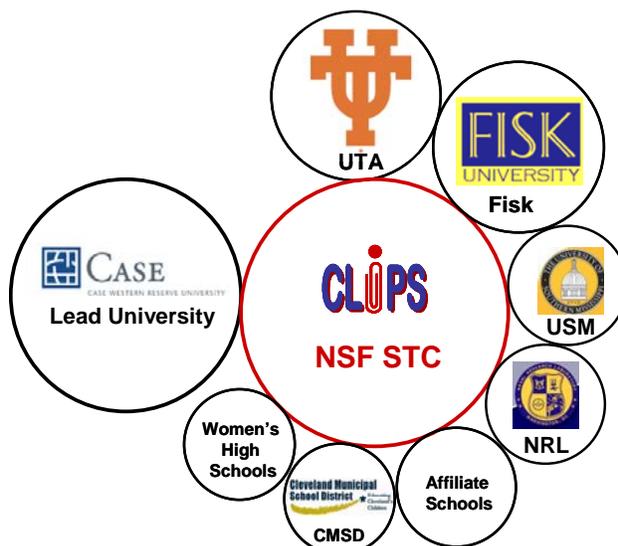


## CLiPS ANNUAL REPORT 2007 - CONTEXT STATEMENT

### *CLiPS Vision and Goals*

The **Vision** of the Center for Layered Polymeric Systems (CLiPS) is to create an integrated program of research and education through the vehicle of a unique microlayering and nanolayering process technology at Case Western Reserve University (Case). CLiPS will be a powerful national model for distinguished research and for successful recruitment of diverse American students into the science and engineering workforce. To create CLiPS, Case has partnered with the University of Texas at Austin (UTA), Fisk University (Fisk), the University of Southern Mississippi (USM), and the Naval Research Laboratory (NRL) under the leadership of the Director, Professor Anne Hiltner. The strategic plan for achieving the CLiPS vision is distilled with the assistance of a diverse External Advisory Board.



**CLiPS Partner Institutions**

The envisioned Center will:

- Integrate research activities in three platforms with multi-level educational programs to train a diverse American workforce that can meet the challenges of the new nanotechnologies.
- Focus the impact of the integrated research and education activities on national priorities in defense, environment, energy, and health.
- Disseminate the knowledge developed through the integrated Center activities to the larger audience beyond the partner institutions.
- Serve as a compelling model for expanding relationships between HBCUs and research universities.

The CLiPS approach strategically integrates polymer science with research in nanotechnology, optics, laser physics, membranes, biomedical engineering, device development and other scientific disciplines in a “**polymers-plus**” concept. The multidisciplinary nature of the research program flows naturally into graduate and undergraduate education. Integrated educational programs mirror the polymers-plus idea to introduce modular coursework in emerging cross-disciplinary areas. Students and faculty trained in this area will be uniquely positioned to make major contributions to the emerging field of nanotechnology.

A full research and education partnership between Case and Fisk is broadening participation of African-American students in the science and technology programs at both universities. The Polymer Envoys Program engages students from the Cleveland Municipal School District in the exploration of polymer science and engineering as academic pursuits and eventual careers; this program will serve as a model for Fisk and UTA to form linkages with local public high schools.

Recognizing that personal contacts are an important influence in the career choice of college graduates, CLiPS has established affiliations with non-PhD-granting schools that offer strong undergraduate science and engineering programs to stimulate enrollment of American students in CLiPS graduate programs.

CLiPS research programs focuses on three platforms: (1) unique **process technology** that enables fabrication of hierarchical microlayered and nanolayered polymer-based structures and systems; (2) development of **membrane and barrier systems** that exploit the layered hierarchy to achieve unique transport properties; and (3) development of **electro-optical devices** based on the advanced layered materials. Fundamentally new materials are obtained by forced-assembly of polymers into layers no

thicker than the radius of gyration of individual polymer molecule. New functionalities are obtained by combining polymers with organic dyes, inorganic and hybrid particles, and reactive materials that possess high levels of molecular recognition. Organization of the aggregate materials into microlayers and nanolayers will produce new devices by conventional technologies.

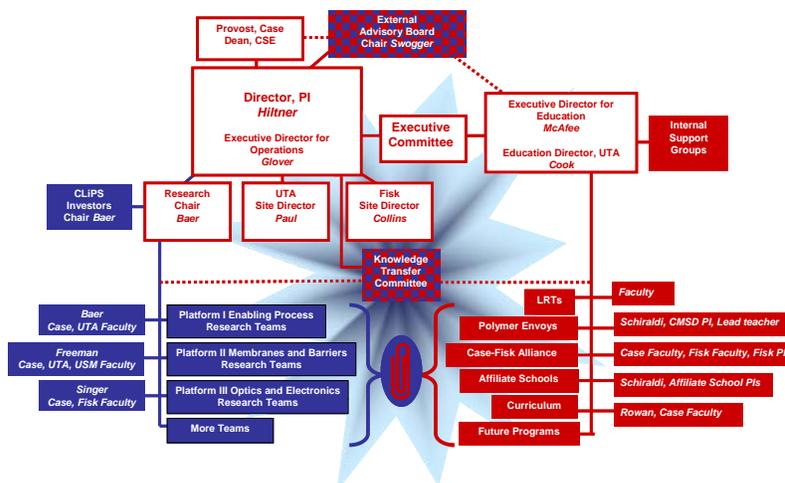
The Center endeavors to become a unique global resource for the dissemination of knowledge in the area of layered polymeric systems and a national force for engaging audiences at all levels in polymer science and engineering. The Center fosters linkages between academia and industry in order to accelerate the development of new product initiatives. In some instances, these linkages will stimulate innovative entrepreneurial ventures and small businesses.

### Leadership and Management

The CLiPS organization and operation plan enable the Director and management team to:

- Provide leadership for realization of the Vision through the Strategic Plan
- Ensure integration of multidisciplinary research, education and knowledge transfer activities
- Promote broad participation of the various constituencies that make up CLiPS
- Establish team-based research programs with mechanisms for growth and renewal
- Create a national model for expanding relationships between HBCUs and research universities
- Enable recruitment and education of students with diverse cultural backgrounds into science-oriented careers
- Facilitate education of multi-disciplinary, team-oriented students within traditional university settings
- Maintain effective day-to-day management, fiscal responsibility and reporting functions

The management and operation plan evolved during the startup period and the result is described in the figure. The **Director** is Anne Hiltner, a faculty member who sets the Vision of CLiPS, leads the strategic planning process with involvement of the membership in an ongoing manner, acts as the intellectual leader in setting research priorities in collaboration with the Platform Leaders, verifies communication across participating groups, ensures integration of diversity throughout CLiPS programs, identifies and mentors new faculty into CLiPS, negotiates fiscal and policy issues with the university on behalf of CLiPS, and makes final decisions on key management positions and resource allocation. With the Executive Committee, the Director identifies measures for evaluating success in both research and education, and defines indicators of success in year-4 of the program.



**CLiPS Management Organization**

The Director, Anne Hiltner, is the Herbert Henry Dow Professor of Science and Engineering. Dr. Hiltner led the CLiPS proposal and site visit phases. As Director of CLiPS, her first priority was to put in place the management team. Key staff positions were filled by September 1, 2007. Pam Glover joined CLiPS as Executive Director for Operations. She is a full-time hire who assists the Director in day-to-day management of CLiPS and takes leadership in certain aspects as delegated by the Director. Dr. LaRuth

McAfee joined CLiPS as Executive Director for Education. She is also a full-time hire who leads in planning, implementation, assessment and innovation of the integrated research and education programs. Pam Cook joined CLiPS as the Assistant Director for Education and Diversity at the University of Texas Austin where she is committed half-time to CLiPS education and outreach programs at UTA. Offices for the Case staff were provided in the Kent Hale Smith Building.

Concurrently, a search was initiated to fill the first of two faculty positions committed by Case which targeted members of underrepresented minorities. An offer was made and accepted by Dr. LaShanda Korley, and she will join the faculty of the Department of Macromolecular Science on July 1, 2007. A search to fill the second committed faculty position has been initiated. The Case Provost has committed startup funds for Dr. Korley. In addition, CLiPS has been promised extensive laboratory space in the Kent Hale Smith Building.

The Executive Committee is chaired by the Director with membership inclusive of the CLiPS faculty and staff. The committee meets weekly and is joined by faculty and staff at the partner institutions via teleconference. The high level of commitment of the faculty has ensured that this is a dynamic and effective group that enjoys input from all the partners. The 1-hour meetings follow an agenda set by the Director, and cover management and organizational aspects of the center and include discussions aimed at enhancing the research and education experience of the students and the integration of diversity into the programs. Minutes are recorded.

Technical topics are addressed in regular Platform meetings. The platform committees are chaired by the platform leaders and consist of the platform faculty, students and research associates. It became apparent early in the startup period that the highly interactive research projects required regular meetings for planning and discussion. The flexibility of web-based meetings greatly facilitates inclusion of faculty and students at the partner institutions. Similarly, small program-specific groups assist Dr. McAfee with planning, implementation, translation, and evaluation of the integrated education and outreach programs. The groups are drawn from the faculty and staff of the participating institutions.

The committee structure facilitated rapid startup of the research, education and diversity programs while maintaining close communication and interaction among the faculty and staff. The research projects are fully staffed at this time. The education and diversity programs are in place and in some cases, translation to partner institutions has started.

The Director is assisted by a diverse External Advisory Board. Four of the members are African-American, three are women, and one is handicapped. The EAB meets regularly to review the CLiPS strategic and implementation plan (SIP), to review progress toward research and education goals, to assess the sufficiency of available resources for CLiPS to ensure achievement of the CLiPS integrated research and education mission, and to make a written assessment for the university administration. At the first meeting of the EAB on April 11, 2007, the EAB distilled a set of objectives, reviewed the activities of the center, and submitted a written report to the Director and the university administration. The EAB plans to meet twice during the year in order to review progress toward goals and to contribute to the Annual Report.

The Center interfaces with industry through the CLiPS Investors. Members each contribute \$35,000 annually to CLiPS in the form of a graduate fellowship. To date, 6 companies have become CLiPS Investors. The first meeting of the CLiPS Investors to review the research and education activities of the center was held in conjunction with the Annual Meeting on March 14 and 15, 2007.

## Intellectual Merit of the Center

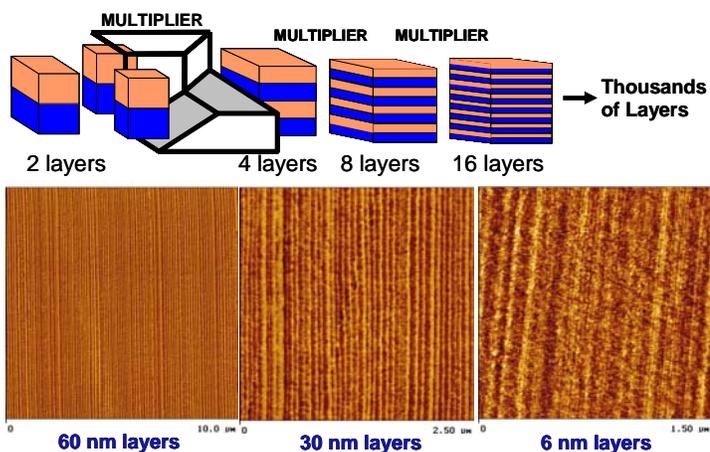
### Research Vision and Goals

A broad range of new science and innovation will emerge from the CLiPS unique technology that will be the basis of a global resource for microlayered and nanolayered polymeric materials. The CLiPS research activities will

- Define and implement interdisciplinary research programs that exploit the large interfacial area and the unique interphase properties made possible by reducing the dimensions and dimensionality of the layers.
- Use these architectures to create and explore new materials with unique transport behavior and interactions with light.
- Focus the integrated research activities on national priorities of security, health, environment, and energy.

To achieve these goals, the research program focuses on three platforms:

- Unique **process technology** at Case enables fabrication of hierarchical microlayered and nanolayered polymer-based structures and systems. Case plays the leading role in growing this enabling technology and probing a fundamental understanding of these new systems.
- Novel **membrane and barrier systems** exploit the layered hierarchy to achieve unique transport properties. Researchers from UTA, Case, and USM collaborate in this thrust under the leadership of UTA.
- Innovative **optic and electronic materials** are based on advanced layered materials. Teams from Case, Fisk, and NRL collaborate in the development and testing of devices.



### Layer Multiplying Coextrusion Technology

#### Platform I

Platform I supports a continuous coextrusion process that facilitates creation of microlayered and nanolayered systems by forced assembly of polymers on a size scale as small as molecular dimensions, as shown in the figure. This flexible, solvent-free technology accommodates the diverse needs of research in Platforms II and III. The process is user-friendly and students at all levels gain hands-on laboratory experience in processing layered systems.

During the start-up period, 3 major processing projects were launched that are directed toward maintaining and expanding the enabling technology. An additional 5 projects aim at understanding and exploiting the vast interfacial area in micro and nanolayered systems. All of these have been staffed by at least one graduate student.

(1) Efficient and effective operation of the coextrusion process is key to the success of the CLiPS research goals. Teams of 3 were staffed with a total of eight graduate students and one research associate. All of the individuals were fully trained in the operation of the co-extrusion process. The processing teams interact with CLiPS research faculty and students through regular web-based meetings with the partner institutions, and through weekly processing team reviews.

(2) The world's smallest polymer micro co-extrusion system was designed to extend the capabilities of CLiPS enabling microlayering technology to the gram size scale. This would allow the structure-property relationships to be probed for materials previously unavailable for study based on limited availability and high cost. The initial design required the miniaturization of the existing layer multiplying die with considerably smaller feed channel dimensions. These dimensions had to be compatible with the proposed Microtuders®. Two miniaturized multipliers were built and tested with the existing system. However, good layer uniformity could not be achieved due to the frictional edge effects on the polymer melt at the miniaturized multiplier walls.



**Students Operating the Coextrusion Process**

This necessitated the development of an alternative, perhaps even better approach to a miniaturized forced assembly co-extrusion process.

An alternative approach focused on modifying the existing co-extrusion system using recent advances in melt pump technology which are capable of precise flow metering as low as 10 gram/hr. Very low flow rates are achieved by inline inclusion of a special Mini-max injection system. The concept is to precisely inject a small amount of material into the process as it is running. Plans call for this system to be installed in May/June, with co-extrusion trials with gram scale batches of material to come online in June/July 2007. Training of the student-led processing teams will begin with the equipment installation to ensure that the full potential of the injection-modified co-extrusion process is realized in all areas of CLiPS research. The initial experiments will challenge the injection-modified system to precisely deliver small (gram sized) batches of polymer as one of the alternating layers. It will demonstrate the expansion of the layering process to materials previously unavailable for co-extrusion layering trials due to the current requirement for at least 100 grams.

(3) Layer uniformity achieved with our system of multiplying is adequate for most of the proposed applications, and the process can be scaled up to commercial operation. However, some of the proposed applications, particularly in the optic and electronic materials, challenged us to achieve better layer uniformity. We have dramatically improved layer uniformity by coextruding a thick sacrificial skin layer onto the assembly in a final step before spreading the melt. This has also substantially improved the surface quality. It should be noted that in the event that a specific system with strict requirements on layer uniformity is developed for commercialization, an alternative method of layer multiplication is available. This feedblock method is used by 3M to produce high performance optical films and achieves exquisite layer uniformity with hundreds of layers. However, it does not possess the flexibility of our system.

(4) The effect of the multilayer constraint on aging of thin films of an amorphous polymer is being studied. Several successful multilayer co-extrusions of polysulfone (PSF) and an ethylene-octene copolymer (EO) have been made. The aging response of such materials will be studied by the gas permeation response of these films as a function of aging time. The first steps of the evaluation by permeation have been to construct gas permeation cells for this project, eliminate the leaks and calibrate them. These steps are currently underway and should be completed in summer 2007.

(5) The nature of the polymer interphase is being studied by incorporating a fluorescent probe. Preliminary experiments were conducted using 6-propionyl-2-dimethyl aminonaphthalene (Prodan), a commercial photoluminescent solvatochromic dye. In preparation for co-extrusion, the dye was incorporated into poly(methyl methacrylate) (PMMA) and polystyrene (PS) by solution-casting in

chloroform. It was observed that Prodan displays different emission spectra in PS and PMMA indicating that solvatochromatic fluorescent dyes are able to probe the interfacial environment.

(6) Nucleation studies using nanodroplets with and without nucleating agents have proceeded rapidly. Nanolayers of polypropylene with microlayers of polystyrene were co-extruded. Breakup of the 12 nm PP nanolayers resulted in primarily submicron particles with a crystallization exotherm at 40°C, which was identified with homogeneous nucleation of these particles in the smectic form. Addition of specific nucleating agents to PP microlayers and nanolayers is being conducted to study the nature of heterogeneous nucleation of specific polymorphic crystal forms. This project has already resulted in several publications.

(7) Efforts to exploit the potential for reactions at the interphase has been initiated with focus on the study of self-assembly by means of metal-ligand interactions. To this end a new synthetic route to a ditopic end capped macromonomer has been devised. The goal was to find a synthetic protocol which would allow (i) production on a relatively large scale, 5-10 g and (ii) facile control over the resulting molecular weight of the macromonomer which forms a supramolecular polymer when bound to transition metals and lanthanides. Europium salts are especially interesting in that a significant change in emission is observed upon binding to the ligand.

(8) The concept of forced assembly has been combined with self-assembly in nanolayers of a hydrogenated styrene-b-isoprene copolymer, Kraton® G1730, and polystyrene (Styron 685). These candidate polymers were identified based on rheological compatibility as suitable materials for co-extrusion. The Kraton G1730® and polystyrene materials were successfully co-extruded into films of 1024 layers. The individual layer thickness of the Kraton layer was varied by changing the relative feed rates of the Kraton to polystyrene to produce films with layer thickness from 40 to 7 nm. Currently, these films are being analyzed using oxygen flux as the probe. By using transport models, it should be possible to elucidate whether layer confinement affects the microphase morphology of the block copolymer.

## Platform II

Platform II focuses on mass transport phenomena and, more specifically, on membranes and barrier materials. Six multi-investigator research teams were created and are fully staffed. The teams focus on a fundamental understanding of transport phenomena in micro and nano layered systems by performing systematic experimental and modeling studies to identify the dominant controlling structural variables. This understanding of fundamental transport phenomena will be used to design and optimize unique layered systems for food and electronic packaging, drug delivery and diagnostic devices. Layered material systems will be optimized to exhibit transport-property profiles that may be otherwise inaccessible.

(1) The research on oxygen scavengers for packaging applications has been initiated using polybutadiene. Initial efforts to build a foundation in modeling the scavenging performance were undertaken. Currently, this approach is being extended to block copolymers containing polybutadiene, such as the Kraton family of materials from Kraton Polymers. Such materials could be used to provide scavenging centers. For example, a polystyrene layer will be co-extruded in microlayer format with a Kraton to give an additional degree of freedom to tune the scavenging performance of a composite layered film. We will characterize the oxygen scavenging performance of first-generation layered materials and are planning to understand the ability of first-generation models to describe the experimental data.

(2) Research on layered materials for controlled atmosphere packaging has begun using the PEBAX family of thermoplastic elastomers. Initial efforts have focused on learning to use permeation equipment to make single gas permeation measurements. We are now extending this research to block copolymers containing ethylene oxide (and related, high CO<sub>2</sub>/O<sub>2</sub> selectivity materials), such as the PEBAX family of thermoplastic elastomers and related materials that could be synthesized through resources available in

the Center. Such materials would be co-extruded with thermal switching materials to provide both highly sensitive control of the overall gas transport rate through the structure and high CO<sub>2</sub>/O<sub>2</sub> selectivity.

(3) Studies on enzymatically-active membranes for separation and barrier applications have begun using the PEBAX family of thermoplastic elastomers. Initial efforts have focused on learning to characterize enzyme activity and identifying a good enzyme candidate. In this regard, we have decided to begin with lysozyme, which is available in large quantities. It has good anti-bacterial properties for use as an antibacterial additive to layered structures. It should be emphasized that this focus on both molecular biology and chemical engineering would be initiating a unique interdisciplinary training program that should prove interesting to other students and educators. During this first year of the program, most of the research is being focused on developing the student's ability to prepare, characterize, and immobilize enzymes, and to learn the analytical techniques necessary to monitor both the ingress of enzymes into normal membranes and foamed materials.

(4) Layered polymeric films with controlled CO<sub>2</sub>/O<sub>2</sub> selectivity have been prepared. Blends of ethylene-acrylic acid copolymer (EAA) with up to 50% polyethylene oxide (PEO) were prepared and characterized in terms of thermal behavior and gas transport. It was found that when PEO was dispersed as small domains in the EAA matrix, the PEO particles did not crystallize during cooling to ambient temperature. This occurred because most of the PEO particles did not contain a sufficiently active heterogeneous nucleant. As a consequence, the permeability to both O<sub>2</sub> and CO<sub>2</sub> increased substantially without affecting the high selectivity of PEO for CO<sub>2</sub>. We also co-extruded the first microlayers of EAA and PEO. The individual layers were relatively thick, and the layers exhibited the properties of the constituents. A series model accurately described the gas transport properties. This program is being extended to investigations of ultrathin layered systems down to the nano-scale.

(5) Glasses having low glass transition temperatures have been prepared for polymer/glass layered composites with very high barrier. A family of phosphate glasses with T<sub>g</sub> values ranging from 90 – 150°C, and moisture regain values of 0.7 – 4% have been produced. A 117°C T<sub>g</sub> glass has been chosen as the first material to be evaluated in combination with polypropylene. Melt mixing the inorganic glass with polypropylene and maleated polypropylene produced a range of materials ranging from nearly transparent to opaque. Under polypropylene processing conditions, the inorganic glass was shown to be stable for over an hour, and no major processing problems are anticipated. Current efforts are focused on finding a rheological match of glass and polymer at a single processing temperature. Initial results show that polypropylene/glass blends exhibit polypropylene-like viscosity behavior, and that neat glass and neat polypropylene rheologies can also be closely matched. In the near future, both unoriented and biaxially-oriented films of phosphate glass/polypropylene will be produced and characterized. Orientation of glass particles will be studied as a function of glass T<sub>g</sub> values and incorporation of maleated polymer coupling agent.

(6) The use of inorganic particulates for high barrier systems is being explored in multilayered composites. Research has begun towards optimizing the amount of LLDPE-g-MA compatibilizer that has to be added to disperse the clay in LLDPE. Improvement of clay dispersion with adding more of LLDPE-g-MA has been achieved. At about 10 wt% LLDPE-g-MA, the corresponding nanocomposite diffractograms became practically featureless suggesting exfoliation of the mineral layers. TEM conducted on these same systems are in agreement with the X-ray observations. Currently these nanocomposite compositions are being optimized to achieve the best mineral layer dispersion. The corresponding nanocomposites and pure polymer systems will then be co-extruded into multilayered systems and predictive models for gas diffusion in these systems will be created.

### Platform III

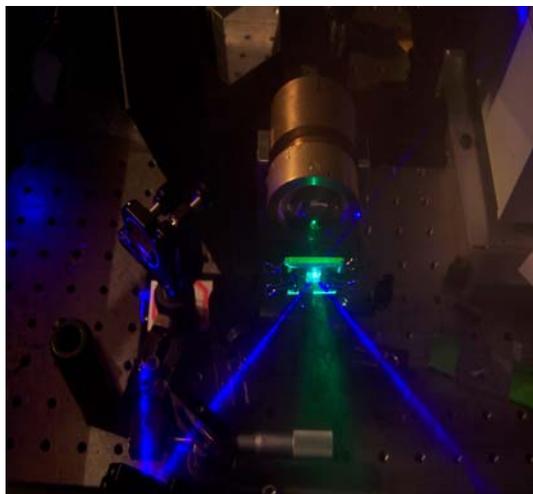
CLiPS's enabling process technology is uniquely suited to facilitate new science and technology relevant to the broad field of optical and electronic phenomena where multilayer structures represent a common general architecture. Research Platform III seeks to exploit this tremendous opportunity by carefully

addressing selected projects in areas of significant national interest through the application of core competencies. Projects are underway to study the interactions of light with micro- and nano-layered polymeric materials with the applications in photonic and optoelectronic devices. During the first year, 6 multi investigator projects were launched.

(1). A project is underway to investigate linear and nonlinear optical phenomena in multilayered polymer films, and to demonstrate photonic switching phenomena. Students have been recruited and assigned to the project. Numerical methods to calculate the bandgap are operational. Finite difference time domain software is installed and early results are emerging. The z-scan apparatus is operational, and is in the last stage of development. Three poly(*p*-phenylene ethynylene) (PPE) chromophores have been synthesized and preliminary z-scan results have been completed. In addition to nonlinear optical studies of PPE derivatives in solution and solid films, the incorporation of new dyes into polymers and multilayered films is being initiated.

(2) A team to create and study photonic crystals for optical limiting has been assembled and research is underway. Z-scan measurements of Pb-phthalocyanine are underway in order to study its nonlinear optical response. We are also proceeding with nonlinear optical measurements on the Pb-phthalocyanine chromophore/multilayer polymer system. Some initial results on microlayered films are being analyzed in order to plan the next experiments. Currently, further experiments and conditions are being planned, structures designed, fabricated and measured. Based on the results, the next generation multilayer optical limiting experiment will be carried out. Characterization of the polymer-dye dispersions that are used in the multilayer system has resulted in 2 publications.

(3) Research has been initiated to investigate the use of multilayer films as feedback elements in all-plastic lasers. The research team made several attempts to produce a distributed feedback dye laser. It was found that migration of the laser dye during the processing was a problem. In addition, the rhodamine-6G chloride was found to quench easily in PMMA. Instead, an all-plastic photonic bandgap defect laser, consisting of multilayer film mirrors physically layered with a monolithic gain medium, was processed under less demanding conditions using a new luminescent dye, C1-RG. Low threshold lasing action was obtained as seen in the figure. A careful theoretical and experimental study of the lasing conditions was carried out. Several ways to address the migration problem were identified and are being investigated. Plans are to fabricate DFB lasers and multiline defect lasers.



**A Distributed Feedback Laser**

(4) A unique opportunity to investigate multilayered films in terahertz applications has been investigated. A THz spectrometer covering the spectral range of 0.1- 1.5 THz in the transmission mode is operational. Many commonly used polymeric materials have been characterized in this spectral region. Proof-of-concept of photonic crystals in the THz spectral region was demonstrated by assembling 6 pairs of PC-air films with thickness of ~100 microns each. A careful co

mparison of the experiment to theoretical models was successfully carried out. Currently, a THz spectrometer covering frequencies beyond 1-2 THz is being constructed. The new capability will allow us to investigate multilayers of micron layer thicknesses. Blending BaTiO<sub>3</sub> particles into polymers is being investigated and a thorough study of the dependence of the refractive index on the particle concentration is being initiated.

(5). Utilization of layered systems in the development of electronic materials systems with photovoltaic properties has been started. A new low- temperature ( $T < 600^{\circ}\text{C}$ ) ZnO weblike nanowire growth technique has been developed, and CdTe and PbTe quantum dots deposition has been carried out. A presentation of the progress was given at Black American Physicist Conference in Feb, 2007. Although, the initial results seem to show photovoltaic effects, there exist a number of issues that must be addressed. These include inorganic and polymeric materials compatibility, structural reproducibility, stability, photovoltaic effect optimization and the fundamental physics and chemistry of interfaces.

(6). Photopatternable films can be produced by incorporating an additive in one of the layers that on exposure to high-intensity UV radiation will permanently change the refractive index of the photoreactive layers in a controlled fashion. The initial blend system employed cinnamic acid as the photoreactive agent. This small molecule diffused and sublimed out of the melt during blending and coextrusion. An alternative, poly(vinyl cinnamate) (PVCi), a well known negative photoresist, was chosen to take its place, since it possessed the same reactive cinnamate chromophores as cinnamic acid. This polymer gave much higher refractive index change and solved diffusion and sublimation issues during melt processing. The photocrosslinking reaction of PVCi has been extensively studied over the years by many researchers, and it is known that PVCi can be photopatterned as a monolith. We found the polymer to be partially miscible in SAN polymers (SAN17 and SAN25), which maintains a relatively large refractive index change compared to the initial cinnamic acid system. Preliminary stability tests made in anticipation of coextrusion with this system indicate that these blends may be sufficiently stable for microlayering.

### ***Integration of Research and Education***

#### Vision and Goals

CLiPS' vision is to be the global leader for integration of research and education in polymer science and engineering. In order to accomplish this, CLiPS will integrate its research with multi-level educational programs to stimulate and prepare American students to pursue successful professional careers with advanced degrees in polymer science and engineering. The multidisciplinary resources of the Center will be employed to develop focused programs that connect and educate a diverse group of American students from middle school through the PhD level.

In order to achieve these goals, the program objectives are to

- Design and implement new graduate courses in polymers, to create courses in polymer science for Fisk and Affiliates, and to develop advanced modular graduate courses in “polymers plus”.
- Build a supportive environment for polymer research and teaching at all CLiPS institutions
- Foster undergraduate research experiences in polymer science
- Excite and encourage students at a young age in polymer science and engineering
- Engage the broader community in polymer science through CLiPS research and education programs

Evaluation tools have been developed for all initiatives to determine their success. An external evaluator, Dr. Jan Uston, has been engaged to independently evaluate the initiatives.

#### Course and Curriculum Development

The interdisciplinary nature of CLiPS engages students from different academic disciplines in the “polymers plus” concept. Recognizing a broader need to provide graduate students with a common basic level of understanding in polymer science and engineering, the Case Department of Macromolecular Science and Engineering was motivated to perform a comprehensive evaluation of its graduate curriculum, a process that had not been seriously attempted in over twenty years. The CLiPS faculty (Stuart Rowan and others) led the process and worked to ensure that CLiPS-related concepts were included in new courses.

The evaluation process revealed that the basic polymer science courses as presently taught had too much overlap in some areas and omissions in other areas. Moreover, it appeared that there were not enough elective courses for the students in advanced topics in polymer science and engineering. The curriculum was completely redesigned in order to:

- Provide fundamental knowledge in polymer science for graduate students who come into the program with a diverse undergraduate background
- Ensure that the curriculum meets the needs of the graduate students from the point of view of their graduate research and their future career development.
- Minimize overlap between courses.
- Offer advanced, interdisciplinary elective courses that include current trends in polymer science and engineering.

Four new “Foundation Courses” were designed which will bring all the students, regardless of undergraduate background, to the same knowledge level in the core areas of polymer science and engineering. Integrated into these courses are laboratory and term paper components, which will directly relate to what is being taught in classes. At the present time, available laboratory space imposes a cap on the lab component of 15 students. A priority of the department is to develop resources to handle larger laboratory classes. In the meantime, students will replace the lab component with an option to write a term paper on a topic directly related to the class. Finally, a series of modular (2 credit hour courses) provide the student for options to go into more depth in specific polymer areas. The CLiPS faculty members in the Department of Macromolecular Science are involved in all aspects of teaching the new courses. In addition, CLiPS faculty from other departments will contribute to the interdisciplinary modular courses in CLiPS research areas. The new curriculum has been approved by Case and will be introduced in Fall 2007.

To support the CLiPS’ goal to develop the future leaders in the polymer science and engineering community, CLiPS has started professional development seminars for graduate students. To this end, The University of Texas has offered technical writing seminars for students who feel they need guidance in that area. This has been well-received and will become a regular series. At Case, graduate students who have mentored younger students have expressed an interest in learning techniques for becoming better mentors. To support these students, CLiPS will begin a mentoring seminar series in Summer 2007 that will discuss best practices in mentoring. This will be based on a seminar that was developed at the University of Wisconsin and has been used successfully at Case in the Department of Biology. Based on feedback from this pilot seminar series, the topics will be refined and/or expanded to best meet the needs of the students. In addition to learning proper mentoring techniques, this seminar series will allow for the development of a network of mentors who can support each other through issues that arise with their mentees. In the future, it may be developed into a graduate curriculum module so that students will receive credit for their participation in mentoring activities.

#### Affiliate Institutions

A main focus for the Affiliate Institutions is to expose and involve undergraduate students in CLiPS research and teaching. These are primarily undergraduate higher education institutions in the geographic region surrounding Case. The Affiliates are currently Ohio Northern University, Pennsylvania State University at Erie, Rochester Institute of Technology, Rose-Hulman Institute of Technology, and the State University of New York at Fredonia. In consultation with the CLiPS Executive Director for Education, each institution prepared a statement of work that described the specific objectives and activities for the collaboration.

The Affiliate Institution program was kicked-off at a meeting in September, 2006. This meeting was an opportunity to reintroduce Affiliate representations to CLiPS and to have all the representatives. At the meeting, significant overlaps were noticed in the activity interests of the various institutions, and educational and research collaborations were initiated. In Year 1 of CLiPS, planning began for some of

these joint activities. Representatives were so pleased with the initial meeting that they intend to have an annual Affiliate Institution meeting that will be hosted by a different institution each year.

While the Affiliates have primarily developed opportunities to work with each other and with Case, one interesting example of collaboration with the general community is happening at SUNY Fredonia. Two SUNY Fredonia faculty members, Philip Kumler and Cheryl Campo, along with Lee Servatius, Chairman and NY State Commissioner to the Ohio River Valley Water Sanitation Commission (ORSANCO), have begun planning a “Polymers Plus” module intended to serve as a vehicle for informal polymer education with a target audience of middle/high school-aged students in the southern Ohio/western NY region. The module will deal with how polymers are used in aquatic environments. It will be disseminated, at first, through the river education program currently run by the ORSANCO Education Foundation (OEF), with relevant modifications made to suit other interested parties (e.g., teacher training programs). This activity will both engage pre-college students in polymer science and extend the Center’s educational outreach to more areas in Ohio and the Great Lakes region.

### Undergraduate Research

The summer REU (Research Experience for Undergraduates) program is a cornerstone of CLiPS’ efforts to introduce CLiPS technologies, polymer science, and more broadly research in STEM disciplines to a diverse group of American students. The REU program enables a group of students to conduct research in an intensive manner for 10 weeks each summer on the Case campus. Students work as members of research active faculty groups, under the mentorship of a PhD student or Research Associate. In addition to daily research activities, REU students also participate in Friday REU group meetings during which they present their results to one another, in addition to receiving lectures on areas of polymer science and engineering ethics. An active calendar of social activities provides for a well-rounded summer. The summer program culminates with the Northeast Ohio Undergraduate Polymer Symposium, which brings together summer students from Case, the University of Akron, Kent State University, and the NASA Glenn Research Center. In Summer, 2007, the Case REU program will host three students from Fisk University, and two students each from Ohio Northern University, Penn State Erie, Rose-Hulman Institute of Technology, and SUNY Fredonia. In this way, CLiPS supports students at the Affiliate institutions and encourages them toward careers in polymer science and engineering.

The broad participation of American undergraduate students in STEM-related research careers is an overarching goal of CLiPS. To that end, research conferences that bring together such undergraduates can be an important venue from which to both advertise CLiPS technologies (increasing the eventual PhD candidate pool) as well as broadly increasing the level of interest and excitement about these career options. Beginning in Fall 2007, CLiPS will host the INSPIRE conference, an annual national conference for undergraduate and high school polymer researchers. CLiPS also supports its undergraduate and high school student researchers who attend other conferences to present their research.

### Pre-College Initiatives

In addition to exposing current college students to polymer science and engineering, CLiPS endeavors to excite and encourage students at a young age to consider such fields. To this end, the partner institutions are developing educational initiatives for pre-college students, especially those in middle school and high school. At Case, relationships have been formed with the Cleveland Municipal School District (CMSD) and local private women’s high schools, allowing pre-college students to participate in CLiPS research under the supervision of a graduate student and part of a layered research team.



**A Polymer Envoy Presents his Research**

The initiative with the CMSD is called the Polymer Envoys Program and it is also one of the Center's two primary diversity initiatives. Case has daily responsibilities for activities within the Polymer Envoys Program, including financial support of the participating students. Initiatives with private women's high schools are coordinated by the high school; Case recruits and hosts the students. One goal of the pre-college initiatives is to encourage the participants to attend college at a CLiPS Institution.

The CMSD has developed parallel activities for students and teachers in the district so that a larger number of students may be positively affected by the CLiPS initiatives. These parallel activities include support for the Polymer Envoys students to present polymer demonstrations in middle school science classes and support for teachers to be involved in the Program. The CMSD central administration has responsibility for identifying the high schools that participate within the center, and for matching Case with teachers and administrators in the high schools for student recruitment and retention purposes. The CMSD works closely with Case to ensure that these efforts stay aligned throughout the duration of the initiatives.

### General Education Outreach

Recognizing the importance of reaching the greater community, the Polymer Envoys Program events are used to share polymer information with the families and friends of the participating students. Each participant is required to bring at least one parent to the Welcome Meeting where the goals of the program are described, and parents are encouraged to attend the poster sessions at which students present their projects. In addition to these formal activities, CLiPS sponsors informal activities that reach out to the community. At The University of Texas, CLiPS sponsors monthly Science Sundays at the Austin Children's Museum. At Case, CLiPS faculty and students run a polymer science room at an annual Martin Luther King, Jr. Day event at the Cleveland Museum of Natural History. Both of these events engage a large group of pre-college students, as well as their parents.

One such event at The University of Texas was called "Happy Polydays!" because it occurred in early December. The three-station activity cluster was designed to familiarize users with properties of polymers and terminology. The activities were staffed by CLiPS faculty (Don Paul), staff (Pam Cook), and graduate students from the chemistry and chemical engineering departments. The learning stations were *Polymer Slime*, *PDMS Imprints*, and *Layered Polymer Clay Ornaments*. The attendees learned what a polymer is and how to describe characteristics of a polymer. They identified common items that are made from polymers and articulated changes they observed in materials.



**"Happy Polydays!" at UTA**

Case also participates in general outreach activities directed toward the campus and local organizations. One example of a recent event is CLiPS participation in the annual Research ShowCASE. CLiPS had a booth at the event that featured a general poster on the Center and examples of the materials produced. Research ShowCASE is open to the entire Case campus and local community, so people who visited the booth expressed interest in both the research and educational activities in the Center. Some local industrial researchers and on-campus research centers expressed interest in developing ways to incorporate CLiPS materials into their projects, and local students and educators discussed ways to introduce CLiPS concepts into their courses and programs. Overall, this event was a wonderful opportunity to raise awareness to the community in general, and make connections that will help to advance the educational and research goals of the Center.

## ***Integration of Diversity into CLiPS Programs, Projects and Activities***

### Diversity Vision and Overall Goal

CLiPS' overall goal for diversity is to become a national resource for broadening participation of women, under-represented minorities, and persons with disabilities in polymer science and engineering and related fields. In order to accomplish this, CLiPS has developed and will continue to develop initiatives that attract, train, and graduate diverse American students into polymer science and engineering, and related fields. The two main diversity initiatives are

- The Case-Fisk Alliance, which involves pre-college students through faculty
- The Polymer Envoys Program, which is geared toward high school and middle school students

The goals and objectives for these initiatives as stated below have not changed since the CLiPS Year 1 SIP.

### Case-Fisk Alliance

The primary goal of the Case-Fisk Alliance is to serve as a compelling national model for fully-integrated, broad interactions between *Minority-Serving Institutions* and *Research Universities* to broaden participation in STEM fields. The Case-Fisk Alliance will be a vehicle for research accomplishments in the area of layered electro-optical systems and diversity in human resource development within the STEM fields. This integration of Fisk as a full research and education partner in CLiPS is the main objective to be accomplished through the Case-Fisk Alliance.

The partnership between Case Western Reserve University and Fisk University encompasses educational initiatives ranging from the faculty level to the high school student level. Some of these activities include joint student and faculty recruitment, internship programs, and new courses. Having this type of partnership between the two universities allows for mentorship of faculty with less research experience and resources by faculty with more experience and resources. Additionally, it exposes graduate student and postdoctoral researchers to research and professional opportunities on each campus. This is a rare complete research and educational partnership between a research university and a minority-serving institution. The CLiPS' goal is to become a model from which other institutions can develop similar partnerships. Within CLiPS, the University of Texas is already working to develop a similar relationship with the University of Texas – Pan American.

Fisk undergraduate students can choose to participate in a new 3/2 binary program offered through the Case-Fisk Alliance. This allows students who begin their undergraduate science coursework at Fisk to easily transfer to Case and obtain a BS in an engineering discipline. Such a program eases the students' transition from high school into an engineering program. Since some students may not want to transfer institutional enrollment, another option offered to students is a semester exchange between Case and Fisk. An exchange allows a student at either school to spend one or two semesters at the other institution in order to take classes and perhaps do research. In this way students can experience life and the academic rigor on the other campus. Fisk students also have the opportunity to participate in summer research at Case through the CLiPS REU program, and three Fisk students will be at Case this summer in the CLiPS REU program. Undergraduate students who participate in these and other Case-Fisk Alliance initiatives are encouraged to apply to Case and/or Fisk for graduate school. Faculty at each institution work to facilitate the admissions process for students who do apply.

High school outreach is an important component of the Case-Fisk Alliance. In CLiPS, the Polymer Envoys Program has been developed to identify talented students in local high schools who can participate in CLiPS research during their junior and senior years of high school. When the Polymer Envoys students prepare their college applications, they are encouraged to apply to Case and Fisk, and are supported through the application process. Scholarship programs specifically for the CLiPS high school

students who attend Case or Fisk are being developed in order to help defray college costs. In Year 1, the Fisk Director of Admissions visited Case to meet with the CLiPS Polymer Envoys students and encourage them to consider Fisk for college. One of these students, a high school junior, has expressed interest in attending Fisk for her undergraduate studies and coming back to Case for her graduate studies. CLiPS will continue to encourage her to pursue that educational plan. Not only would it be an excellent option for her, it would be a great success for the Case-Fisk Alliance.

Fisk faculty participate in CLiPS research programs in Platforms I and III. Fisk researchers regularly participate in Platform III research meetings via teleconference. The collaboration has already produced one co-authored research publication. Faculty, students, and staff at each institution visit the other campus regularly to do research, attend meetings, and present research seminars. Visits between Case and Fisk faculty include:

- Jie Shan (Case) presented a Fisk/Vanderbilt Joint Optics and Condensed-Matter Seminar at Fisk on 7-14-06
- Hazel O'Leary (Fisk President) visited Case and met with CLiPS faculty and staff on 10-13-06
- Weijie Lu (Fisk) presented a seminar at Case on 10-18-06
- Richard Mu (Fisk) presented a seminar at Case on 10-30-06 accompanied by one of his CLiPS students
- Ken Singer (Case) presented a seminar at Fisk on 11-6-06
- LaRuth McAfee (Case) participated in a Case Fair at Fisk on 11-9-06
- LaRuth McAfee (Case) and David Schiraldi (Case) visited Fisk to recruit REU students and graduate students on 11-28-06
- Keith Chandler and Tiffani Southall (Fisk Admissions) visited Case for meetings with Polymer Envoys Students on 12-13-06
- Weijie Lu and Richard Mu (Fisk) together with their students and a postdoc visited Case for research meetings on 1-18-07
- David Schiraldi (Case) presented a seminar at Fisk on 2-28-07
- Weijie Lu, 4 students, and a postdoc attended the CLiPS Annual Meeting at Case on 3-15-07
- Christoph Weder presented a seminar at Fisk on 4-16-07

The Case-Fisk Alliance has had a tremendous impact on increasing diversity within CLiPS. One of the faculty members at Fisk, half of the graduate students, and most of the undergraduate researchers are Black Americans. Four of the six graduate students are women as well. Additionally, Fisk has sent three of its current students to the Case REU program and a Fisk student who recently completed his Masters degree will enroll in the Macromolecular Science and Engineering PhD program at Case this fall. All are African-American and two are women. It is expected that Fisk will continue to play a major role in developing Black American talent for CLiPS programs. The matriculation of a Fisk alumnus into a Case PhD program happened two years earlier than planned. This is a major accomplishment and speaks to the positive relationships formed quickly between the two institutions through CLiPS. Through the Case Fair at Fisk, students have additionally expressed interest in binary and semester exchange programs.

Though the Case-Fisk Alliance, CLiPS has significantly increased the presence of African-Americans on the Case faculty and in the Case undergraduate and graduate programs. For example, in January, 2007, an African-American woman enrolled in the graduate program at Case and is working on a CLiPS project for her PhD thesis. She indicated that the partnership with Fisk was very attractive to her. As part of the university commitment to CLiPS, an African-American woman will join the CLiPS faculty in the Department of Macromolecular Science and Engineering in Summer, 2007. The Case-Fisk Alliance was one of the reasons she was interested in the position. It is anticipated that opportunities afforded by the Case-Fisk Alliance will continue to be a recruiting tool for involving African-Americans the educational programs at Case and at Fisk.

Questionnaires were given to all faculty and students at the CLiPS Annual Meeting in March 2007. The responses by Case and Fisk representatives were the basis for evaluating the progress of the Case-Fisk Alliance in Year 1. Faculty responses were highly positive overall and indicated that progress on the research projects was supported by their collaborations within CLiPS. Student responses on the questionnaire were also quite positive. Some Fisk students commented that they felt they had made contributions to their joint research projects and the interactions have encouraged them to consider careers in polymer science. Since Fisk has not been active in the polymer science field, this career interest is indicative of the impact the Case-Fisk Alliance has had on the students.

### Polymer Envoys Program

The goal of the Polymer Envoys Program is to create opportunities for underrepresented students in STEM fields. The pilot program was established between Case and the Cleveland Municipal School District (CMSD). The intent is to translate the model to the CLiPS partners and, after assessment, to the nation. Translation to the partner institutions is well ahead of schedule. The University of Texas initiated a Polymer Envoys Program in Winter 2007 with students from the Austin Independent School District. A Polymer Envoys Program at Fisk University is now planned for Year 2. According to the timeline in the SIP, the program at UTA was to start in Fall, 2008 and the program at Fisk was to start in Fall 2009. In addition, one of the Affiliates, Rochester Institute of Technology, is also set to begin a Polymer Envoys Program in Year 2. The initial objective of the program is to create an innovative high school outreach program that will provide a research experience for students from underrepresented groups. High school participants are part of layered research teams with CLiPS graduate students and undergraduate students. Therefore, the limiting factor in the size of the program is the number of CLiPS-related graduate students.

The creation of the Polymer Envoys Program involved Case faculty and staff working with the Math and Science Program Officers at the CMSD. It uses a model that was developed with local private women's high schools, which also participate within CLiPS. While the Case representatives ultimately select the students, CMSD teachers and counselors are heavily involved in the student recruitment process. Due to their highly positive experiences in the program, current participants have also been excellent recruiters of their peers. CMSD program officers assist with reading applications and interviewing the applicants, making this a wonderful partnership between Case and the CMSD. Six students were chosen for the initial class, three of whom will continue in Year 2. Six additional students were selected in February 2007, who will begin their lab research experience in Summer 2007 or Fall 2007.

During the academic year, meetings were held monthly with the Polymer Envoys students in order to allow the students to interact and the coordinators to know how well the students are progressing. Meetings generally feature a technical discussion and a professional development component. During the summer, when students are in the lab full-time for six weeks, meetings are held weekly with the students and the mentors so that any issues will be caught quickly. The activities during meetings in the summer session also focus on the college application process since most of the students will be rising seniors who are preparing for the college application process. Outings to local polymer companies are also being planned to show the students the industrial opportunities for polymer scientists and engineers.

In addition to regular meetings, Polymer Envoys students are expected to participate in at least two poster sessions each year. Starting in May 2007 the Spring poster session is combined with the Welcome Meeting for incoming students, giving incoming students and their families the opportunity to learn from participants. In addition to presenting to their peers, participating students develop polymer demonstrations that will be shown to middle school or younger high school students. These presentations are not only a recruiting tool for the Polymer Envoys Program, but will also get younger students excited about polymer science and engineering concepts and opportunities.

Case selects approximately six new Polymer Envoys students each year. In Years 1 and 2, all Polymer Envoys students at Case are African-Americans and nine of the 12 students are women. In January 2007, The University of Texas at Austin launched a Polymer Envoys Program with the Austin Independent

School District that has four participants. This program has a large Hispanic student population, owing to the population of the AISD. Additionally, Fisk University and Rochester Institute of Technology will begin programs with their local high schools during Year 2 of CLiPS. Due to the student ethnic distributions in the local schools, the Polymer Envoys Program has had and is expected to continue to have a significant impact on increasing diversity within CLiPS. Activities and best practices are being shared among CLiPS partners so that all institutions can learn from each other and improve continuously.

In addition to quantitative enrollment numbers, various instruments are used to evaluate the program. The following results are taken from responses in Fall 2006 from Case participants:

- The students completed an initial questionnaire in September 2006 to give the program coordinators a better understanding of the students' current experiences with research and related techniques/software, as well as their attitudes toward math and science. In these questionnaires, the students expressed little or no experience in research or technical communication. The responses were expected considering the lack of laboratory facilities in the two high schools that the students attend.
- The questionnaire also asked questions about the students' academic interests and aspirations. Students stated that they enjoy math and science, and they want to and can see themselves as engineers or scientists someday. This interest in math and science is something CLiPS wants to track in order to determine how the program excites students academically. When asked about their college or work aspirations, students listed opportunities such as science, engineering, business, and law. Finally, students' reasons for being in the program included helping to decide whether to be a scientist or engineer, gain more experience and knowledge, better understand polymers, network, jump start college work, and increase personal enjoyment.
- At the end of the semester the students completed another questionnaire allowing the coordinators to determine what worked over the semester and what needed to be modified to improve the program. On this questionnaire, most students stated that they gained experience in analyzing data and in technical communication. When asked about their future aspirations, all students indicated that they wanted to pursue doctorates. This was a very positive outcome which showed that the program has had a positive impact on the students and perhaps helped them consider opportunities they thought previously unattainable.
- The graduate student mentors also filled out end-of-semester questionnaires about their experiences with the Polymer Envoys Program. One positive response was that all felt that they made a positive difference in their high school student's life. However, some felt that their involvement took too much time away from their own research and studies. This was partially because the high school students' lack of lab experience sometimes slowed the project and caused the mentor to spend more time than expected with the high school student. Some mentors indicated that they wanted more guidance on what was expected of them. One outcome is that a mentorship seminar series will begin in Summer, 2007.
- In the future, follow-up surveys and interviews will be used to determine the long-term personal, academic, and professional impacts of the students' involvement in the Polymer Envoys Program.

Although the student involvement in the program officially lasts two years, the relationships developed are intended to lead to long-term interactions. Students who attend CLiPS Institutions will be mentored, supported, and invited to the Center's programs with the goal of increased retention of these students. Scholarship initiatives are being pursued in order to obtain financial assistance for Polymer Envoys alumni who attend CLiPS Institutions. One of the current Polymer Envoys students has already expressed interest in attending Fisk for undergraduate studies and pursuing her graduate degree at Case. Two of the four students in the program at The University of Texas at Austin have been accepted into

their undergraduate program, and the CLiPS faculty and staff are working to encourage the students to accept their offers.

### ***Partnerships and Knowledge Transfer***

#### Knowledge Transfer Vision and Goals

The goal set forth for the Center regarding knowledge transfer is to be a unique global resource for the dissemination of knowledge in the area of layered polymeric systems. The goals are further defined as implementing a high-tech communications infrastructure within the Center that will:

- Facilitate research, education and knowledge transfer within the Center
- Outreach to the community, the nation and the world

To realize these goals, CLiPS will:

- Design and maintain a website to disseminate information within and beyond the Center
- Create and translate courses in polymer science for Fisk and Affiliates with media courseware
- Organize meetings to review Center activities with faculty, students, the CLiPS External Advisory Board and CLiPS Investors
- Utilize more traditional methods of knowledge transfer including presentations at conferences, workshops and publications.

#### CLiPS Web Site

The Center's web site was created with the assistance of a professional web designer and is published at <http://clips.case.edu/>. Responsibility for maintenance of the web site is about ready for transfer to the CLiPS faculty and staff. The web site will serve as a source for interested students and members of the public to learn more about CLiPS, including its opportunities and activities. It will also serve as a portal for Center participants to access and share information. Continuous updating will track the development and evolution of the Center's activities in research, education and diversity, including the activities of the partner and affiliate institutions.

#### Course and Curriculum Development

The foundation and modular courses developed as part of the new graduate curriculum in polymer science and engineering will be available to the partners and Affiliates in their entirety, in part, or as modified. It became apparent that there was a wide range in the existing course and program offerings of the partners and Affiliates, from fully realized undergraduate polymer courses to essentially no course content in polymers. At this time, syllabi for the foundation courses are available. It is anticipated that in the next year, the partners and Affiliates will distill their specific needs in this area. At that time, the appropriate method for translation will be identified and implemented. The possibilities include streaming video, multi-point video conferencing, technology-enhanced classrooms, and digital television. Modular courses could be disseminated to the partner institutions and Affiliates as "e-books" on streaming video.

The more traditional methods of distance communication are used extensively in the day-to-day communication within CLiPS. Frequent meetings of the Executive Committee were clearly indicated in order to make rapid progress during the startup phase. The weekly meetings are attended regularly by faculty and staff at the partner institutions via teleconference. It also became apparent early in the startup period that the highly interactive research projects required regular meetings for planning and discussion of technical matters. The flexibility of web-based meetings has facilitated inclusion of faculty and students at the partner institutions in Platform meetings.

#### Review of CLiPS Activities

Meetings to review CLiPS activities with the various constituencies took place in accordance with the proposed timetable. The Annual Meeting of the entire center, which was held at Case on March 14 and

15, 2007, covered both review and planning aspects of the center. The CLiPS Investors, which is a group of representatives from companies that sponsor a CLiPS graduate fellowship, met in conjunction with the Annual Meeting. The External Advisory Board held its first meeting on April 11, 2007. Input from these groups guides the planning process and sustains the momentum of the center.

### Broader Dissemination

The activities of CLiPS have been disseminated to the public in articles in the local newspaper and feature articles in university publications. Technical contributions from CLiPS research have been disseminated through the established mechanisms, including numerous invited seminars, abstracts and publications. The center strives to maintain a high quality of research as evidence by publication in prestigious peer-reviewed publications. The accomplishments of the CLiPS researchers are recognized through awards and invited seminars. CLiPS researchers have developed international collaborations with scientists in Spain and France.

### *Value-Added of CLiPS*

A very exciting new field of interdisciplinary macromolecular science and engineering has rapidly emerged over the past ten years at the crossroads of polymer science, materials science, engineering disciplines, chemistry, physics and biology. This field of “polymers plus” enjoins inspiration from nature, innovative processing of microlayer and nanolayer polymeric assemblies (forced assembly), and revolutionary new synthetic polymers with greater control of macromolecular and supermolecular architecture (self assembly). A critical need exists for innovative microprocessing and nanoprocessing technologies to achieve the envisioned materials systems.

The potential application and economical impact of hierarchically organized polymer and hybrid polymer/inorganic layered systems with length scales ranging from a few nanometers to many microns are extremely broad and encompass diverse areas such as healthcare, energy, defense and environment. To exploit microlayering and nanolayering for commercial applications, important fundamental issues will be addressed in Platform I. Novel and technologically relevant applications, such as membranes and optic/electronic systems, are addressed in Platforms II and III. The fundamental problems and applications are extremely complex, and require participation of outstanding researchers and educators in many disciplines, including polymers, optics, electronics, material science, and transport. To meet this challenge, CLiPS has assembled a multidisciplinary, multi-institutional team of investigators. The knowledge transfer program provides a vehicle for intellectual exchange with the public and the links to industry will allow for significant technology impact, fostering science and technology in service to society.

Research and education aspects are integrated to create a special environment for discovery, learning and innovation by students, faculty and associated researchers. Emphasis is placed on teamwork, communication and engagement of students at all levels in research and education activities to make CLiPS a unique place for training well-qualified academic and industrial workforce. Enhanced diversity and engagement of underrepresented groups is considered a critical component of well-balanced programs and workplaces. CLiPS aims to capture the features of modern US society with an emphasis on teamwork, communication, and workforce diversity, in addition to excellence in research and education.

#### **CLiPS Removes Boundaries**

- Students: high school/undergraduate/graduate
- Faculty: secondary/college/university
- Educational Institutions: non-PhD-granting schools/HBCUs/research universities
- Focus Activities: science/technology/application

**Not Possible with a Single Investigator/Institution**