phenylene Terephthalates): A Series of Linear Rigid Thermotropic L.C. Polymers"
Chemical Engineering Department University of Massachusetts Amherst, Massachusetts 01003	

POLYMER LIQUID CRYSTALS

GORDON RESEARCH CONFERENCES

July 9 - 13, 1984

CONTRIBUTIONS TO POSTER SESSIONS

ADDENDUM

Authors and Adresses	Title
28. D. Wisne and H. G. Zachman Institute for Technical and Macro- molecular Chemistry University of Hamburg Hamburg, Federal Republic of Germany	Crystalline and Liquid Crystalline Behavior of Copolyesters of Polyethylene-naphthol 2,6-dicarboxylate and p-hydroxybenzoic acid
29. P. Fabre, M. Veynise and C. Casagrande College de France Li-Ping Yu and Edward T. Samulski University of Connecticut Storrs, CT	Physical Properties of Side-Chain Nematic Polymers Linear Polymers Solubilized in a Nematic Solvent: A Deuterium NMR Study
30. Robert Matheson CR&D E. I. du Pont de Nemours & Co., Inc. Wilmington, DE	Conformational Selection in Block Molecules
31. M. D. Polk, E. M. Stickler, A. Blumstein, R. B. Blumstein and F. Volino* Polymer Science Program University of Lowell Lowell, MA *CNRS and DRF, CENG Grenoble, France	Model Compounds of Mesophase Polymers
32. Gerhard Kossmehl and Angelika Heinz Free University of Berlin Institute of Organic Chemistry Berlin, West Germany	Liquid Crystalline Polymers with 2,2'- Bithienyl Units
33. N. Koide, Y. Kanai and K. Iimura Science University at Tokyo Kagurazaka, Shinjuku-ku Tokyo, Japan	Effect of Flexibility and Chemical Linkage on the Liquid Crystalline Properties of Polyesters and Polycarbonates
34. Paul J. Shannon Armstrong World Industries, Inc. Lancaster, PA	Photopolymerization in Cholesteric Mesophases

Table 3

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