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FINAL TECHNICAL REPORT

PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS/STUDENTS REPORT

for

CONTRACT: N0014-89-J-1828

T & T Code 3132080

LIQUID CRYSTALLINE POLYMERS

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September 1, 1995

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OFFICE OF NAVAL RESEARCH
PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT

R&T Number: 3132080
Contract/Grant Number: N00014-89-J-1828
Contract/Grant Title: Liquid Crystalline Polymers
Principal Investigator: Virgil Percec
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a. Number of papers submitted to refereed journals, but not published: 0
b. Number of papers published in refereed journals (provide complete citations): 74
c. Number of books or chapters submitted, but not yet published: 0
d. Number of books or chapters published (provide complete citations): 11
e. Number of printed technical reports/non-refereed papers (provide complete citations): 0
f. Number of patents filed: 0
g. Number of patents granted (for each, provide a complete citation): 0
h. Number of invited presentations (for each, provide a complete citation): 285
i. Number of submitted presentations (for each, provide a complete citation): 0
j. Honors/Awards/Prizes for contract/grant employees (list attached): see attached
   (This might include Scientific Society Awards/Offices, Selection as Editor, Promotion, Faculty Award, etc.)
k. Total number of Full-time equivalent Graduate Students and Post-Doctoral associates supported during this period, under this R&T project number: 12
   Graduate Students: 10
   Post-Doctoral Associates: 2
   including the number of,
   Female Graduate Students: 3
   Female Post-Doctoral Associates: 0
   the number of
   Minority* Graduate Students: 0
   Minority* Post-Doctoral Associates: 1
   and, the number of
   Asian Graduate Students: 2
   Asian Post-Doctoral Associates: 0
l. Other funding (list agency, grant title, amount received this year, total amount, period of performance and a brief statement regarding the relationship of that research to your ONR grant)

Note: Use the letter and an appropriate title as a heading for your list, e.g.: b. Published Papers in Refereed Journals, or, d. Books and Chapters published. Also submit the citation lists as ASCII files via PC-compatible floppy disks
* Minorities include Blacks, Aleuts, Am Indians, Hispanics, etc. NB: Asians are not considered an under-represented or minority group in science and engineering.


31. V. Percec and M. Lee, Molecular Engineering of Liquid Crystal Polymers by Living Polymerization. 14. Synthesis and Characterization of Binary Copolymers of ω-[4-


64. V. Percec and H. Oda, Polymer Effect on Heterochiral Molecular Recognition in Molecular and Macromolecular Pairs of Liquid Crystals of (R)- and (S)-2-Chloro-4-methylpentyl 4'-(8-(Vinloxy)octyloxy)biphenyl-4-carboxylate Enantiomers, Macromolecules, 27, 4454 (1994)

65. V. Percec and H. Oda, Heterochiral Interactions in Molecular and Macromolecular Pairs of Liquid Crystals of (R)- and (S)-2-Fluoro-4-methylpentyl 4'-(8-(Vinloxy)octyloxy)biphenyl-4-carboxylate Enantiomers, Macromolecules, 27, 5821 (1994)


d. Number of books or chapter published: 11 (see no. 2, 39, 41, 48, 50, 52, 62, 63, 66, 68, 74 from list b)

h. Invited Presentations: 285

197. "Molecular Engineering of Liquid Crystal Copolymers" by V. Percec, Plenary Perkin Speaker, Royal Society of Chemistry Meeting, University of Hull, Hull, United Kingdom, April 4-7, 1989.


199. "X-ray Studies of Mesomorphism in Polymers with a Semiflexible Mesogen" by J. L. Feijoo, G. Ungar, A. Keller, R. Yourd, and V. Percec, Poster, British Society of Liquid Crystals, University of Sheffield, Sheffield, United Kingdom, April 10-12, 1989.

200. "Non-Equilibrium States of Order in the Isotropic and Nematic States of Main Chain Polymers" by J. L. Feijoo, G. Ungar, A. Keller and V. Percec, Poster, British Society of Liquid Crystals, University of Sheffield, Sheffield, United Kingdom, April 10-12, 1989.

201. "LCP Based on Conformational Isomerism" by V. Percec, BP Research, London, United Kingdom, April 13, 1989.


203. "LCP Based on Conformational Isomerism" by V. Percec, Goodyear Tire and Rubber Co., Akron, OH, April 18, 1989.

204. "LC Polymers" by V. Percec, Pennsylvania State University, University Park, PA, April 27, 1989.


208. "LCPs New Synthetic Trends" by V. Percec, Case Western Reserve University, Cleveland, OH, May 11, 1989.


211. "Molecular Engineering of Side Chain LCPs" by V. Percec, Army Technology Laboratory, Watertown, MA, June 23, 1989.

212. "Highly Decoupled Side Chain LCPs" by V. Percec, Conference on LCPs, University of Massachusetts, Amherst, MA, June 24, 1989.


214. "Virtual LCPs" by V. Percec, BASF Ludwigshaffen, Germany, July 18, 1989.


216. "Virtual LCPs" by V. Percec, Bayer, Leverkusen, Germany, August 3, 1989.


223. "What are LCPs Providing Us With?" by V. Percec, Mobay, Pittsburgh, PA, October 12, 1989.


233. "Smectic and Crystalline Phases in Main Chain Copolymers with a Semiflexible Mesogen" by V. Percec, Poster, British Society of Liquid Crystals Annual Conference, Bristol, United Kingdom, April 9-11, 1990.


236. "Synthesis and Determination of the Virtual Mesophases of Polyethers Based on 1-(4-Hydroxyphenyl)-2-(2-Methyl-4-Hydroxyphenyl)ethane with α,β-Dibromoalkanes Containing from Four to Twenty Methylene Units" by V. Percec and Y. Tsuda, ACS Meeting, Boston, MA, April 22-26, 1990. Polymer Preprints, 31/1, 514 (1990).


241. "Virtual LCP" by V. Percec, Rensselaer Polytechnic Institute, Chemistry Department, Troy, NY, April 30, 1990.


250. "PTC in Polymer Chemistry" by V. Percec, Royal Institute of Technology, Stockholm, Sweden, June 4-6, 1990.

251. "Virtual Liquid Crystal Polymers" by V. Percec, Invited Main Lecture, Scandinavian Meeting on Polymer Science, Helsinki, Finland, June 4-6, 1990.


263. "Aromatic Polymers" by V. Percec, Bayer, Krefeld, Germany, August 8, 1990.

264. "Virtual LCPs" by V. Percec, Twente University, Enschede, Holland, August 9, 1990.


267. "Molecular Engineering of LCPs" by V. Percec, Xerox Research Center, Missisauga, Canada, September 21, 1990.

268. "Influence of Constitutional Isomerism of Mesogenic Units Based on Combination of Rigid Rod-like and Flexible Moieties" by A. D. S. Gomes and V. Percec, Macromolecular Colloquium, Puerto Allegre, Brazil, October 14-18, 1990.


271. "Virtual LCPs" by V. Percec, Waseda University, Tokyo, Japan, November 2, 1990.

272. "Molecular Engineering of Side Chain LCPs" by V. Percec, NTT, Tokyo, Japan, November 5, 1990.

273. "What Do We Expect From LCPs?" by V. Percec, Toyota Central Research Laboratory, Nagoya, Japan, November 6, 1990.


276. "Functional LCPs" by V. Percec, Tokyo Institute of Technology, Tokyo, Japan, November 9, 1990.


279. "Molecular Engineering of Side-Chain LCPs by Living Polymerizations" by V. Percec, University of Freiburg, Freiburg, Germany, February 20, 1991.

280. "Molecular Engineering of LCPs by Living Polymerization" by V. Percec, Chiao Tung University, Hsinchu, Taiwan, March 20, 1991.

281. "Liquid Crystalline Polymers Bond on Conformational Isomerism" by V. Percec, Tsing Hua University, Hsinchu, Taiwan, March 20, 1991.


283. "Virtual Liquid Crystalline Polymers" by V. Percec, Tsing Hua University, Hsinchu, Taiwan, March 21, 1991.

284. "Liquid Crystalline Polymers" by V. Percec, Tsing Hua University, Hsinchu, Taiwan, March 22, 1991.


-16-


303. "Virtual Liquid Crystalline Polymers" by V. Percec, Max Plank Institute for Polymer Research, Mainz, Germany, July 31, 1991.


308. "Molecular Engineering of LCPs" by V. Percec, University of Bordeaux, France, September 26, 1991.


312. "Synthesis of Soluble Polyphenylenes and Aromatic Polyethers by a Combination of Ni(O), Pd(O), and Cation Radical Reactions" by V. Percec, International IUPAC Symposium on New Polymers, Kyoto, Japan, November 30 - December 1, 1991.


316. "Supramolecular LCPs" by V. Percec, MPI, Mainz, Germany, January 29, 1992.


318. "Supramolecular LCPs" by V. Percec, University of Freiburg, Freiburg, Germany, January 31, 1992.


320. "Introduction to Molecular, Macromolecular and Supramolecular LCs" by V. Percec, University of Utrecht, Holland, February 25, 1992.


324. "Molecular, Macromolecular and Supramolecular LCs with Complex Architecture" by V. Percec, MIT, Cambridge, MA, March 10, 1992.


352. "Supramolecular LCPs" by V. Percec, University of Sheffield, United Kingdom, September 3, 1992.


356. "Molecular Recognition Directed Self-Assembly of Supramolecular Polymers" by V. Percec, University of Pittsburgh, Chemistry Department, Pittsburgh, PA, October 8, 1992.

357. "Molecular Recognition Directed Self-Assembly of Supramolecular Polymers" by V. Percec, Dow Invited Speaker, University of Detroit, Chemistry Department, Detroit, MI, October 15, 1992.

358. "LCPs with Complex Architectures" by V. Percec, University of Bordeaux, France, October 26, 1992.


360. "Molecular, Macromolecular and Supramolecular LCs with Complex Architecture" by V. Percec, University of Mississippi, Hattiesburg, MS, February 3, 1993.

361. "Macromolecular and Supramolecular LCs with Complex Architecture" by V. Percec, Virginia Polytechnic Institute and State University, Chemistry Department, Blacksburg, VA, February 10, 1993.


376. "Macrocycle Liquid Crystals" by V. Percec, Max Planck Institute for Polymer Research, Mainz, Germany, July 15, 1993.

-22-
377. "Supramolecular LCPs" by V. Percec, Cavendish Laboratory, Cambridge University, Cambridge, United Kingdom, July 19, 1993.


393. "Molecular Directed Self-Assembly of Supramolecular Architectures" by V. Percec, University of Munchen, Munich, Germany, March 10, 1994.

394. "Towards TMV-Like Supramolecular Polymers" by V. Percec, University of Ulm, Ulm, Germany, March 11, 1994.

395. "Macrocyclic Liquid Crystals" by V. Percec, University of Freiburg, Freiburg, Germany, March 15, 1994.


397. "Supramolecular Rods from Collapsed Macro cyclics" by V. Percec, Max Planck Institute for Polymer Research, Mainz, Germany, March 17, 1994.


440. "Nature as Model for the Design of New Macromolecular and Supramolecular Architectures" by V. Percec, Mini-Symposium on Polymer Chemistry, Department of Chemistry, National Taiwan University, Taipei, Taiwan, ROC, November 19, 1994.


442. "Molecular, Macromolecular and Supramolecular Liquid Crystals with Complex Topologies" by V. Percec, Iwate University, Morioka, Japan, November 22, 1994.


457. "Willow-like Hyperbranched and Dendrimeric Liquid Crystals" by V. Percec and P. Chu, ACS Meeting, "Recent Advances in Step-Growth Polymerization -


467. "Liquid Crystals with Complex Architecture" by V. Percec, Albert-Ludwigs-University-Freiburg, Freiburg, Germany, April 26, 1995.


**j. Honors/ Awards/ Prizes**

1990 and 1995: NSF Research Award for Exceptional Creativity in Research (V. Percec)
1993 Elected Honorary Foreign Member to the Romanian Academy (V. Percec)
1993 Leonard Case Jr. Professor of Macromolecular Science and Engineering (V. Percec)
Elected Member of the Editorial Board of 8 International Journals

**k. Total number of Graduate Students (10) and Postdoctoral associates (2) supported**

1. Coleen Pugh (PhD) Assistant Professor University of Michigan Ann Arbor
2. C. Hsu (PhD) Professor Hsinchu University , Taiwan
3. Caroline Ackermann (MS) industry
4. J. Zheng (PhD) Stanford Research Institute
5. D. Tomazos (PhD) Deceased
6. M. Lee (PhD) Professor Yosheva University, Korea
7. A.S. Gomes (post doc) Professor and Director E. Mano Institute of Macromolecules, University of Rio de Janeiro, Brasil
8. G. Johansson (PhD) IBM
9. H. Jonsson (post doc) BAYER
10. D. Crawford (Msc) industry
11. L. Lemon (Msc) industry
12. Beatrice Lin (MSc) Graduate student, University of Chicago

**Significant Results Obtained During this Period**

This research produced the first quantitative approach to the elucidation of the structure-properties relationship in the field of side chain liquid crystalline polymers via a molecular engineering approach. The elucidation of the mechanisms required for the formation of nematic, smectic, various chiral smectic, reentrant nematic and other phases in conventional end-on and in side-on side chain liquid crystalline polymers was approached via a combination of living polymerization reactions for the first time. This approach generated the first: molecular understanding-molecular engineering-technological applications concept from this field (see attached Scheme 1). The knowledges generated from this program were applied to the field of functional liquid crystalline polymers.

The results of this research were published in 74 refereed publication, reviewed in 11 book chapter published by invitation and 285 invited lectures.
SIDE CHAIN LIQUID CRYSTALLINE POLYMERS

MOLECULAR UNDERSTANDING

APPLICATIONS
- ANISOTROPIC GLASSES
- SELECTIVE WAVELENGTH DETECTORS
- POLARIZABLE FILTERS
- LARGE LC DISPLAYS
- INFORMATION STORAGE
- FERROELECTRIC MATERIALS
- PIEZOELECTRIC ELASTOMERS
- NON-LINEAR OPTICS
- INTEGRATED OPTICS
- DETECTORS & SENSORS
- SUPER-IONIC CONDUCTORS
- CHROMATOGRAPHIC STATIONARY PHASES
- PHOTOCHROMIC & PHOTO-CONDUCTIVE POLYMERS
- SUPERBARRIERS
- HIGH PERMEABILITY & SELECTIVITY MEMBRANES
- CONTROLLED DRUG RELEASE
- EXTERNALLY REGULATED SYSTEMS

SCHEME 1