Nanotechnology— From Electronics to Sunscreen

Phillip Miller & Francisco Gonzalez

How small is small? That depends on the reference point. It is generally accepted that the "nano" world begins somewhere around 0.1 micron (μm) or 100 nanometers (nm)—that's 10^{-7} meters (m), for all you engineers—or 500 times smaller than the diameter of a human hair. **Now, that's small!**

"Nanotechnology" is a broad range term. In other words, before you can think about implementing "nanotechnology," you need to consider the application of interest.

In the April issue, we introduced the AESF Emerging Technology (ET) Committee. As promised, in subsequent articles, we will introduce readers further to the happenings of this important venture.

This article is the third in a series that includes interviews with the Emerging Technologies (ET) Committee, and subcommittee chairs. We will conclude this series by interviewing the current chair of the AESF Research Board to see how some of its R&D funds are being directed toward emerging technologies.

This month's article focuses exclusively on the ET Committee's sub-committee on nanotechnology. We especially thank Dr. Francisco Gonzalez, vice president of process and product development at Integran Technologies, Inc. for his help and expertise on this subject.

AESF: *So far, we've asked all the subcommittee chairs why their committee is important and necessary. When was the Nanotechnology Sub-committee formed and what is its purpose?*

FG: Our sub-committee was formed in Nashville at the 2001 SUR/FIN® Conference. At that conference, there were several contributions introducing nanomaterials produced by electrochemical deposition. The reason I mention this is it proves that there is, behind the subject of nanotechnology materials, a driving force to learn and discover more about this field. At subsequent conferences we've found the same thing: a lot of people interested in nano-materials. On the ET Committee itself, there were several members showing a great deal of interest in the field. More simply, it was formed because there is enough going on in a variety of industries to justify it.

AESF: *How should one define Nanotechnology?*

FG: Actually, that can present somewhat of a dilemma. There is a complex and far-reaching array of fields in which nanomaterials can have an impact. It can realistically include anything from electronics to sunscreen to the repair of nuclear reactors. We all know that, in some areas of technology, going small has very clear advantages. The electronics industry has been constantly trying to develop smaller and smaller devices and it is only logical that they are heavily involved in nanotechnology. In some other cases, for example in sunscreen, decreasing the size of particles makes them more effective. That is why nanotechnology has already had an impact on the semi-conductor industry. In the case of nanotechnology, we are talking about devices and/or systems that consist of a few clusters of atoms versus the trillions of atoms that make up a common familiar item, such as a coffee cup.

Nano-materials are one important aspect of nanotechnology. Typically, when we describe a nano-material, it will have a characteristic the dimension of $10^{(-9)}$ meters. The material may be in particulate form, and then the particles will have a dimension of 100 nanometers or less, or alternatively, the material may be fully dense but with a crystal size of 100 nanometers.

The beauty of nanotechnology is that at these seemingly impossible small sizes, characteristics become available that were not reachable at larger sizes. For example, when nanotechnology is applied to sunscreen, it is found that certain oxides have the capability of absorbing UV radiation without absorbing visible light. They also glow at different colors depending on the grain size. But, this happens only at the nano-material level.

So, nanotechnology includes the study of crystal or grain size, too. When reduced to a nanometer level, crystals or grains have properties that reveal themselves only at this uniquely small level. And, these properties are often useful and interesting as they can have the ability to solve problems previously unsolved, or those that require very expensive options to solve.

Nano-materials can also be magnetic and thermal. Through the use of nanotechnology we can study fully consolidated materials, such as metals or polymers, in a way that we previously couldn't even imagine.

AESF: *Do you have a sense of how many companies are out there studying nanotechnology and applying its discoveries*?

FG: No, we don't. Although, I do not have specific data on the numbers, there are lots of companies and research groups that are presently involved in the development of nano-materials using more than 200 different methods to produce them. Again, we strongly believe that the use of nanomaterials is essential to nanotechnology, and this is a complex answer, because nanotechnology spans so much. I would not be surprised to find out that there is a vast amount of nano work being done in a variety of industries. I should emphasize that there are many different techniques to produce nano-materials. In fact, nanotechnology can be divided into six categories: (1) electrochemical deposition, (2) vapor phase processing, (3) solid state processing, (4) liquid phase processing, (5) chemical synthesis, and (6) electrochemical synthesis. The electrochemical synthesis is perhaps the most cost effective one. Other production methods such as vapor phase processing, solid state processing, liquid phase processing and chemical synthesis are not as effective, or they require the use of high cost equipment.

Ironically, there are only a few companies that are involved in the use of electrodeposition to produce nano-materials. There is, however, an increasing number of academic and research organizations that are becoming active in this line of research, which will ultimately lead to the industrial implementation.

There has been a tremendous boost given to nanotechnology by the relatively recent approval by the U.S. Congress of a multibillion ($3.7b) appropriation to be divided among eight government agencies. Experts predict that by 2015 the worldwide market for nanotechnology products and services may reach one trillion dollars, and materials will be a very important component of it.

AESF: *How has nanotechnology evolved in recent years?*

FG: As I mentioned before, in some cases, such as the electronic industry, the move to nanotechnology seems fairly predictable, while in other cases it has come as a complete surprise, such as the application of nano-materials in the nuclear power industry.

The beauty of nano-materials is that, at these seemingly impossibly small sizes, characteristics become available, or are enhanced, that are not so obvious at larger sizes. For example, when nanoparticles are applied to sunscreen, it is found that certain oxides have the capability of absorbing UV radiation without absorbing visible light, and they do this much more effectively than when using larger partlcles.

Also, when reduced to a nanometer level, particles have properties that reveal themselves only at this uniquely small level. For example, the color of certain oxides will change depending on their size. These properties are often useful and interesting as they can have the ability to solve problems previously unsolved or solved with very expensive options.

Another example of "smaller being better" is the strengthening of metals when the grain size of the metal is reduced. When the reduction is to the nano size the metal becomes very strong, but it can still deform without breaking, which makes it very attractive for engineering applications. This property was used to develop an *in-situ* structural repair technology for nuclear steam generators. This repair, called Electrosleeve, is already being used and is perhaps one of the first ever large-scale industrial applications for nanostructured materials.

Nano-materials also have interesting magnetic and thermal properties. For example, when the grain size of some iron-nickel alloys is reduced by using electrodeposition techniques in their synthesis, the material becomes more efficient as a soft magnet and could be used to construct transformers with reduced power losses.

In the area of industrial coatings, the wear and corrosion properties of nanomaterials have created interesting applications and alternatives to existing coatings. The aerospace industry is in the process of assessing nano-material coatings for special applications.

AESF: *What will the sub-committee do to help those exploring nanotechnology?*

FG: We have seen an increasing interest in nanomaterials at the AESF conferences and a steady increase in the amount of papers that have been presented on this topic. The sub-committee has promoted the concept and has tried to encourage researchers to present their work at AESF meetings. We will continue to do more of the same, allowing plenty of time and space for more presentations at upcoming events. It will be the job of our sub-committee to continue to pass information on to members and advertise the concept of nano-materials in the hopes of attracting more and more presenters.

The two most important roles we will play are in education and organization. Last year we published the article "Nanotechnology Opportunities for the Electroplating Industries," a sort of "Nano-Materials 101" in AESF's *Plating and Surface Finishing* Journal. This article. kindly put together by Professor Uwe Erb and Integran's workers, described the possibilities of the electroplating industry and community in the field of nano-materials. We are considering preparing a course for next year's AESF Week entitled "Micro-Structural Properties of Nano-Materials." Several presentations have been given to local AESF chapters. One in Montreal recently was well attended and counted with the presence of AESF President, Doug Lay, CEF-2. This helped to promote the event even further. We would like to continue this type of promotion to enhance the awareness of our members to the potential of nano-materitals for the industry.

Also, we hope to play a key role in impacting education at the university level. Unfortunately, as we all know, electrochemical engineering is not as popular as it once was among students choosing careers. Electroplating is not being seen as a high-tech choice. Among other things, I think part of the problem is that many of these technology science-minded students may simply not be aware of how promising and exciting opportunities are in this field (such as the production of nano-materials) is and will continue to be. It is critical that we promote these emerging technologies within the fields of science and engineering so students can learn how nanotechnology is exploding. Perhaps we should even consider offering scholarships for students who want to be involved in studying nano-materials research or other emerging technologies.

AESF: *Do you think there are any obstacles that the proponents of nanotechnology are currently facing?*

FG: Ironically, it's the popularity of nanotechnology that could become an obstacle. Everyone wants a part of the action. That is human nature. We are going to have to sort out which nanotechnology efforts are more worthy of study and funding. I am optimistic about the future, but also aware of potential pitfalls.

In the coming years, a lot of funding will be available for the study of nanotechnology and I sincerely hope that the development of nano-materials will have its fair share. But, nanotechnology is becoming a widely used term, a fancy word that is used to gain attention. Some researchers have just added the label of nanotechnology to what they have been doing for years. Others are just getting into the field because it's fashionable. It is important that we do not have a repetition of the .com fiasco and we develop and commercialize nano-materials with a sound business approach.

Also, we have to make sure we do not consider electronics as synonymous with nanotechnology. There are many additional possibilities that deserve as much attention and focus as electronics.

As the sub-committee continues to interact with other societies that are involved in nanotechnology, and specifically the study and development of nano-materials since it is very important to take a holistic approach in this activity, I strongly believe that the field of nanomaterials development will continue to advance in the coming years and will overcome all the obstacles. But, as the adage goes, "talk is cheap." We plan to offer action and a holistic approach.

About Dr. Gonzalez

Dr. Francisco Gonzalez received his MA Sc and PhD in Chemical Engineering at the University of Toronto. His professional career spans more than 35 years in both academia and industrial research and development. He has been involved in all aspects of chemical technology development, intellectual property protection and technology commercialization. His main areas of expertise include water chemistry, corrosion and electrochemical processes in nuclear power reactors. Dr. Gonzalez has several U.S. patents and has written more than 60 scientific publications.

About Phillip Miller

Phillip Miller is the marketing director at Faraday Technology, Inc., 315 Huls Drive, Clayton, OH 45315. He coordinates the technical marketing and business development activities in support of Faraday's technology platform. Prior to joining the company, he worked as an independent business consultant and a senior business analyst for a Manufacturing Small Business Development Center sponsored by the U.S. Small Business Administration.

Miller has received honors as a Business Counselor of the Year by the Dayton Area Chamber of Commerce and the Ohio Department of Development. He currently teaches college-level small business management and planning classes. At Faraday, Miller is responsible for new business development, technical marketing, and program management.