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BIOMIMETIC INFRARED (IR) SENSORS

Dr. Morley O. Stone

Hardened Materials Branch (AFRL/MLPJ)
Survivability & Sensor Materials Division
Materials and Manufacturing Directorate
Air Force Research Laboratory, Air Force Materiel Command
Wright-Patterson Air Force Base, OH 45433-7750

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This technical report has been reviewed and is approved for publication.

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14. ABSTRACT
The objective of the program was to investigate naturally occurring infrared (IR) photosensitive materials for use in future systems. The work will concentrate on materials that are found in common pit vipers.

15. SUBJECT TERMS
infrared detector materials, photo-response

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Laboratory Task Annual Report: 1 October 2000

TITLE: Biomimetic Infrared Sensing Initiative

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I. RESEARCH OBJECTIVES / SUMMARY OF PROGRESS / FORECAST FOR FY01:

The research objectives and forecast for FY01 have been presented in the form of a new research proposal submitted to AFOSR entitled "Biomimetic Sensors and the Exploration of Novel Optical Transduction Mechanisms."

Notable progress was made within our task during FY00. At the beginning of FY99, we established a milestone for FY01 of "successfully demonstrating an optical sensing device based on cloned thermoreceptive protein(s) from our 6.1 task." This milestone was reached this past year with the cloning of TlpA from bacteria and using it to create a fusion protein with green fluorescent protein (GFP). The resulting TlpA-GFP fusion protein produced a fluorescent signal that was directly proportional to the temperature of the surrounding environment. The details of this accomplishment were presented at *Biosensors 2000* in San Diego, California and submitted for publication to *Biosensors and Bioelectronics*.

This past January, we were the first to demonstrate the recording of biological information, i.e., snake skin, inside a polymeric matrix using a two-photon initiated photopolymerization process. The details of this accomplishment were presented at SPIE's

Photonics West meeting in San Jose, California and published in the *Proceedings of SPIE.* This result was significant from an optical memory storage perspective and has enormous potential in the Bio-MEMS field. More importantly, we developed this process to be compatible with the addition of aqueous solutions, such as the addition of a thermoreceptive protein. In our opinion, this is an incredibly important enabling technology for biosensor creation because one can now pattern a polymeric optical device, e.g., a diffraction grating, whose performance (diffraction efficiency) is driven by the biological macromolecule (thermoprotein). The polymeric matrix enables the protein to retain activity and the two-photon process (near-IR) avoids the intrinsic biological absorption that usually occurs in a one-photon (near-UV) process.

This past year we also branched into the realm of biological inorganic chemistry. Specifically, we cloned a protein from diatom (a marine algae) DNA that catalyzes the poly-condensation of silica (-SiO_2-). Again, we feel this is an extremely important accomplishment due to the desired optical properties that inorganics like silica possess — namely higher indexes of refraction. Recently, we discovered how to control the morphology of the resulting silica structures. The details of this process have been submitted as a manuscript to the journal *Nature*. We have begun combining this silica-condensing enzyme with our two-photon polymerization process to produce hybrid polymer/silica structures. Not only will we be able to produce better optical devices due to the larger index of refraction mismatch, we feel this will enable an important breakthrough in micro-fluidics. We envision creating a complex three-dimensional polymeric network, holographically, then bio-catalyzing the production of a silica coating on the outside, following by etching the polymer core away — leaving behind a silica network of micro-capillaries.

In conclusion, the forecast for FY01 is hopeful and optimistic. We feel we can continue to combine in-house-developed technology to create truly innovative science. We are optimistic that we can continue to improve upon our optical transduction methodology and we will continue to push the state-of-the-art in biosensor technology. The applied biotechnology that is biomimetics has made all of this possible. Biomimetics will continue to break new innovative ground, especially in the field of materials science.

II. USE OF FUNDS (FY00, $K):

In House	Capital Equip.	On-Site Contractor	Contracts/Grants	Total
35	8.38	357.33	10	410.71

III. FUNDING PROFILE ($K):

FY99	FY00	FY01	FY02
487	487	485	?

APPENDIX A

PERSONNEL:

	Name	Degree	Discipline	Involvement
Air Force Employees	Morley Stone	Ph.D.	Biochemistry	60%
	Alexandra Nolan	STEP Apprenticeship Program		50%*
	Cojean Wang	STEP Apprenticeship Program		50%*
On-site Contractors	Rajesh Naik	Ph.D.	Genetics	100%
	Lawrence Brott	Ph.D.	Materials Science	100%
	Laura Sowards	MS	Chemistry	100%
	Sharon Jones	MS	Molecular Biology	100%
	Bryan Jones	BS	Biomed Engineering	20%*
	Patrick Whitlock	MS	Materials Science	50%*
	Isaac Humphrey	USAF Academy Cadet		100%*

*Student and/or summer research personnel

Publications and Presentations in FY00:

Whitlock P W, Naik R R, Brott L L, Clarson S J, Tomlin D W, Stone M O. (submitted) "Control of Biosilica Nanostructures by Motion," *Nature.*

Jones S W, Naik R R, Stone M O. (submitted) "Use of Small Fluorescent Molecules to Monitor Channel Activity," *Biochem. & Biophys. Research Comm.*

Brott L L, Naik R R, Kirkpatrick S M, Pikas D J, Stone M O. (submitted) "Near-IR Two-Photon Induced Polymerization Using a Benzophenone-based Photoinitiator," *Macromolecules.*

Naik R R, Kirkpatrick S M, and Stone M O. (submitted) "Determination of the Two-Photon Cross-Section of Green Fluorescent Protein," *J of Physical Chem A.*

Naik R R and Stone M O. (submitted) "Applications—Biomimetic Electromagnetic Devices," Encyclopedia of Smart Materials, ed. James Harvey. John Wiley and Sons Inc, New York.

Jones B S, Lynn W F, Stone M O. (submitted) "Thermal Modeling of Snake Infrared Reception: Evidence for Limited Detection Range," *J Theoretical Biology.*

Naik R R, Kirkpatrick S M, and Stone M O (accepted) "The thermostability of an alpha-helical coiled-coil protein and its potential use in sensor applications," *Biosensors and Bioelectronics.*

Stone M O, Baur J W, Sowards L A, Kirkpatrick S M. (2000) "Ultrafast holographic recording of snake infrared pit tissue using two-photon induced polymerization," *Proceedings of SPIE* **3934**: 36-42.

Kirkpatrick S M, Denny L R, Stone M O. (2000) "Ultrafast holographic recording using two-photon induced photopolymerization," *Proceedings of SPIE* **3951**: 102-107.

Stone M. (June 2000) Invited Seminar, Department of Chemistry, University of Cincinnati.

Stone M. (October 2000) Invited Seminar, Department of Materials Science, University of Connecticut.

Brott L L, Kirkpatrick S M, Stone M O. (October 2000) "Biologically-compatible Polymeric MEMS Devices Fabricated Using Holographic Two-photon Induced Photopolymerization." *American Vacuum Society National Meeting*, Boston, MA.

Naik R R, Kirkpatrick S M, Stone M O. (May 2000) "Thermostability of an alpha-helical coiled-coil protein and its potential use in sensor applications." *Biosensors 2000*, San Diego, CA.

Sowards L A, Stone M O. (May 2000) "Beetle *Melanophila acuminata* (Coleoptera: Buprestidae) Infrared Pit Organ Characterization by LC/MS, SEM, and FT-IR." *American Chemical Society Regional Meeting*, Covington, KY.

Nolan A M, Naik R R, Stone M O. (March 2000) "Spectral variants of green fluorescent protein using DNA shuffling." *American Chemical Society National Meeting*, San Francisco, CA.

Naik R R, Kirkpatrick S M, Stone M O. (March 2000) "Nonlinear Fluorescent behavior of green fluorescent protein." *American Chemical Society National Meeting*, San Francisco, CA.

Professional Activities of Personnel

Active Society Memberships:

American Chemical Society
American Association for the Advancement of Science
Materials Research Society
Genetics Society of America

Extended Scientific Visits: None