Center for Affordable Nanoengineering of Polymeric Biomedical Devices

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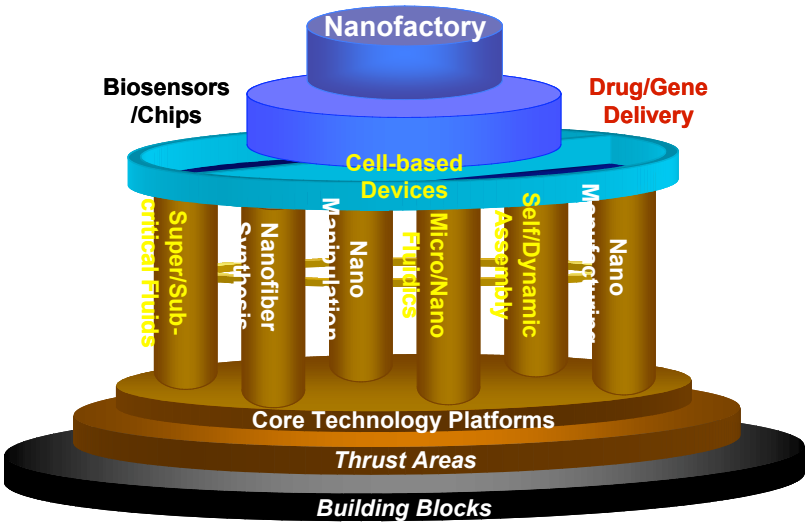
The **primary goal** of the Center for Affordable Nanoengineering of Polymeric Biomedical Devices (CANPBD) is to develop **polymer-based, low-cost nanoengineering technology**. This technology is then used to produce nanofluidic devices and multifunctional polymer-nanoparticle-biomolecule nanostructures **for next-generation medical diagnostic and therapeutic applications**. The center is organized into six Core Technology Platforms that provide fundamental understanding and essential nanotechnology techniques towards developing certain types of biomedical devices through a series of interconnected testbeds, depicted in the following figure.



Polymer nanoengineering and nanofluidics are two important areas in nano-technology that have not yet been explored in great depth. Despite many individual research efforts and those of several biotechnology centers, a focused effort is lacking to address the impact these two nanotechnologies can bring to society, particularly in the biomedical field. Our center seeks to develop polymer-based, low-cost nanoengineering technologies that, when combined with relevant nanofluidic designs and biological functionalization, can lead to many near-term applications such as micro/nanofluidics-based bio sensors/chips, advanced drug delivery devices, and 3D cell/scaffold structures for tissue engineering, and eventually the long-term goal, a nanofactory. The nanofactory will link various nanofluidic designs to form an assembly line to manipulate and move molecules and/or nanoparticles along a pre-specified 'assembly line' in well-defined patterns with controlled velocity and displacement. Externally tunable surface forces at the nanoscale will be used to overcome the Brownian motion and relaxation forces of biomolecules, polymers, and nanoparticles, so that they can be caged in the fluid or at the solid surface with the desired shape and orientation. Together with covalent chemistry and biological complexation, this nanofluidic assembly line will allow continuous production of well-defined, multi-functional 3D biomimetic nanostructures through polymer-biomolecule and polymer-nanoparticle-biomolecule conjugation. These structures may greatly enhance the clinical realization of new drugs and genes discovered by extensive genomics and proteomics research for the treatment of cancer, infectious and parasitological disease, chronic illness, and genetic disorders.

In the past year, Center researchers at The Ohio State University (OSU) and 8 collaborating universities have made significant progress in research. CANPBD published 73 technical papers, and submitted 12 invention disclosures and 9 patent applications. Our research program and industrial collaboration were strongly enhanced by recently winning a $22.5M capital investment funding from Ohio Department of Development. More than $7M state-of-the-art new equipment items in nanomachining, nanoscale polymer processing, nanobio characterization and manipulation, and micro/nanofluidic analysis are being purchased and installed in a centralized location at OSU Nanotech West. A "supply chain" linking CANPBD with nearby national laboratories, major centers at OSU such as the Columbus Cancer Center and OSU's Heart and Lung Research Institute, and Ohio biotech industry has been established. Results from several of our near-term testbeds such as Magnetic Cell Separation, CD-ELISA, and Biodegradable Drug Delivery Devices have gained strong interest from industry. Commercialization of these devices is being explored through collaboration with industry and the Center for Entrepreneurship at OSU's Fisher College of Business. To address the impact of new nanomaterials and nanoscale devices on environment and public health, CANPBD is working closely with the National Institutes for Occupational Safety and Health (NIOSH) through joint research projects, invited lectures, and student internships.

Examples of major, recent research accomplishments are summarized here. For ***nanomanufacturing***, a proximal probe system combined with femtosecond laser demonstrated 85nm width channel fabrication on 200nm conductive transparent material. The experiment was also done on gold film with 200nm to 300nm resolution. A nanoscale precision piezoelectric motion system was combined with the femtosecond laser system to demonstrate the integration of precision motion system control and the laser ablation technique. For ***self/dynamic assembly***, the concept of dynamic assembly in micro/nanoscale features (e.g. long channels) using external forces (e.g. electrokinetic mobility) has been demonstrated. We also found that the size, shape (e.g. nanofibers, nanoparticles), and orientation of nanostructures formed in the self-assembly process can be controlled by the material composition and processing conditions. We were able to synthesize thin films, nanoparticles and nanofibers using conductive polymers, carbons, and silica precursors. For ***micro/nanofluidics***, our researchers have established both hydrodynamic and electrokinetic micro/nanofluidic systems allowing direct and indirect measurements of velocity profiles, wall slip, and particle/molecule movement and deformation in both Newtonian and non-Newtonian fluids. This experimental effort is supported by a strong modeling team. We have developed a model for molecular interactions near solid walls using molecular dynamics simulations. This study is complementary to our continuum calculations. We have also developed several coarse-grain molecular modeling techniques to simulate DNA stretching and alignment in micro/nanofluidics. For ***nanomanipulation***, we are developing optical, magnetic, electric, and hydrodynamic methods to manipulate either single or a large number of biomolecules and nanoparticles. We have designed and fabricated a high precision motion control stage for automation and advanced control of AFM imaging, and optical trapping of particles and cells. Using dielectrophoresis or a modified molecular combing technique, our researchers are able to stretch and align a large number of DNA molecules into well-ordered nanowires. For ***nanofiber synthesis***, extensive collaboration took place between UA and OSU in the areas of electrospinning and nanochannel generation. The production of electrospun polycaprolactone, polyethylene terephthalate, acrylic terpolymer and collagen scaffolds for tissue engineering studies has been achieved. Aligned polyaniline nanofibers were successfully grown onto many types of substrates. The surfaces coated by aligned polyaniline nanofibers show the

property of superhydrophilicity with water contact angle less than 5 degrees. However, after exposure to CF_4 plasma, these same surfaces exhibit a dramatic change to superhydrophobicity and water contact angles higher than 175°. For ***supercritical/subcritical fluids***, our team has explored the feasibility of using supercritical and subcritical CO_2 to enhance polymer molding, fusion and surface impregnation at the nanoscale. We found that low molecular weight proteins and chemicals can be delivered into the polymer surface by supercritical CO_2 to modify the surface properties. At very low CO_2 pressure (e.g. less than 200 psi) and temperature (e.g. below body temperature), polymer micro- and nano-structures can be bonded together with a very high weld factor (i.e. bond strength near the bulk material) and excellent dimension integrity. This may lead to biologically benign assembly of biochips and tissue engineering scaffolds in the presence of sensitive biomolecules and even living cells. Biologically benign molding of polymeric materials at the micro- and nanoscale was also successfully demonstrated.

Many materials and techniques developed in the six core technology platforms have been successfully applied to center's near-term and long-term testbeds. For ***biosensors/chips***, we have developed CD-ELISA, nanowire, and magnetic cell separation devices. The CD-ELISA project received $1M and the magnetic cell separation project will receive more than $4M from the Ohio Department of Development for product development and magnetic cell separation. For ***nanofluidic drug/gene delivery***, our researchers have developed a series of passive and active delivery devices based on nanoscale diffusion/flow channels, pores and nozzles. One example is a cell patch by integrating nanoporous membrane with an electrokinetic microfluidic platform. We have accomplished tests with Dextran (as model drugs), small genes (GFP and SeAP). Our preliminary results demonstrated that all of these three materials can be delivered into NIH 3T3 fibroblast cells with efficiency much better than the existing electroporation method. Development of a molecular assembly line, i.e. ***Nanofactory*** for the synthesis of multifunctional nanomaterials and devices is our long-term goal. In the last reporting period, we have designed and fabricated a microfluidic system for dynamic assembly of nanoparticles. An electrospraying device for production of nanoparticles has also been built and tested. A technique for micropatterning stretched DNA was developed. Cationic polymers with different charges and quantum-dot-conjugated plasmid DNA have been prepared as raw materials for subsequent production of nanoparticles. Sorting of nanoparticles has also been developed. These components are essential for the assembly of a nanofactory.

We have also made good progress in teaching, training, outreach and diversity in the past year. CANPBD has developed four new courses, continued to offer three courses previously developed, added nanotechnology related material to six existing courses, and contributed to one on-line course. Through these course developments, the core of an undergraduate minor and graduate certificate in nanobiotechnology is being organized. The graduate fellows of CANPBD collaborate through research group activities as well as a student organization (CONGS) to better integrate the student researchers and provide a social fabric for the center. Outreach to K-12 students and teachers reached over 150 students in the past year through visits to center laboratories and mentoring of science fair students. Outreach activities were reviewed by an outside evaluator to assess effectiveness and provide input for further improvement. In diversity, we reported significant improvements in the number of female faculty and students participants in the past year.

References

[1] For further information about this project link to **<http://www.nsec.ohio-state.edu>** or email **stevenson.2@osu.edu.**