A Rice University Interview: Q&A with the NSF's Mike Roco

Mihail Roco, the National Science Foundation's senior advisor for nanotechnology and key architect of the National Nanotechnology Initiative, visited Rice's Center for Biological and Environmental Nanotechnology (CBEN) this spring for a three-day Nanotechnology-enabled Water Treatment conference.

During his visit, Roco discussed the conference, CBEN and the future of U.S. nanotechnology with Rice News' Science Editor Jade Boyd.

Mihail Roco

Q: Tell me about this meeting. What have you learned here?

A: This meeting is on a relatively less-explored topic in nanotechnology: how to use new developments in water filtration. This is a topic of significant interest to the public at large and there are many stakeholders. That said, the developments in this area are not as fully developed as advances in areas like electronics, materials science and pharmaceuticals, so we have to make a sustained effort to bring the production of nanotechnology in water filtration to the same level as that of other technologies.

Q: What is the state of U.S. nanotechnology today?

A: Nanotechnology in the United States is developing at a fast pace and has made significant advances in five years that other technologies in 20th century took 15 or 20 years to achieve.

NNI is investing about $1.4 billion annually in 2007, which is about one-quarter of the worldwide government investment in nanotechnology. Industry has already exceeded the investment made by the federal government in the United States.

The United States has more than 50 percent of highly cited papers in the field, more than 60 percent of patents related to nanotechnology at USPTO and about 70 percent of start-up companies. That means we are a little bit more efficient, on average, for the investment. This is partly because we organize nanotechnology using a horizontal, multidisciplinary approach that uses the same methods, the same architecture, the same instrumentation and the same principles in different areas. This promotes the exchange of ideas. We are also funding proportionally more fundamental, exploratory research. We leave applications to be picked up by industry. Another reason the United States is doing relatively well in outcomes is because of the better foundation in physics, chemistry and biology in our university system and industrial labs.

If you look toward the future, the field is moving very fast from studying simple components – like nanotubes, nanoparticles, quantum dots – to studying active devices and nanosystems. We are also beginning to see investigations into the close integration of these nanosystems for applications, and eventually we'll be developing nanosystems that have very small components that are nanoscale devices and even molecules or macromolecules. At that moment, we will arrive at so-called molecular nanotechnology.

Q: What about nanotechnology products?

A: At this point, about $60 billion to $70 billion worth of products that incorporate nanotechnology are sold annually in the United States. The vast majority of these are not consumer products, like the tennis racquets and tennis balls that you're likely to read about in the media. The most important of the products are: nanostructured catalysts that are already dominant in the oil industry; very simple nanolayers in transistors, which have changed the electronics industry; new nanostructured materials; new devices like special lasers; and special instrumentation. These are not visible to the public at large in an obvious way.

By 2010, I think we will start to see revolutionary products in nanotechnology. These will differ from the many products we have today that incorporate nanoparticles or other nanoscale components for increased performance. For instance, today you find nanoparticles in the paint on some cars and in the amorphous alloys that are used to improve engine performance. These products – the paint, etc. – are new versions of old products, but the quality is improved. By 2010, I think we'll start to see completely new products and architectures that are resulting from nanotechnology. Why 2010? Because it takes about 10 years to develop a completely new product.

Q: Will these revolutionary products also be used in large industrial processes, where companies are looking to save costs and be greener?

A: Yes. The main reason that nanotechnology is being introduced is not because people are looking to nanotechnology per se, but because they are looking to improve productivity, improve outputs, have less of an impact on the environment.

The main drivers for the development of nanotechnology are the benefits from nanotechnology. And in the long-term, some of the biggest benefits are to the environment because nanotechnology allows us to do more precise manufacturing, with less waste, less consumption of energy, water and materials.

As many people are now starting to realize, there will be some secondary environmental effects from nanotechnology, some potential damaging effects due to the toxicity of some nanomaterials. So far, we've found no catastrophic negative effects, nor have we found any problems that can't be addressed in the shorter or longer term. Therefore, when taken as a whole, all indications are that the costs of addressing the secondary environmental effects of nanoparticles will be far less than the primary benefits of introducing the technology. Certainly, this has to be studied on a case-to-case basis, but so far this is the reason that nanotechnology is growing on a fast pace – the benefits are larger than the potential costs.

Q: Don't the costs of addressing negative effects go down exponentially if they're addressed early, before materials are produced on a commercial scale.

A: This is a very good point. In fact, CBEN was created in 2001 to address the environmental and biological effects related to nanotechnology, and some of the pioneering work at CBEN showed how to treat nanomaterials so that there is reduced environmental damaging effect. That means, instead of sitting aside and being afraid of potential secondary effects, Vicki Colvin – a leading expert at home and abroad – and and her colleagues have advanced this idea of treating nanomaterials before they are used. They've shown that by adding coatings or other methods they can reduce the potential negative effects, and in this way, avoid the problem at its source.

Q – You mentioned that the U.S. provides about one-quarter of the worldwide investment in nanotechnology today. Is that the federal $1.4 billion? Does that count the industrial side, or are you lumping that in?

A: When I refer to one-quarter, I was referring mainly to the federal investment because it's better defined. Information on industry's investment is less complete. However, in industry it seems that the United States has about 30-40 percent of worldwide annual investment in research, compared to the government's 25 percent.

Q: What about growth? How much is research funding increasing year to year?

A: The rate of increased investment in research and development continues to be in double digits worldwide. That means we're seeing more than 10 percent growth per year, and this shows us that the field is in a very dynamic stage of development. The market incorporating nanotechnology has a rate of increase of about or over 25 percent.

We expect this growth rate to continue for three reasons. First, as I explained, we are moving now from the study of rudimentary nanostructures to investigations into more complex devices and systems, which will require increased research and development. Secondly, nanotechnology is expanding horizontally in various disciplines and areas of relevance as well. Initially, the field was mainly dominated by electronics, materials, pharmaceuticals and chemicals. Now, we are seeing the field expand into agriculture, all parts of medicine, in manufacturing, in energy conversion, in water treatment. That kind of expansion requires integrating nanotechnology with biotechnology, information technology and cognitive sciences. The third reason that investment will increase is that in many areas like electronics, advanced materials, pharmaceuticals and chemicals, we are moving now from fundamental discoveries to technological innovation. In moving to technological innovation, the level of cost for development is much higher.

In the first five years of NNI we had an annual rate of increase of R&D funding of over 30 percent. We expect the rate of research and development to continue in double digits for the next five years, and I estimate that we will probably have another 10 years of significant growth in research and development because of these three reasons.

Q: It is budget time in Washington. Historically, NNI has gotten strong bi-partisan support, but a lot of budgets are flat this year. Do you think that NNI will do well?

A: The President's request, which was submitted on Feb. 5th to the Congress, is $1.45 billion, which is roughly 15 percent higher than the request of $1.27 billion made one year ago.

One reason that nanotechnology is growing is because we have results. People see this in each state and in almost every industrial sector.

We are also seeing budgetary increases because the initiative was organized from the bottom up. That means we do not have a fixed amount of money that we try to divide among the participants. Instead, we build projects. For example, the NSF has proposed in this budget a new center for environmental health and safety, and we've proposed another idea for new ways to address common resources like water, energy and food. We build these programs from bottom up, and when we go to Congress we compete with other programs and have to justify why we are better than the others.

Nanotechnology is on a path that is slightly different from other post-World War II initiatives because it is justified on the merits of fundamental research and does have such a broad impact across industrial sectors. In 2000, when President Clinton announced this initiative, no other country had any kind of initiative like it. Just thee years later, about 60 countries had similar programs. By comparison, information technology started in the United States in the 1960s and it took other countries 10-20 years to follow with similar initiatives.

Q: There are other countries that are investing even more than the United States per capita. How do we stack up against the competition?

A: Many countries have very strong programs and offer different strengths. And certainly the United States is a part of this international competition. So far, in part because of our infrastructure and in part because of how we are organized, our results are pretty competitive with other countries. We have more innovation and many news ideas. A recent survey asked who brings the most important ideas to the field. This survey was taken in Europe, and it found that more than 80 percent of people thought the United States was producing most of the important ideas in the nanotechnology field at this moment.

And here I would like to underline that Rice's CBEN has an important role, because the center started early, with this main topic – the environmental and biological aspects of nanotechnology. On the one hand, it's looking for potential implications on the environment and how to defuse damage. On the other, it is looking at using nanotechnology for potential medical purposes and benefits. Certainly, CBEN was created and began to be active in this field before public attention started to focus on these issues in 2003. That means the center had about two years of preparation to address these topics. And now the center is in a leading position, not just in the United States but worldwide, in addressing environmental concerns related to nanotechnology. Vicki Colvin and Kristin Kulinowski are among the leading voices on this issue, and ICON (the CBEN-affiliated International Council on Nanotechnology) has growing recognition and importance as a multi-stakeholder organization in the field. One has to congratulate this group for their achievements.

Q: You spoke earlier about the way research in the field is evolving from the study of discrete particles toward the study of nanosystems and the development of revolutionary products. Can you give some examples?

A: One would be the ongoing work on artificial organs. This involves first developing, from basic components, a scaffold to guide the growth of the engineered tissues. Thereafter, answering the questions of how the blood vessels will grow following this scaffold. Also answering questions about how to grow the cells under control. And so, you start to see that the organ, the whole system, is based on things that are occurring at the nanometer scale.

To give another example, let's consider sensors that are engineered to react to a fire in a building and release gas that's stored in a material. In electronics, we aim at changing the current system architecture and look at replacing existing CMOS assemblies with new architectures that could change completely the carrier of information, say from an electron charge to another carrier of information like a spinning electron or photons of light.

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