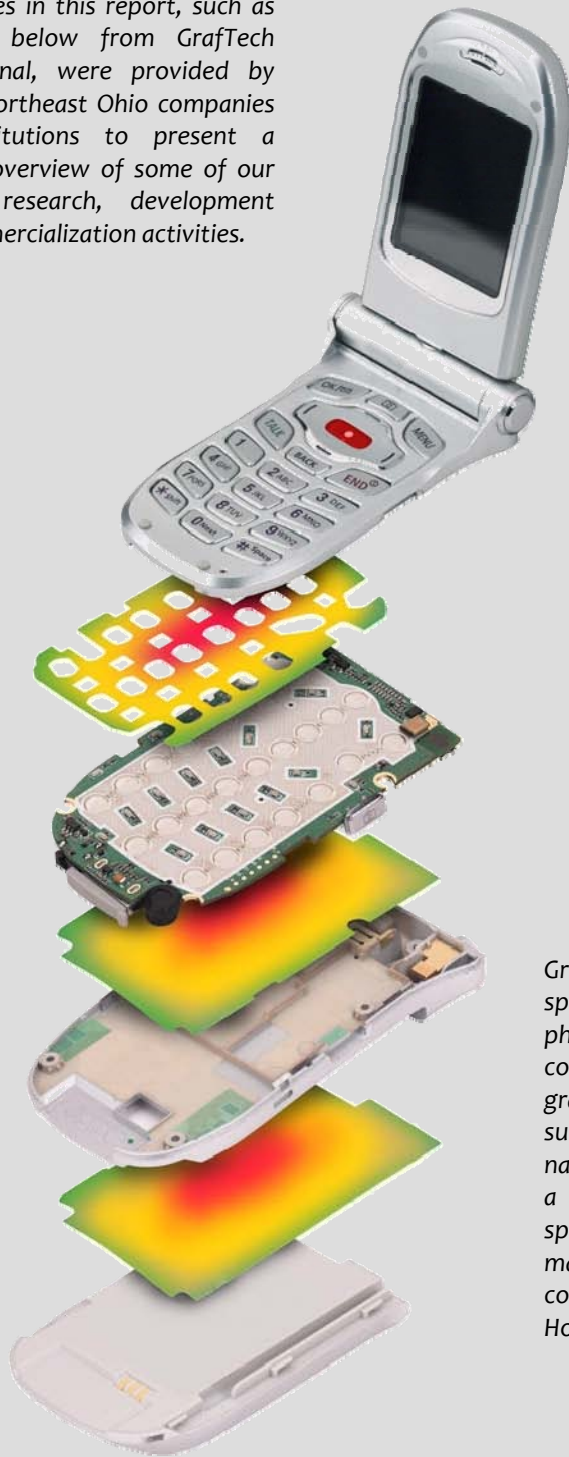


A grayscale microscopic image showing a dense field of biological cells, likely yeast or bacteria, with various shapes and internal structures. The cells are distributed across the entire frame, creating a complex, textured background.

The Northeast Ohio Nanotechnology Report
prepared by NorTech and the Nano-Network

January 2008

The images in this report, such as the one below from GrafTech International, were provided by various Northeast Ohio companies and institutions to present a pictorial overview of some of our region's research, development and commercialization activities.



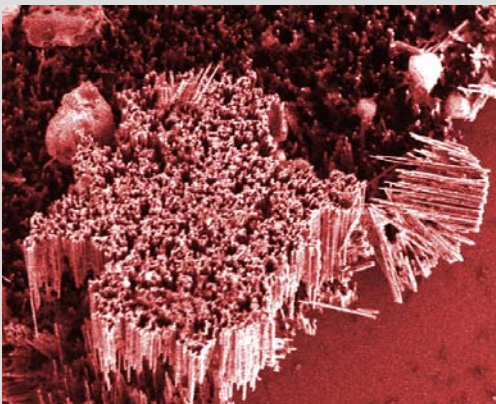
GrafTech's SpreaderShield™ heat spreaders are illustrated here in a cell phone application using a multi-colored reconstruction of the thermal gradients on the heat spreaders' surfaces (red = hot). Novel nanomaterials are being developed by a group of collaborators in Ohio specifically for this type of thermal management application. Picture courtesy of GrafTech International Holdings, Inc., Parma, OH.



The Northeast Ohio Nanotechnology Report

Northeast Ohio is a leader in nanotechnology innovation in the Midwest. The region has a number of strengths including a solid nanotech research base, enthusiastic nano focused start-ups, existing mature companies involved in nanotech R&D, a wide variety of industries that can benefit from nanotechnology, and, of course, the Nano-Network, helping to connect our region's nanotechnology assets. However, there are also a number of significant challenges facing Northeast Ohio. The nanotech research environment is fiercely competitive, regional collaboration on nanoscience/technology within the State could be stronger, academic-industrial partnerships in the nano arena are limited, the region's biggest nanotech strength is not in an area that attracts much venture capital attention, and many major industrial players are apparently not yet heavily invested in nanotech. If nanotechnology is a critical enabler of technological innovation, then Northeast Ohio must further leverage its strengths and face many of its challenges to ensure a vibrant technology landscape of the future.

This report presents an overview of the nanotechnology landscape in Northeast Ohio and Ohio based on a study conducted by the NanoBusiness Alliance. The report also discusses steps to consider in order to cultivate an ecosystem that fosters nanotechnology-enabled innovation. In particular, the study concluded that a priority of the Nano-Network, Northeast Ohio and Ohio should be consideration of a statewide nanotechnology initiative. In addition, the Nano-Network must continue to involve the region in a nanotech focused dialogue to stimulate collaborations and partnerships that engages our top researchers in commercially focused R&D, includes a cross-section of industrial sectors (e.g. materials and healthcare), and brings together our large corporations with our small to mid-size nanotech companies. Finally, the Nano-Network must work to increase the visibility of our nanotechnology landscape, thereby attracting more investment, talent and technologies to our region and our State.



Bismuth nanowires synthesized at Case Western Reserve University are being explored as novel materials for efficient and inexpensive energy conversion devices. Image courtesy of A. R. Abramson, Case Western Reserve University.

Front/back cover: The nanostructure of a multi-component polymer surface coating as revealed by atomic-force microscopy. Image courtesy of PolyInsight, Akron, OH.



What is Nanotechnology?

Nanotechnology involves the manipulation of materials which have a characteristic length scale between approximately 1 and 500 nanometers (1 nanometer = 1 billionth of a meter) to achieve a capability or function that could not otherwise be realized if this nanoscale feature were not present. The category of “nanostructures” might then include an ultra-thin film coating that repels water, or a composite embedded with carbon nanotubes that is stronger and lighter-weight, or a quantum dot nanoparticle that fluoresces various colors depending on its size. As a result, nanotechnology is enabling innovation in a wide range of applications such as cosmetics, automobiles, solar cells, sporting goods, cancer treatment, building materials, computers, environmental clean-up and much, much more. The National Science Foundation has forecasted that nanotechnology goods and services are expected to be a \$1.1 trillion industry by the years 2010 – 2015 (that is approximately 10% of the total US economy and 7 million jobs). Additionally, venture capital investments in nanotechnology focused companies have quadrupled since the year 2000. Believing in its promise, President Clinton in 2000 announced the inception of the National Nanotechnology Initiative, devoting \$500 million to funding nanotech research. In 2008, that investment is slated to have reached \$1.5 billion.

Who is the Nano-Network?

The Nano-Network was formed in 2003 as a result of a grassroots effort to bring together those from Northeast Ohio with an interest in nanoscience and nanotechnology. Since then the organization has matured in size and scope, and has grown to become an initiative of NorTech, Northeast Ohio’s technology-based economic development organization. Membership to the Nano-Network is free, and to date, we boast a directory of approximately 600 people from academia, the venture capital arena, government, industry, the non-profit sector, business services and beyond. Since 2003, the Nano-Network has:

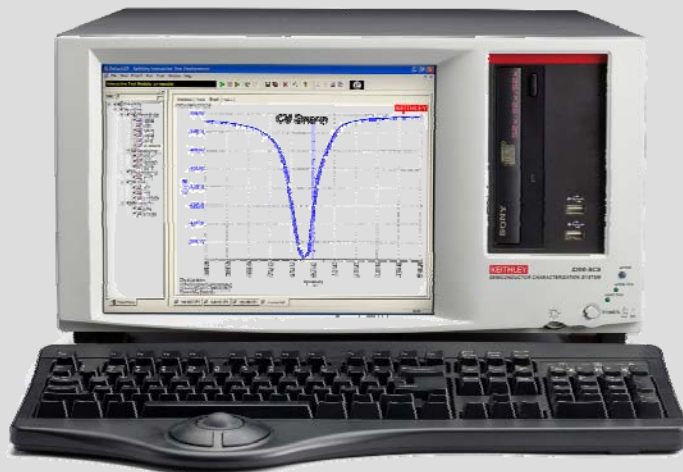
- Organized a speaker series with a focus on networking, bringing major national nanotechnology players to our region.
- Coordinated “Nano Week” consecutively each year since 2004.
- Hosted the Nano App Summit, a national conference held in Cleveland with a focus on nanotech applications (2005 and 2007).
- Hosted the Nanomedicine Summit, a national conference held in Cleveland with a focus on how medicine is being influenced by nanotechnology (2004 and 2006).
- Managed the Nanotechnology Business Idea Competition (2004 and 2005).
- Coordinated the Nanomanufacturer’s Forum, a regional conference providing traditional manufacturers with solutions for tomorrow (2005, 2006 and 2007).
- Presented “Nano 101,” an educational lecture that explains the basics about nanoscience/technology, to the Northeast Ohio business community and the public.



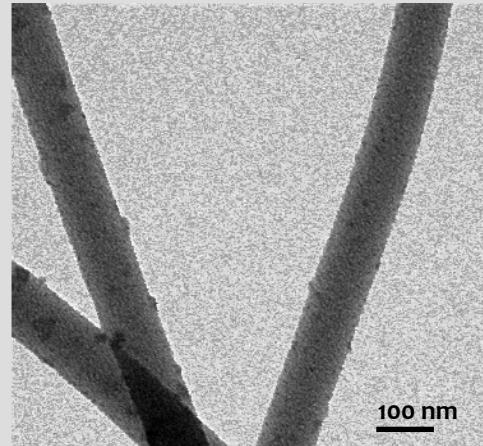
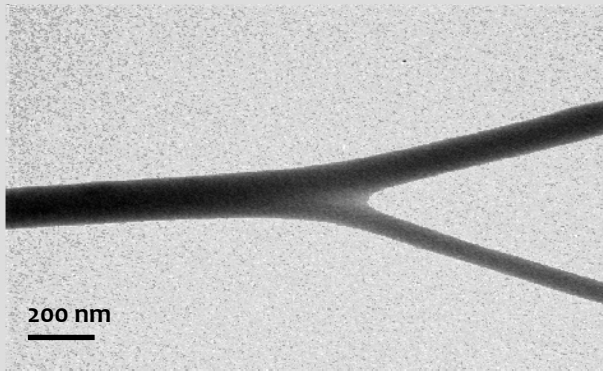
The Northeast Ohio Nanotechnology Report (2008)

- Put together “The nanoPages,” an online directory of nanotech companies, institutions and centers in Northeast Ohio, to enhance our visibility and credibility, stimulate new collaborations and partnerships and bring new customers to our region (currently under development).
- Launched “Nanovate,” a unique program in which companies receive subsidized technical consulting to help them evaluate how nanotechnology can stimulate innovation in their products and processes (2006 – present).
- Contributed to government-industry workshops connecting representatives from regional, state and local nano-focused initiatives across the country.
- Participated in “public policy tours” in Washington D.C. to help our government officials understand the importance of nanotechnology.
- Coordinated strategic meetings of start-up companies in Northeast Ohio with venture capitalists.
- Entered into a partnership with the Nano-Network of New Mexico, who began using the name in 2005 with our permission.

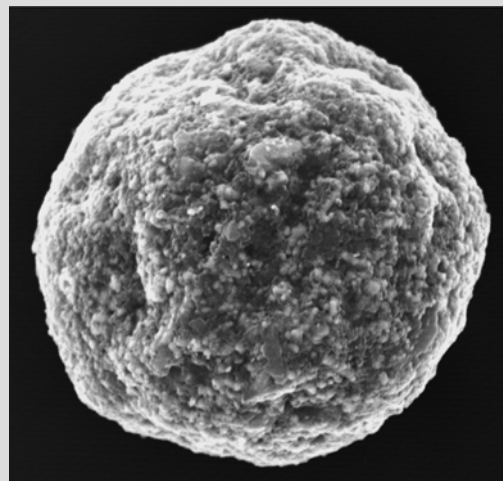
The Nano-Network’s activities have led to fruitful collaboration among companies and researchers in Northeast Ohio, and in a recent survey of our members, nearly 50% said that a Nano-Network event has led to a collaboration or partnership that they otherwise would not have had. Moreover, the organization has helped increase the visibility and credibility of our region and provided education about state-of-the-art developments in the nano world to our own community and beyond.



Originally developed for the semiconductor industry, the Keithley Model 4200 Semiconductor Characterization System was discovered by nanotechnology researchers for its effectiveness in developing and studying nanoscale materials and devices. Today, this powerful characterization system is the industry-standard tool used in nanotechnology labs around the world. Image courtesy of Keithley Instruments, Solon, OH.



MemPro Ceramics Corporation synthesizes ceramic nanofibers, like the ones shown above, for specialized filtration applications. Generally the fibers are continuous strands (right), but the fiber on the left split into two directions – an unexpected “four-leaf-clover” discovery! Images courtesy of MemPro Ceramics Corporation, Akron, OH.



The PComP nanocomposite thermal spray powder (a single particle is shown above) made by Powdermet Inc. combines the hardness of a lightweight ceramic with the ductility and toughness of metal. These materials offer higher performance at lower cost with a reduced environmental footprint. Image courtesy of Powdermet Inc., Euclid, OH.

Our Nanotechnology Landscape

For three years, *Small Times*, the premier publication on micro/nanotechnology has ranked the state of Ohio 10th in the nation in micro/nano-activity (see Figure 1), which constitutes an analysis of our research, patent filings, company activity, workforce, venture capital dollars, and more. This “top ten” ranking demonstrates that Ohio is currently well positioned to be a leader in nanotechnology research, development, commercialization and entrepreneurship, but maintaining this ranking in the future (or reaching an even higher position) will likely require the State to focus more effort on strengthening its own nanotechnology landscape. To better understand our current status, we investigated our position relative to other peer states and regions in four key areas: nanoscience/technology research, nano-related patents, the number of small to mid-size companies focused on nanotechnology and large corporate nanotech activity and patenting.

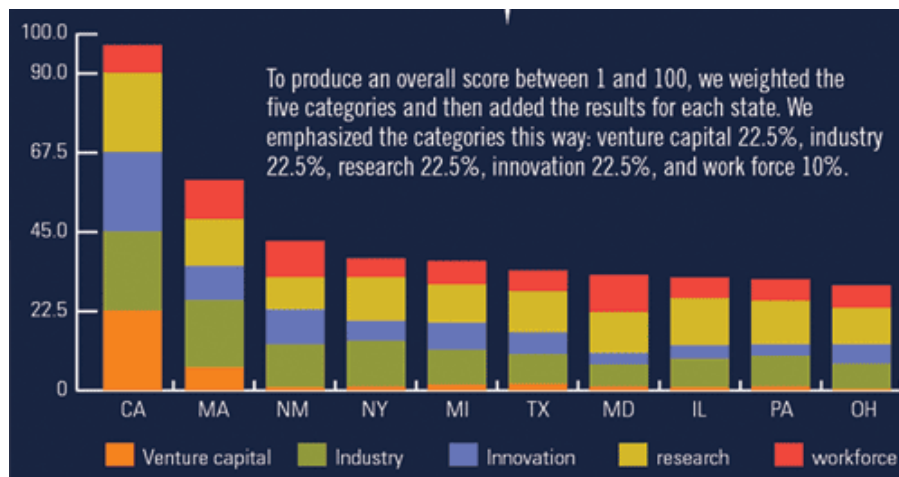


Figure 1. Overall state rankings for micro/nanotechnology. Reprinted with permission from *Small Times*, July 2007 issue (© 2007).

Research

Research funding is the basic investment for the development of all nanotechnologies. Ohio receives one of the highest allotments of federal R&D dollars in the Midwest and the nation and was ranked 8th in the country for federal R&D funding in 2003 - 2004. Nanoscience/technology research activity within Ohio and Northeast Ohio has been funded, in large part, by the numerous nanoscience/nanotechnology grants that have been received by our researchers and small businesses, including a myriad of federal projects as well as various State funded Third Frontier awards. For example, nearly sixty million of Ohio’s Third Frontier dollars have been invested in commercialization focused nano research activities to date. This does not include the many Third Frontier grants that do not have a specific



emphasis on nanoscience/technology even though they may incorporate aspects of nano within them. Additionally since 1995, the National Science Foundation alone has awarded over \$100 million to Ohio institutions for nano-related research. This does not include all of the funds granted by agencies such as the National Institutes of Health, the Department of Defense or the Department of Energy.

One would expect that a healthy nanotech research funding portfolio would lead to an active publication record, and from Figure 2 it is evident that Ohio and Northeast Ohio do exhibit “satisfactory” ratings for their nanotech research based on numbers of articles published from 2002 - 2007. Though Ohio falls behind Illinois and Pennsylvania and Northeast Ohio lags Pittsburgh, Detroit/Ann Arbor and greater Chicago, the differences are relatively small. The study conducted for this work also demonstrated that the greater Columbus, Dayton and Cincinnati areas are also publishing ample nanotech-focused articles though Northeast Ohio leads in terms of raw numbers of nanotech publications. Interestingly, in an Ohio regional comparison of the number of nanotech publications *as a percentage of overall publications*, smaller regions such as the Dayton area and Southeast Ohio lead the pack, indicating a concentration on nanotech research and development in these parts of the State. In Northeast Ohio, about 16% of all publications from the University of Akron were nano-related, followed by NASA at ~8%, Kent State University at ~5%, Case Western Reserve University at ~3% and the Cleveland Clinic at ~1%.

Academic Patents

While fundamental research is necessary for commercialization, it is not sufficient. Patents are required to create companies with defensible IP portfolios and distinctive capabilities, and therefore for this report we collected data on the number of nano-related patents applied for by academic institutions from 2002 – 2007. For this part of the analysis, we were primarily interested in examining how well the universities transfer their high quality nano research into patents, particularly as compared to other Midwest/neighboring states and regions. Figure 3 illustrates this nano tech transfer “efficiency” as the number of nanotech patents coming from the universities as a percentage of their overall nanotech publications. While Ohio’s research publication numbers are fewer than but close to those of PA and IL (Figure 2), our number of nano patents does not similarly correlate, and MI jumps ahead of OH on the chart. Similarly, there is a much larger difference between Northeast Ohio and the comparative regions in terms of nano tech transfer efficiency than there is with regard to sheer number of publications. However, the study did show that the Central Ohio region boasts a nano tech transfer efficiency comparable to greater Chicago, far surpassing Northeast Ohio’s ranking. In general, Ohio and Northeast Ohio’s academic nano tech transfer efficiencies could be better.

“Satisfactory” rating for nanotech research earned by Ohio and Northeast Ohio.

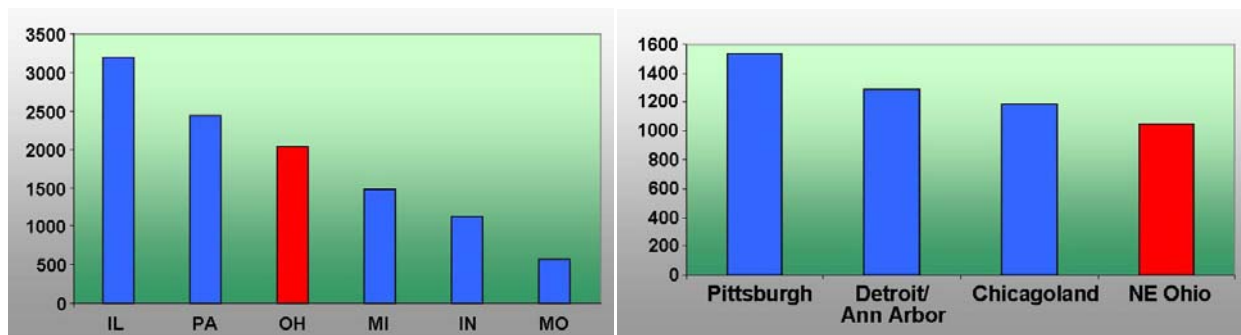


Figure 2. Number of nanotech publications by academic and research institutions in designated states and regions, 2002 – 2007.

Ohio and Northeast Ohio universities founder in nano tech transfer “efficiency.”

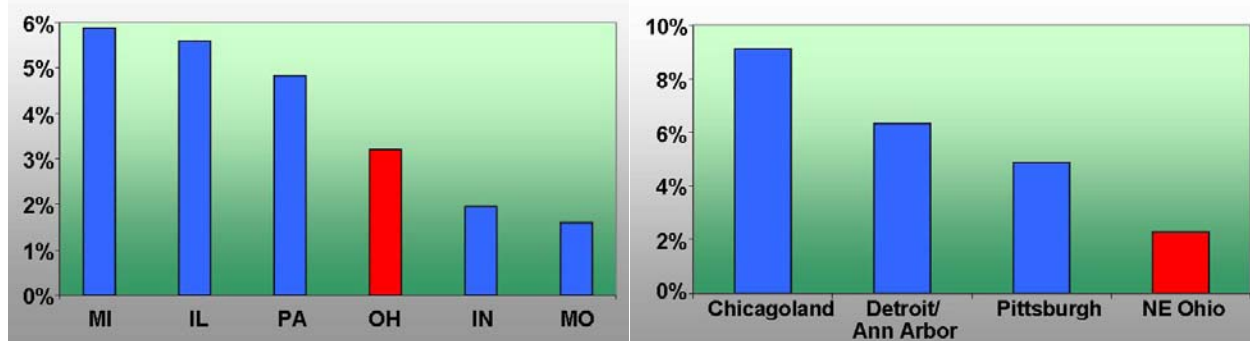


Figure 3. Number of nanotech patents applied for by academic institutions as a percentage of overall nanotech publications from those institutions in designated states and regions, 2002 – 2007.

Small to Mid-Size Nanotechnology Companies

Nanotechnology-focused businesses around the globe are typically small to mid-size companies and are commonly categorized as “start-up,” “early-stage” or “expansion-stage.” These types of companies drive entrepreneurship activity and innovation and set the stage for future technology-based economies, and therefore their presence (or lack thereof) is a critical measure of technological growth potential of a region. Moreover, as demonstrated by a recent Nano-Network survey, the expansion-stage companies are also most likely to collaborate with other companies (small to large) as well as the academic and research institutions. Therefore, the strength of these small to mid-size companies within the nanotechnology landscape is an important component to measure. Figure 4 compares the total number of nanotech-focused small to mid-size companies by state as well as by region with a further categorization by stage (i.e. expansion, early, start-up). From this plot, we see that the number of small to mid-sized nanotech-focused companies in Ohio is greater than in Michigan or Illinois. Additionally, Ohio’s top two nano active regions, Northeast and Central Ohio (inclusive of the Dayton area) are faring quite well in comparison to greater

Ohio and Northeast Ohio are populated by small to medium-size nanotech-focused companies.

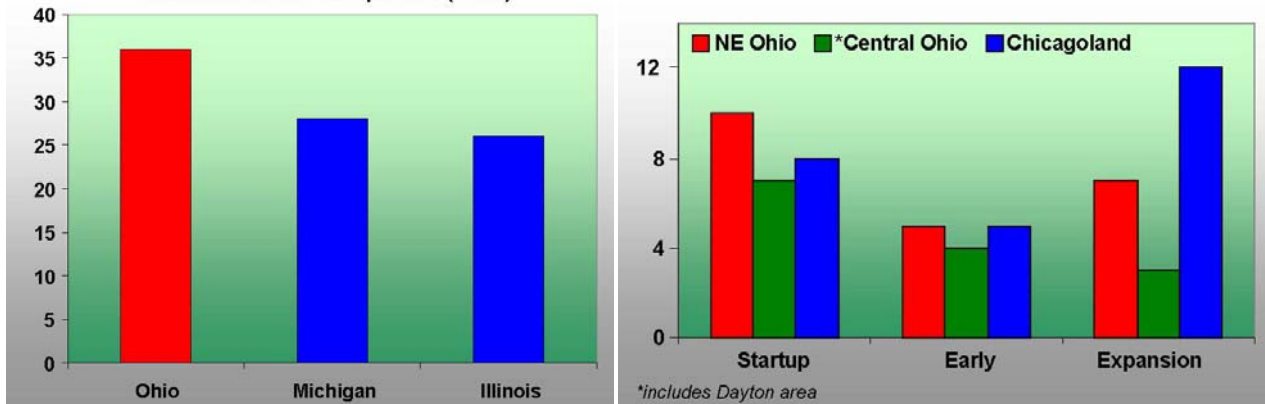


Figure 4. Number of nanotech-focused small to mid-size companies in designated states and regions, as of mid-2007.

Chicago, which has a population approximately four times the size of Cleveland. These figures demonstrate that Ohio has a relatively rich concentration of growing nanotech companies which provide an attractive target for investors and corporations.

Assigning Northeast Ohio’s nanotech small to mid-size companies to sectors, we can also examine the breakdown of our region’s nanotech commercialization focus. Figure 5 illustrates that when placing these companies in their respective categories, the “Materials and Chemicals” sector dominates, followed by “Electronics,” and then “Healthcare Applications/Biopharmaceuticals.” The “Auto/Aero” and “Power/Energy” sectors are significantly smaller. The fact that a large fraction of the nanotech companies fall into the materials sector comes as no surprise since Northeast Ohio has a prominent history of strength in this area. The electronics sector is varied in scope ranging from companies commercializing liquid crystal display technologies to others producing MEMS devices; the healthcare applications companies are largely involved in medical diagnosis or drug delivery. In the next section, we compare this sector breakdown with a similar categorization for the larger innovators in the region.

Northeast Ohio is strongest in nanomaterials commercialization.

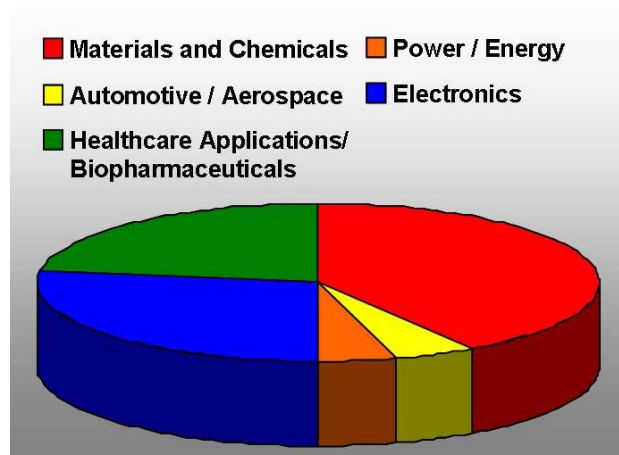


Figure 5. Breakdown count of Northeast Ohio small to mid-size nanotech companies by sector.

Large Nanotechnology Companies

Just as the universities and growing companies are valuable contributors to the nanotechnology landscape, many of our large technology-focused corporations, which are critical to our region's economy, are also at the forefront of nanotechnology enabled innovation. Therefore, we further examined the nanotech patent activity of the technology-focused Fortune 500 companies in Ohio and beyond (financial and IT service providers, wholesalers and retailers were excluded). Certainly, some corporate cultures encourage patenting while others favor trade secrets or open innovation models, but the normalization helps assess the degree

to which these corporations in their respective states are actively pursuing nanotechnology. Figure 6 shows a state to state comparison of the number of nanotech patents applied for by these Fortune 500 companies as a percentage of their overall patents between 2002 and 2006. It does appear that the big industrial players in Ohio are not as nano active as their counterparts in some of the other states. For example, Ohio's companies such as Owens Corning or Sherwin Williams are patenting nanotech innovations at rates lower than similarly categorized corporations such as PPG Industries (PA) or Dow Chemical Company (MI). Motorola, Inc. (IL) also patents nanotech innovations at a relatively high rate and has a dedicated nanotechnology research group at its company. Nonetheless, Ohio's auto/aero businesses have demonstrated some prominence with Dana Corporation nano patenting at a rate higher than others such as General Motors (MI) or The Boeing Company (IL).

To further extend the analysis, the study also assembled a list of companies that were recipients of the highest number of utility patents in Ohio from 2001-2006. Since utility patent productivity is a good approximation for technological innovation, we refer to the top 50 of these companies as the "Top 50 Innovators" in the state of Ohio. Not surprisingly, these businesses are typically large and often public corporations, and nearly half the companies on the list are located in the region of Northeast Ohio. For the cases of Ohio as well as Northeast Ohio, more than half of these top innovators had not yet filed any nanotech related patents as of 2006. This may be further evidence that a majority of Ohio's top technology corporations are not enthusiastic about exploring and/or patenting nanotech innovations.

Are Ohio's Fortune 500 companies savvy about nanotechnology?

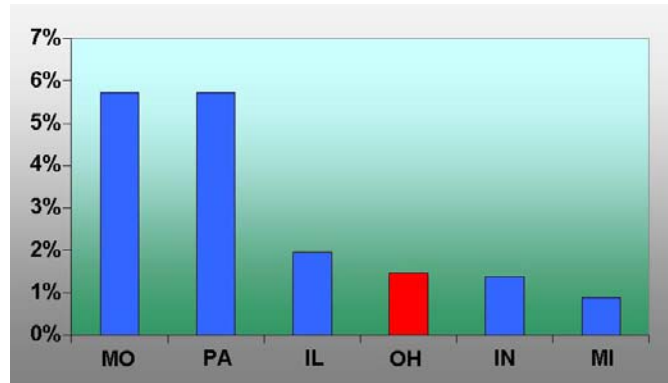


Figure 6. Number of nanotech patents applied for by Fortune 500 technology companies as a percentage of the overall patents from these companies with headquarters in the designated states, 2002 – 2006.

For this report, we also examined the breakdown of the “Top 50 Innovators” by sector (Figure 7) and found that nearly 50% of these large corporations can be classified in the “Materials and Chemicals” category, followed by “Automotive/Aerospace” and then “Healthcare Applications/Biopharmaceuticals” with a small percentage of companies designated in “Electronics” and “Power/Energy.” Comparing the breakdown in Figure 5 with the classification in Figure 7 allows an analysis of the alignment of the small/mid-size companies with the top innovators. A similar level of activity within these sectors is indicative of a healthy sustainable technology ecosystem in which the larger technology corporations can reach out to the smaller nanotech companies to establish collaborations or partnerships that stimulate innovation. Nonetheless, a misalignment is not necessarily cause for alarm since these innovative corporations may also look to companies outside their sector designation for technological solutions. Figures 5 and 7 do indicate that in the areas of “Healthcare Applications/Biopharmaceuticals” as well as “Materials and Chemicals” there is good alignment: the percentage of small/mid-size companies is nearly equivalent to the percentage of top innovators. Nonetheless, we discovered that “Materials and Chemicals” companies such as Goodyear, Bridgestone and Lubrizol are interested in plastics, rubbers and lubricating oils, whereas many of the smaller nanotech materials companies such as Ecology Coatings, Nanofilm, Powdermet and Five Star Technologies are focused on coatings and nanopowders. Similarly in the “Healthcare Applications/Biopharmaceuticals” area, many of the smaller businesses such as Analiza and Copernicus Therapeutics are focused on diagnostics and drug delivery whereas the Cleveland Clinic (considered a “Top 50 Innovator”) has applied for nanotech patents mostly in areas such as prosthetics, implants and imaging. A comparison of Figures 5 and 7 also illustrates that the “Electronics” and “Auto/Aero” categories essentially swap rankings, with “Electronics” as an important sector for the small/mid-size nanotech companies, but not a significant designation for the top innovators, and the “Auto/Aero” category as sizeable in the top innovator analysis even though there are few small/mid-size nanotech companies focused on this sector. This misalignment could be somewhat problematic as the larger auto/aero companies may not find themselves surrounded by nanotech companies within their own sector pushing them to innovate further, and the smaller electronics-focused nanotech companies may not have enough involvement from nearby larger corporations to help sustain them.

Materials and Auto/Aero dominate the technology focus of Northeast Ohio’s top innovators.

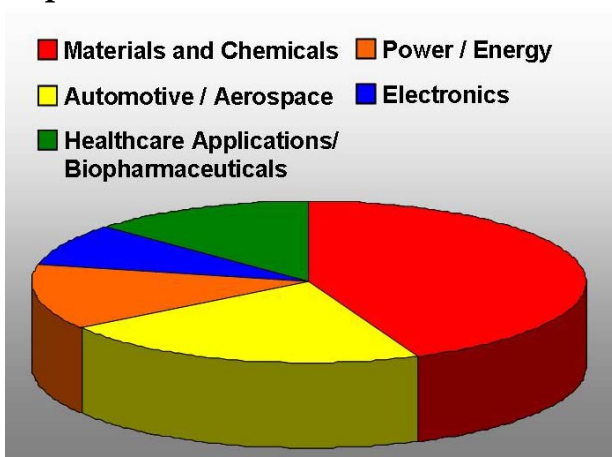


Figure 7. Breakdown count of Northeast Ohio “Top 50 Innovators” by sector.

Venture Capital Investment

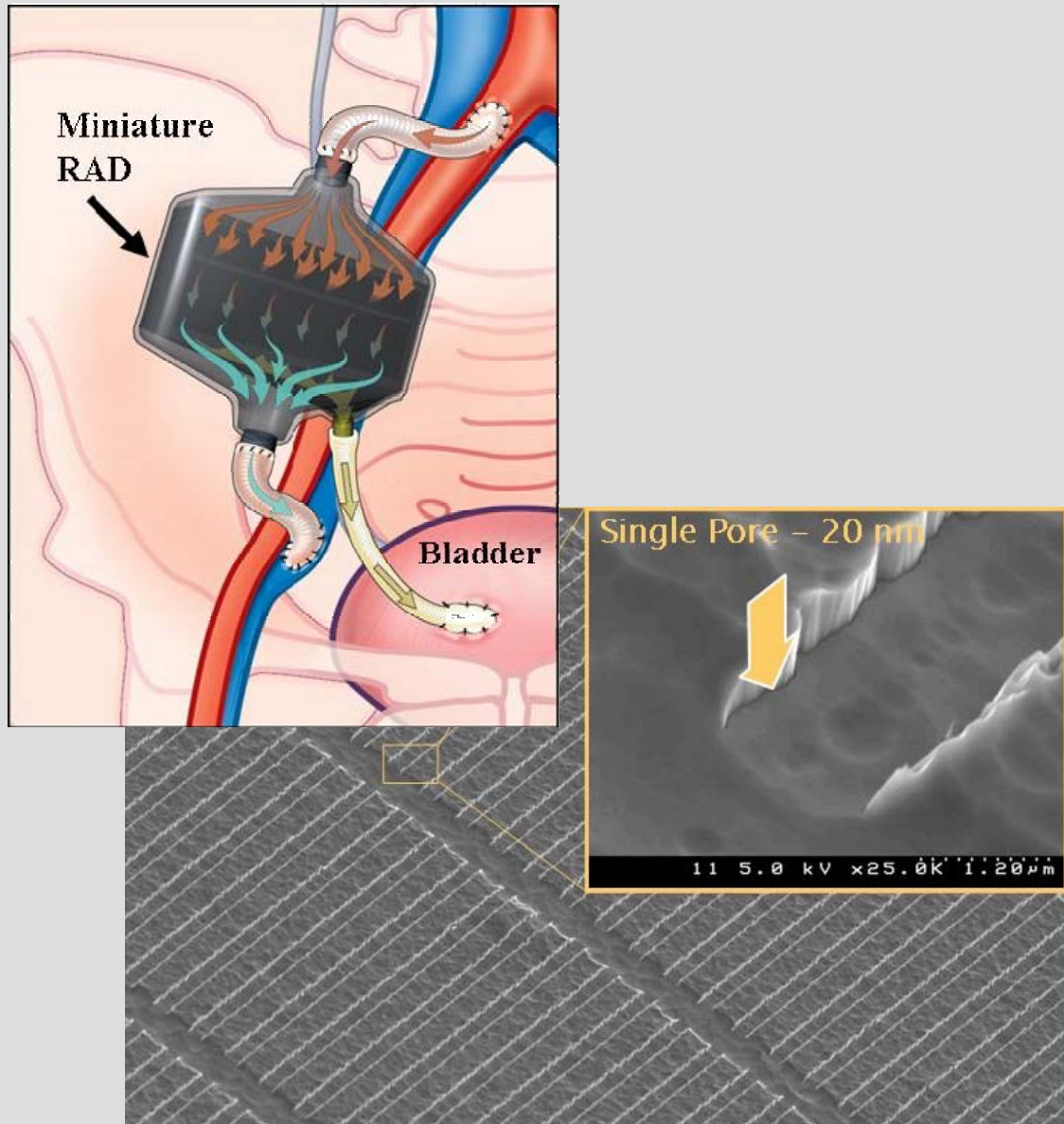
Northeast Ohio is strongly competitive in the Midwest in terms of the aggregate capital invested since 2005. Furthermore, it leads the Midwest in the percentage of that capital invested in high-risk seed and early-stage companies. This creates a powerful “pull” for company formation and the commercialization of technologies. However, venture capital spending in Northeast Ohio does not track well with the regions’ nanotech strengths. Materials companies in Northeast Ohio, which represent a large fraction of the nanotech start-ups overall, fall in a category that has received only 5% of the total funding from venture capital coming into the region. In fact, the majority of venture capital investment in the region goes towards sectors in which nanotech has a limited part to play: information technology, software, and healthcare/business/consumer services. A look at U.S. venture capital spending patterns shows us that this situation is not unusual. Nationally, venture capital invests only ~5% in the industrial/energy sector which includes materials. Nonetheless, Ohio should strive to ensure that a significant portion of that national venture capital commitment goes to Ohio companies.

Workforce

Nanotechnologies are largely platform solutions that can be integrated into a wide variety of different products. This means that nanotech companies require workers that not only have expertise in developing fundamental materials, but also in integrating them with the specific product in question. For example, using carbon nanotubes to improve the resonance of an MRI requires a very different skill set than using them to enhance the structural integrity of an automobile’s bumper. As a result, nanotech companies require a variety of scientists and engineers from multiple disciplines to succeed. Ohio as a state scored highly in a ranking of graduate workforce across the U.S. in 2003-2004: we placed 10th in the nation for doctoral scientists (inclusive of social scientists) and 8th in the nation for doctoral engineers. Certainly, a challenge for Ohio and Northeast Ohio is to continue to attract, educate and retain top graduate students that can work at our nanotech start-up companies as well as our technology corporations to help push innovation forward.



Applications Technician Terry Graham is preparing optical lenses to apply one of Nanofilm’s self-assembling nano-coatings, which is less than ten nanometers in thickness and provides a more durable protective coating to resist soiling and stains. Image courtesy of Nanofilm, Valley View, OH.



A miniature renal assist device (top) constructed using silicon nanoporous membranes (bottom), which are designed for high efficiency ultrafiltration applications, are being developed at the Cleveland Clinic. Images courtesy of the Cleveland Clinic.

Where do we go from here?

The nanotechnology landscape in Ohio is vast. From research, to innovation to commercialization and entrepreneurship, Ohio and Northeast Ohio have many of the right ingredients to be considered nanotechnology leaders. These strengths include:

- An impressive research publication record, complemented by large aggregate nanoscience/nanotechnology research expenditures.
- A relatively rich concentration of growing nanotech companies which provide an attractive target for investors and corporations.
- A significant concentration of active, public-market resourced companies hungry for new technology.
- A nexus of world-class polymer materials companies and a strong presence in the healthcare/biotechnology space, which are both areas of nanotech strengths in the region and State.
- A growing venture capital community with an appetite for early stage investment.
- An established and successful nanotechnology focused organization, the Nano-Network, which has been a catalyst for nanotech activity in Northeast Ohio and an attractor of national attention.

To achieve “powerhouse” status and help ensure that technological innovation happens here, Ohio and Northeast Ohio must consider how to prioritize and face various challenges such as:

- Ohio lacks a collective nanotechnology strategy.
- Inter-regional collaboration on nanoscience/technology could be stronger.
- Ohio has a low rate of converting its high quality nanotech research to patents.
- “Pre-pre-seed” or “first money” for scientists and entrepreneurs is very difficult to find.
- A large fraction of Ohio and Northeast Ohio’s small to mid-size nanotech companies are focused on products low on the value chain.
- Ohio’s Fortune 500 technology focused companies are not as “nano active” as counterparts in other areas of the Midwest.
- Industry sectors need to come together, married by nanotechnology (e.g. materials and healthcare) – this will ensure a bright future ahead.
- There is some product type misalignment between the small and large technology corporations in Ohio (e.g. many large corporations focus on composites while many small nanotech companies focus on films or powders), creating an additional barrier to collaboration within the State.
- The venture capital community outside of Ohio is largely unaware of the high level of nanotech activity and entrepreneurship within the State.
- Ohio must build a trained workforce of doctoral level graduates educated in science and engineering with a background in nanoscience/nanotechnology.

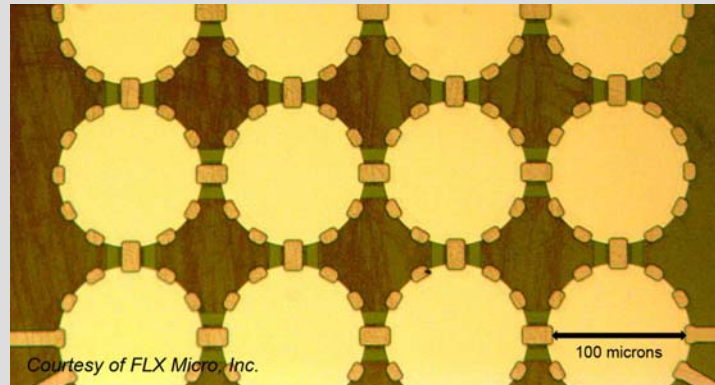


The Northeast Ohio Nanotechnology Report (2008)

The first challenge listed above, to develop an Ohio-wide nanotechnology strategy, could help address some, if not all, of the challenges that follow. The nanotechnology landscape in Ohio is diverse in that some regions' strengths are others' weaknesses and vice versa. A concerted effort of an organization like the Nano-Network that is active throughout the State, not just the Northeast, can bring Ohio's stakeholders into alignment and create an ecosystem that fosters nanotech innovation. There are many such statewide and/or state supported nanotechnology initiatives around the country; most have broad geographic mandates and some even draw multiple states within an area of the country together. For example, the Oregon Nanoscience and Microtechnologies Institute (ONAMI) has a strong partnership with WaTech in Washington State, and the two are co-hosts of major events and initiatives. Leveraging strengths within and around Ohio and perhaps beyond can help facilitate the creation of an ecosystem of innovation enabled by nanotechnology. In the short term, a statewide organization will need to generate a "pull" for nanotech by helping existing nano-start-ups form partnerships that allow them to grow and by assisting the established industrial players find meaningful applications for nanoscience that make them realize the value of the technology and advocate for its development. In the medium-to-long term, an Ohio nanotechnology initiative will need to leverage success stories to motivate a "push" for nanoscience by fostering more commercially viable nanotech research in the area, promoting the formation of more start-ups and increasing nanotech investment via the venture capital arena and through state and federal funding opportunities.

Some of the remaining challenges listed above might be too complex and/or expensive to address in the short term. For example, attempting to increase the nano tech transfer efficiency at the universities may be more of a long term goal requiring incentives to encourage researchers to be more commercialization focused. Nonetheless, working to better connect the large corporations with the smaller nanotech companies and/or the research institutions in order to stimulate additional partnerships or collaborations is certainly a relatively easy and achievable goal since it sometimes only requires making proper introductions to the right people. Furthermore, encouraging intermingling of our sector strengths such as the nanomaterials community with the healthcare applications technologists can be accomplished through targeted networking events.

The evolution of the Nano-Network is somewhat dependent on whether a statewide nanotech initiative takes shape. In any case, encouraging local activity in addition to regional cross-pollination should still be an important part of the Nano-Network's development. The analysis from this report as well as a recent survey of Nano-Network members points to the fact that the Nano-Network should continue to focus on encouraging connectivity through networking events and conferences as well as be a source of information about nanotechnology opportunities to our community, all while bringing visibility and credibility to our region. In addition to its current activities, the Nano-Network within Northeast Ohio will also be considering:



This FLX Micro, Inc. MEMS pressure sensor made from silicon carbide consists of an array of individual capacitors electrically connected in parallel, which allows precise control of capacitance and sensitivity. Image courtesy of FLX Micro, Inc., Cleveland, OH.

- Reaching out to stakeholders from around Ohio to discuss the elements of and the potential for a statewide nanotech initiative.
- Providing more targeted networking opportunities to stimulate collaborations and partnerships that engage our top researchers in commercially focused R&D, and/or include a cross-section of industrial sectors (e.g. materials and healthcare), and/or bring together our large corporations with our small to mid-size nanotech companies.
- Creating a quarterly newsletter to better publicize the nanotechnology assets of the region and provide information to the greater nanotech community.
- Actively bringing venture capitalists to the region to meet with nanotech start-ups.
- Reaching out to neighboring states with strong nano focused efforts such as Michigan and Pennsylvania to form an alliance, and thereby attract additional new investment, talent and technologies.
- Working with colleagues around Ohio to advocate for state support specifically aimed at helping scientists/engineers develop nascent and high-risk, big pay-off ideas with commercial potential.

NorTech, the Nano-Network and the greater nanotech community will be working together over the coming months to prioritize how best to leverage our strengths and address our challenges to cultivate an ecosystem within our region and beyond that fosters nanotechnology enabled innovation. With this, we are certainly guaranteed a prominent role in the global technology landscape of the future.

Methodology

The goal of this report was to help the Nano-Network understand the nanotechnology landscape in Northeast Ohio and beyond to best assess how to proceed with future activities. This report was not intended as a comprehensive “state of nanotech” for Ohio or even Northeast Ohio. Rather, it examined a range of data in order to draw reasonable conclusions about Northeast Ohio and Ohio’s strengths and weaknesses.

Caveat: Nanotechnology is an emerging area and has only been pursued in earnest over the past 5 years. As a result, the amount of data available on nanotech activities is limited and in some cases, the data sets used were not statistically significant. Also, nanotech activities can be hard to measure because companies and institutions may define nanotech differently. Indeed, many companies that employ nanoscience do not necessarily publicize this fact. In addition, the patent searches completed for this report examined applications that are not revealed until 18 months post their date of filing. Therefore, any institutions or companies ramping up their nanotech patent activities as of mid-2006 were not accurately captured in the analysis.

The data and conclusions drawn, nonetheless, serve as initial indicators of what is likely to be true about the nanotech environment in Northeast Ohio, Ohio and beyond. To evaluate our conclusions we also relied on the collective intelligence of the Nano-Network’s membership. Through surveys and in-depth interviews, we tested our hypotheses with employees of companies as well as universities and economic development organizations.

The academic/research institutions analyzed for this report included: Case Western Reserve University, Kent State University, University of Akron, Wright Patterson Air Force Base, NASA Glenn, The Cleveland Clinic, The Ohio State University, Ohio University, University of Cincinnati, University of Dayton, Wright State University, Miami University of Ohio, University of Toledo, University of Chicago, University of Illinois, Northwestern University, Illinois Institute of Technology, Southern Illinois University, Northern Illinois University, Argonne National Laboratory, University of Michigan, Michigan State University, Wayne State University, Michigan Technological University, Central Michigan University, Western Michigan University, Purdue University, University of Notre Dame, Indiana University, University of Missouri, Washington University in St. Louis, Penn State University, Carnegie Mellon University, University of Pittsburgh, University of Pennsylvania, Drexel University, Lehigh University, Temple University. Note that though there are other research institutions within the states of MO, PA, IL, OH, IN and MI, but we did require that in order to be included in the analyses of publications and patents, the institutions must have published at least 50 nano publications within the 2002 – 2007 time period considered.

All publications searches were conducted using an ISI Web of Science Search with TS=(nano* OR “quantum dot” OR “quantum well”).

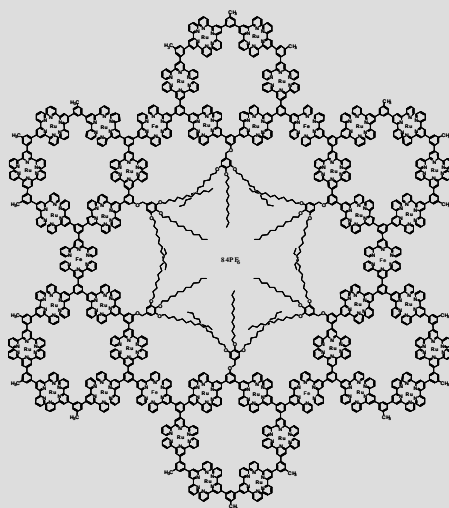
All patent searches were conducted using the USPTO database and the following search terms: (abst/nano or nanomaterial or nanometer or nanoparticle or nanocomposite or nanofiber or nanotube or nanometal or nanowire or nanoscale or “quantum dot” or “quantum well”).

To develop the data for the small to mid-size nanotech company inventory, information was gathered from membership and contact lists from: NanoBusiness Alliance, NorTech, Ohio Polymer Strategy Council, Polymer Ohio, Ohio Fuel Cell Coalition, NanoVIP, Hoover’s Business Database and Small Times Media. These sources are biased towards having particular clarity regarding Northeast Ohio and less insight into other regions of Ohio. Also worth mentioning is that survey respondents indicated that there are various biotech companies in Ohio that employ nanotech but tend not to declare themselves as “nanotech businesses” and so may not be fully represented.

Information on Fortune 500 companies was obtained using Hoovers Business Database.

Data on venture capital investment was derived from the “Greater Cleveland Venture Capital Report” and Price Waterhouse Coopers.

Data on doctoral degrees of scientists and engineers was obtained from the NSF Division of Science Resource Statistics (SRS).



Using self-assembly techniques, the University of Akron develops novel macromolecular structures like the one depicted above for use in applications such as drug delivery, photonics and nanofabrication. The inclusion of hydrocarbon chains on the interior of this hexagonal Sierpinski Gasket appear as domes within mountain-like cavities on a surface. Image courtesy of G. Newkome, The University of Akron.

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