HEART OF THE MATTER

Materials poised for new prominence in wider profession

By Sharon Aschaiek, Nicole Axworthy, Jennifer Coombes and Michael Mastromatteo

It has been described in words ranging from the "backbone" of the engineering profession to "a bridge" between the pure sciences and engineering practice.

It's closely identified (and sometimes confused) with metallurgy and mechanical engineering, and it plays an ever-increasing role in forensics and the study of why some materials undergo catastrophic failure.

But despite its centrality to the profession, materials engineering isn't widely understood or appreciated, and some materials practitioners in Canada lament the dearth of distinct materials engineering departments at Canadian engineering schools.

This obscurity is troubling to some materials specialists in other ways, especially considering the discipline's imperative to draw from other engineering practice areas: chemical, mechanical, metallurgical, mining and more, to delve into the very heart of what materials to use, how to fit them together, what new materials might be created, and how the finished products will operate in the real world.

At its most basic, materials engineering is the study of all the things we see around us every day. Materials engineers study different groups of materials–metals and alloys, polymers, ceramics and composites–and develop new materials for new applications. They also work to improve existing materials to give better performance and look at ways in which different materials can be used together.

Materials engineering evolved from the field of metallurgy, one of the very first disciplines of engineering. This accounts for the lingering over-association of materials with metallurgy today. Subsequent to the massive development of new metals and alloys during the first half of the 20th century, new classes of non-metallic materials based on engineered ceramics, plastics and composites emerged.

To reflect the widening spectrum of materials classes, metallurgy departments expanded and were renamed–as in the case of the University of Toronto (U of T) and others as materials science and engineering.

The university, one of the few Canadian universities that still has the word "materials" showing up in its engineering school description, tells prospective students that materials engineers focus on improving what things are made of and how they are made. New materials, in turn, enable better performance and sustainable technologies.

The University of Alberta (U of A) is one of the few institutes in western Canada to retain a materials department. "In materials engineering," advertises the department of chemical and materials engineering at U of A, "a scientific approach is taken to improving the performance of materials in real-world situations by examining the relationships between their structure, properties and processing. This concept can be applied to a wide variety of materials, including metals, ceramics, polymers and composites."

Comondore (Ravi) Ravindran, PhD, P.Eng., professor of advanced materials and manufacturing processes at Ryerson University in Toronto, is one materials specialist who can speak to the discipline's extensive reach.

"Materials science is the knowledge of materials," Ravindran told *Engineering Dimensions*. "It is the application of this knowledge. Every engineer applies this knowledge in some measure and, therefore, there is embedded materials engineering in every field of engineering."

Ravindran, recipient of a 2012 Engineering Medal for research and development from the Ontario Professional Engineers Awards (OPEA), is also director of Ryerson's Centre for Near-net-shape Processing of Materials and a member of practically every professional association linked with materials science. He is one of only 11 Canadians named as a fellow in the American Society for the Advancement of Science (AAAS).

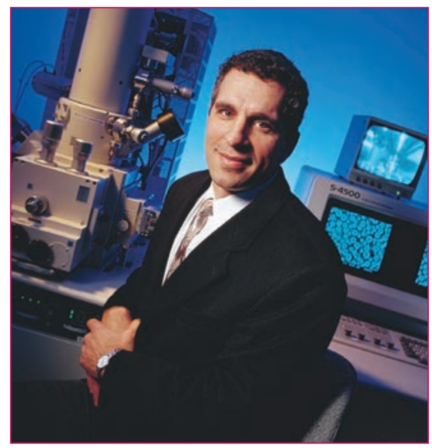
At his lab, Ravindran supervises a group of students doing basic and applied research in casting light alloys (primarily aluminum and magnesium), and cast irons using different casting methods. His work is vital in the development of lighter-weight engine parts in the automotive and aeronautical industries.

Armed with several years of private industry experience as a process development metallurgist with Manitoba Steel Rolling Mills, Ravindran expects his students to keep real-world applications in mind with their research projects.

"We live in a world of materials," Ravindran says. "Everything is material–metals, alloys, composites, polymers, wood. Engineers need to understand the composition of materials, their structure and properties, in order to develop processes, products and services for the benefit of society. In other words, the materials are effectively engineered into products and services. Thus, all branches of engineering function and thrive on a good understanding of materials. Materials are the backbone or the building blocks."

This is a view supported by Carolyn Hansson, PhD, P.Eng., professor of mechanical and mechatronics engineering at the University of Waterloo. A recent recipient of the Order of Canada for her research, Hansson came to Waterloo after several years as head of materials engineering at Queen's University in Kingston.

Carolyn Hansson, PhD, P.Eng., professor of mechanical and mechatronics engineering at the University of Waterloo, says all other engineering areas draw on materials engineering.



Doug Perovic, PhD, P.Eng., professor of materials science and engineering, says materials engineering has a low profile because it tends to be overshadowed by more traditional disciplines.

Materials specialist Ravi Ravindran, PhD, P.Eng. (second from left), in his Ryerson lab with grad students (from left) Suleman Ahmed, Eli Vandersluis, EIT, and Anthony Lombardi, PhD, EIT.

She regrets that budget cutbacks led to Queen's merging its materials department with mechanical engineering, a move copied by other universities in North America.

"I would say other engineering areas, particularly civil, electrical, aeronautical and mechanical, all draw on materials because you can't make anything without making it *out* of something," Hansson says. "So you may design a wonderful circuit, but until you figure out if you can make it *out* of the materials, it won't go anywhere. The other thing is whether those materials are going to survive in the environment that your application is going to be in. That's one of the things many people forget about."

Doug Perovic, PhD, P.Eng., professor of materials science and engineering at U of T and co-director of the university's Ontario Centre for the Characterization of Advanced Materials, suggests one reason for materials engineering's low profile is its tendency to be overshadowed by more traditional disciplines.

"Materials engineering overlaps with all other disciplines of engineering, most notably mechanical and chemical," Perovic says. "However, whereas the other disciplines primarily design with materials, materials engineering is a skill set focused on the design *of* materials. Where other engineers design and build architectures, machines and processes with materials, materials engineers design and build architectures, machines and processes *within* a material."

The lack of profile for materials is ironic in a way, Perovic adds, considering that materials engineering became "interdisciplinary" long before the term came into fashion. "Materials engineering draws on all other disciplines where necessary, since materials are the fundamental basis for virtually all technologies. The cross-fertilization of knowledge from other engineering disciplines and from nature through 'biomimicry' leads to radical advances in materials for new products and industries. Breakthroughs in the engineering of materials have defined all ages of civilization and continue to be a critical path to solving society's most challenging technological problems.

"The materials engineer develops knowledge on the interrelationship between structure-processing-properties-performance of all materials classes such that engineering designs are not only defined by existing materials, but create newly discovered materials that launch novel engineering designs and products," he adds.

It remains to be seen if the next generation of engineering students will cotton on to materials' potential as a potential career. But given its strong links with industry, manufacturing and innovation, a new appreciation for materials engineering's virtues may be in the offing.

For Hansson, the many benefits of materials engineering, though still not widely understood, could inspire a new interest in the discipline. "I think it's fun for students to study materials simply because it helps explain the 'why' of what they already know. Ultimately, though, you have to look at the new applications. This is where I think it should be important for other (engineering) disciplines to rediscover materials."

The following examples of materials engineering show the range of innovative materials that play a supporting role in furthering all areas of engineering.

ADVANCED COATINGS THAT REALLY STICK

Everyone knows that hockey players–at least in the wooden stick era–would wrap their blades in protective tape to shield the business end of the stick from the wear and tear of shooting, passing, slashing and, occasionally, scoring.

It was a rudimentary form of protective coating that, prior to the introduction of composite hockey sticks, extended the life of a player's most basic piece of equipment.

But the idea of a protective coating takes on much greater meaning and significance to materials engineer Javad Mostaghimi, PhD, P.Eng., distinguished professor of plasma engineering, U of T, and director of the university's Centre for Advanced Coatings Technologies (CACT).

Mostaghimi's main research interests include the study of thermal spray coatings, "transport phenomena" and electro-magnetics in thermal plasma sources. In addition, he is involved in the study of flow, temperature and electromagnetic fields within direct current arcs and radio frequency inductively coupled plasmas.

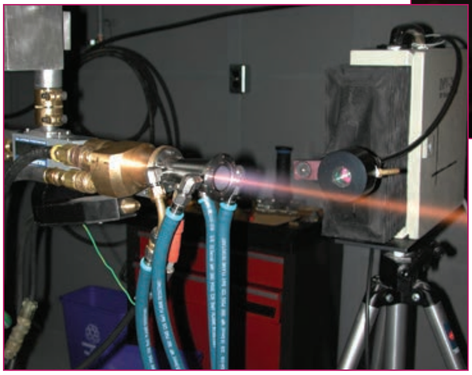
He has also produced simulations of the dynamics of "droplet impact" and solidification in thermal spray processes and automotive spray painting–essentially representations of how fluids or other coating materials might adhere to the surfaces they are introduced to.

Mostaghimi is a fellow of the major materials engineering societies, including the American Society for Metals. In November 2009, he received an OPEA Engineering Medal in research and development for his efforts with thermal coatings.

"Thermal barriers, corrosion and wear-resistant coatings are examples of such coatings," Mostaghimi says. "For example, thermal barrier coatings are applied to turbine blades in a gas turbine. Different sources of energy are used for melting powders and wires. These could be combustion-based or plasmas, that is, partially ionized gases and arcs."

Some of his most promising research involves coating turbine blades with the thermal barrier, zirconia. The coating allows air to flow to and cool a blade so it can withstand temperatures of greater than 1000 C. The coating preserves the efficiency gains of high-temperature operation, while protecting the blade itself from the extreme heat.

Right, Javad Mostaghimi, PhD, P.Eng., distinguished professor of plasma engineering and director, Centre for Advanced Coatings Technologies, U of T, operates a wire-arc coating deposition system.



Left, a high-velocity, oxy-fuel spraying system is used to replace hard chrome electroplating for coating landing gears.

This work satisfies one of the basic challenges of the materials engineer. It's all well to conceive of and develop a new material, but it must also survive all the rigours of real-world operating conditions.

Mostaghimi's advanced coatings research also has wide applicability in the airline industry. His materials are applied to different parts of an aircraft, allowing them to better withstand heat, repel moisture and even resist corrosion.

At CACT, Mostaghimi oversees the collaborative research work of U of T's departments of mechanical engineering and materials science. Established in 1998, the centre conducts fundamental research, both analytical and experimental, in the area of thermal spray coating.

The centre more recently moved into new state-of-the-art laboratory facilities at the university's Bahen Centre, which enables further work into thermal spray application systems, including atmospheric plasma spray, high-velocity oxy-fuel spray and wire-arc spray methods.

Among the most fundamental and long-term studies undertaken at CACT are studies of the impact of molten droplets on a surface and how they deform and make a splatter, formation of the coatings and prediction of their microstructure, and temperature and electromagnetic fields in a "DC plasma torch."

An exciting new application for the coatings work involves improvements in the way municipalities handle waste material–including converting it to a power source.

"With regards to municipal waste, coatings can be very helpful in resisting corrosion at high temperatures," Mostaghimi says. "High-temperature corrosion is a problem in many processes. Nickel-based super alloys are one type of coating that is suitable for these applications. The components are normally built out of manufacturing-friendly materials, such as steels, but by depositing a layer of high-temperature, corrosion-resistant materials, these components will have much longer lives."

In some waste treatment operations, he adds, plasma can be used to "gasify" the waste and generate syn-gas ($CO+H_2$): "The syn-gas may then be used to generate electricity. This is an application called plasma gasification."

But as Mostaghimi's research brings more consistency to the properties of new coating materials, it also benefits from positive collaboration with other disciplines, especially chemical engineering and even nanotechnology.

"The chemical processing and the pulp and paper industries are major users of this (coating) technology," he says. "As you can imagine, there are many processes that are corrosive and/or cause wear.

Mostaghimi's group is now working with the University of Ontario Institute of Technology on hydrogen production by a copper-chlorine cycle. "Due to the corrosive nature of some of the reactors used in hydrogen production, we are developing a proper coating for them," he says.

In a useful overlap with nanotechnology, the advanced coatings team has also developed a nano-structured ceramic coating described as "super-hydrophobic." Mostaghimi explains that super-hydrophobic surfaces are those with a "water contact angle" greater than 150 degrees. "These surfaces repel water and have great applications, and I believe this is the first time that ceramic super-hydrophobic coatings have been developed. Other super-hydrophobic coatings exist, but they are polymeric and thus they wear out much faster compared to ceramics."

Given such potential, it's little surprise that Mostaghimi regards his advanced coating work as "an enabling technology," one that allows engineers and researchers to extend the range and usefulness of materials coming on stream. His research has been said to bring more rigour to an area that in the past was more trial-and-error-based.

"Coating technology used to be more an art than science," he says.

STUDENT START-UP AIMS TO STROKE OUT SUNBURN

Canadian start-up Suncayr is attempting to alleviate the dangers of the summer sun with an innovative colour-changing marker that tells you when your sunscreen is no longer protecting you.

The marker, which looks like a standard Crayola felt-tip marker, contains a specific combination of materials that creates a UV-sensitive, non-toxic ink. Users draw on their skin with the marker and then put on their sunscreen. When the protection wears off, the ink reacts with the sun's UV rays and turns purple. Once the ink is re-covered with sunblock, it turns clear.

The Suncayr marker was created by a group of former University of Waterloo nanotechnology engineering students: Derek Jouppi, Rachel Pautler, Andrew Martinko, Chad Sweeting and Hayden Soboleski. The team came up with the concept as part of a fourth-year Capstone Design project, which challenged them to invent a technology that solves a problem in their daily lives–in this case, they tackled the frustration of forgetting to reapply sun protection with an effective, easy-to-use product.

According to the Canadian Skin Cancer Foundation, more than 80,000 Canadians are diagnosed with skin cancer each year. Skin cancer is preventable, and the reapplication of sunscreen is one of the greatest challenges to staying safe in the sun.

With these stats in mind, Suncayr has the potential to be a practical tool in preventing skin cancer. The appeal of using a marker, the company says, is that drawing on your skin can be fun, making Suncayr a more enjoyable experience for adults and children alike. By drawing ink on your skin, you can get the most accurate knowledge about how sunscreen is protecting you. You can draw or write anything you want, and you have control over the area of application, so you can apply in areas that are most commonly sunburned, like the top of your forearm or your shoulder.

The materials in the marker's ink are water and sweat resistant and leave no tan line, and the colour change is reversible. When you're outside at the beach, you can expect the product to last without chipping or flaking for about six hours. To remove the ink, founders suggest a hot shower with soap and scrubbing will remove it best. Makeup remover will also take it off.

The founders plan to market the product to parents with children between the ages of three and 10, and expect that it will appeal to a broad customer base, particularly in sunny areas of the Unites States.

While a novel idea, one of the company's biggest challenges so far, according to Suncayr's CEO Rachel Pautler, has been the chemical composition of sunscreen itself. "The active ingredients in sunscreen are not very soluble, so non-standard solvents are used to keep everything in solution," Pautler explains. "At first, these solvents also dissolved our ink and removed it from the skin, so we've had to do a lot of work to ensure our ink will last on your skin for several sunscreen applications."

The majority of the marker's active ingredients are already commonly found in marker inks and cosmetic products. They've also introduced a novel UV-responsive dye and several ingredients to increase the ink's durability and ability to mimic skin so that it doesn't wipe off. This new material in the marker–the UV pigment–is being tested by toxicology experts to determine its safety, and the Suncayr team plans to supplement these studies with clinical trials.

"We've optimized the UV-responsive colour change and durability of our ink," explains Pautler. "We're working right now to enhance the amount that the ink mimics skin to ensure that sunscreen will come off our ink at the same rate that it comes off your

The Suncayr team, from left: Sahej Bakshi, Andrew Martinko, Rachel Pautler, Derek Jouppi, Peter Mucha and Chad Sweeting.

The Suncayr team has introduced a novel UV-responsive dye, allowing users to see when they need to apply more sunscreen.

skin. We're also optimizing other cosmetic qualities, such as the shelf life, and comfort of the ink on skin."

The company is working out of the University of Waterloo's Velocity Foundry, a free workspace for student start-ups, and with over $100,000 in grants and awards, including one from the University of Waterloo and the Communitech Women Entrepreneurs Bootcamp. The students were also runners-up of the James Dyson Award in 2014 and received a grant to further develop, test and, ultimately, commercialize their project.

After nearly two years of work, Pautler says the company is in the process of taking the idea to the masses: "We've received approval from Health Canada to sell the Suncayr marker and are working hard to get our manufacturing ready to launch in stores by next summer."

NO MICROBE LEFT BEHIND WITH NEW GENERATION OF NON-STICK SURFACES

Slippery surfaces aren't always a good thing. But sometimes they are–especially when you want to prevent blood from coagulating in a medical device like a heart valve or catheter, deter mussels from attaching to filters at a water treatment plant, reduce bacterial contamination in hospitals, or inhibit ice formation on airplane wings.

Making materials that nothing will stick to is the primary focus of Benjamin Hatton, PhD, EIT, an assistant professor at U of T's department of materials science and engineering.

Prior to his current post at U of T, he and his team at Harvard University had been working for some time on the challenging problem of developing non-adhesive, non-wetting surfaces that would work for both hydrophobic (repels water) and hydrophilic (mixes with water) materials. They could make "superhydrophobic" surfaces that would work in the short term, but not in the long term, particularly under harsh conditions. About five years ago they were running out of options for materials that could perform this function, until a team member came up with the idea of trapping a thin, slippery liquid layer on surfaces, similar to how carnivorous pitcher plants catch their insect prey. It came to be known as SLIPS (Slippery Liquid-infused Porous Surface).

"We decided to generalize the idea to design materials that trap thin, lubricant layers on surfaces at the micro scale as a really robust way of making very slippery, non-adhesive, non-wetting surfaces. This was a turning point," says Hatton.

They initially chose a perfluorocarbon, which is a class of liquids that don't mix with anything else, to create the first, truly

Benjamin Hatton, PhD, EIT, in his lab at U of T. Hatton is developing surface coatings that will repel everything that comes into contact with them.

omniphobic (i.e. repels everything) surface. "We made a fluorinated surface with a layer of fluorinated liquid energetically bound to it and found that it repelled ice, ketchup, bacteria...it's the first example of a surface that repels absolutely everything," Hatton says. He says the coating is reasonably long-lasting and works because the liquid layer is energetically bound and wets the surface preferentially. Nothing is able to displace it.

Their findings were published in *Nature* in 2011 (www.nature.com/nature/journal/v477/n7365/full/nature10447.html), a paper that has been cited over 450 times since then. Hatton says people are realizing that now there is a way to repel anything you want to for practical applications like biomedical devices, water filters, and so on.

It was about that time, while Hatton was working at Harvard's Wyss Institute for Bio-inspired Engineering, when a grant request came in from DARPA (the Defense Advanced Research Projects Agency). The agency was concerned with the number of soldiers being lost to blood-based bacterial infections (sepsis) and wanted to design an external medical device to take blood from a patient, identify bacteria, separate them out, and return the blood to the patient. Blood is sterile in the absence of infection, so any bacteria found would indicate potential sepsis. Separating bacteria from blood would require it to be run through tiny microchannels that are prone to clotting, however. So the challenge was finding a material surface that blood wouldn't stick to and clog the device.

"It was a tricky problem," says Hatton. "Nobody had ever achieved this before. If you put anticoagulants into the blood you reduce the clotting that's going to happen in the device. For a normal, healthy patient, that's okay. But for wounded soldiers, the elderly or very sick, giving anticoagulants can be dangerous."

So, they proposed to use this new SLIPS surface design to effectively prevent blood clots from adhering. The results of that project were published last year in *Nature Biotechnology* (www.nature.com/nbt/journal/v32/n11/full/nbt.3020.html). "It's quite an exciting project, and what's great is it really combined our materials engineering discovery with a clinical need. It was lucky timing," Hatton says.

Hatton has been back at U of T for three years and is further developing this idea. He has traded in perfluorocarbon for a silicone version of the coating because it's easier to engineer for a range of surfaces or devices. "One of the limitations of perfluorocarbon is that you need a reservoir of liquid if you want the surface to last a long time. You need to replace the liquid when it wears away," he explains. So Hatton designed a silicone polymer with lubricant dissolved into it. The liquid permeates the polymer and is also present as a thin layer on the surface, which creates a built-in reservoir that acts as a self-lubricating material.

His group is now testing the surface for its antibacterial qualities using various strains commonly found in bacterial infections, like staphylococcus aureus, under different growth conditions. The surface has shown promise for use in applications like medical devices because it has been observed to reduce bacterial growth by between 1000 and 10,000 times, as compared to normal silicone in 15-day growth trials.

"These slippery surfaces work really well for devices like endoscopes that have to be cleaned after each use to prevent transmission of infection from one patient to another. We're working on these kinds of applications because the devices are much easier to clean when designed this way. Bacteria simply don't adhere to them. Indwelling devices like urinary catheters or endotracheal tubes that stay in place for weeks or months are another area. We're interested in how using almost the same plastics and polymers as the devices themselves we can engineer them to be highly non-stick," Hatton says.

"There are a lot of situations where having a truly non-stick surface just changes the game. You have adhesion problems with so many different industries. There's never been an easy solution to it so industries have just had to live with the problem," he says. Until now.

LEVERAGING SHAPE MEMORY MATERIALS TO PROMOTE WELL-BEING

Shape memory–a property of smart materials that lets them return from an altered state to their original shape in response to an environmental stimulus–is well-known among materials engineers. But what's new are all the promising applications of this function being explored by material sciences engineer Hani Naguib, PhD, P.Eng.

As principal investigator at the Smart and Adaptive Polymers & Composites Laboratory at U of T, Naguib is creating a wide range of what he calls smart, active materials and structures, such as multifunctional polymers, or plastics, that can be used to improve everything from robotic limbs to surgical tools to wound recovery.

"The idea of having smart materials that can activate based on an external stimulus and can perform certain functions is really exciting for me," says the mechanical engineering professor, who is the Canada research chair in smart and functional materials. "It can lead to innovations in the biomedical field and so many other different areas."

One area that stands to benefit from Naguib's research is prosthetics. Since 2003, he has been working on achieving a prosthetic arm featuring specialized actuators and sensors that would allow for lifelike mobility. He and his team have fabricated artificial muscles and joints that use very fine, lightweight, biodegradable fibres containing shape memory polymers that can be programmed to return to preprogrammed shapes with the application of heat. Specifically, they are manipulating the microstructure and nano-structure of the materials, and then exposing them to electrical charges to thermally condition them to change and restore their shape.

For a material to be useful to its intended users–individuals with an injured or missing arm–Naguib says it must optimally perform in three muscle function areas: speed, force and deformation. Currently, the muscle Naguib has developed can allow for movement as fast as milliseconds, but this still isn't as fast as the human body. As well, it can carry up to two kilograms of weight, and the goal is for it to carry up to 20 kilograms.

"We need the material to work as fast as possible, because when you close and open your hand, it's very fast," says Naguib, who is also director of U of T's Toronto Institute of Advanced Manufacturing, which provides organizations with research and development, training and education in advanced manufacturing. "It also needs to be able to carry a certain weight…and deformation will enable the hand to return to its original position."

The bionic arm, which Naguib expects to finalize and commercialize within the next three to four years, isn't the only innovative application for shape memory polymers being fleshed out at his lab. Another involves using the substance to enable medicine to help patients recover from illness more quickly and effectively. Specifically, Naguib has developed a sponge-like biodegradable material for drug delivery that squeezes and releases liquid drugs when it has reached the right spot in the body.

Hani Naguib, PhD, P.Eng., principal investigator at the Smart and Adaptive Polymers & Composites Laboratory at U of T, has created artificial muscles and joints using biodegradable fibres combined with shape memory polymers that can be programmed to return to preprogrammed shapes with the application of heat.

In this case, the polymer is trained to open and close in response to exposure to a specific degree of heat. This could be our body's normal temperature of 37 C, or the exact temperature of each of our organs, which are typically a bit warmer than our general body temperature. If medicine is placed inside, it will only be released once the material senses the precise temperature of the target body area with a wound or infection. Naguib says the material could be adapted to the minute differences in body temperatures that exist in each patient.

In addition to controlling the timing of the drug's release into the body, Naguib is also investigating how to manipulate the speed of the release–specifically, how to extend the drug's delivery over a longer period of time to make it more effective. As well, he wants to see if it's possible for the material to act as a type of tourniquet that can stop bleeding and seal a wound. He is currently working on a skin patch system, but he is also investigating an ingestible solution.

This modulated approach to drug delivery would increase the efficiency of the medicine, Naguib says, which would mean patients would be able to recover more quickly, and may decrease or even eliminate the need for multiple doses of pills.

"The idea is to make the recovery phase more effective for the patient," Naguib says. "It will definitely decrease the time by which patients are taking the drugs, and allow them to heal more quickly."

MATERIALS OPTIMIZATION THE ESSENCE OF INTEGRAN'S WORK

Mississauga-based Integran Technologies Inc. has won numerous awards and patents since its founding in 1999 for its many contributions to the advancement of materials science and engineering in Canada.

Most of the new materials it has brought to market over the last 16 years benefit the aerospace, nuclear and defence industries, but it's the company's work with a new-generation hockey stick that is bringing it more recent attention.

In an application of its patented Nanovate technology, which serves to make composite parts stronger and more durable, Integran was instrumental in developing the new Colt brand hockey stick now used by some elite National Hockey League players.

Although not a part of its core business line, the stronger, more durable Colt hockey stick developed by Integran Technologies demonstrates many of the product enhancements made possible with its patented Nanovate technology.

Incorporating greater strength and energy into the stick shaft, the Colt gives hockey players more speed and power in their shooting–all the while reducing the chance of a dreaded mid-shaft breakage that occurs with other composite hockey sticks.

Earlier, Integran applied its Nanovate technology to the production of hybrid golf club shafts, which, like hockey sticks, put more energy into a golfer's swing.

Though it's a small part of Integran's extensive line of commercial products, the hockey stick and golf club experiences demonstrate the tremendous versatility inherent in materials engineering.

"It's all about materials optimization and development of hybrid structures," says Integran President and CEO Gino Palumbo, PhD, a graduate of U of T's materials science and engineering program.

"Effective materials engineering can only be executed using a multi-disciplinary approach involving a broad range of engineering, such as chemical, mechanical, metallurgical, industrial and electrical, and by involving such areas as solid state physics, electro-chemistry, business and related disciplines."

Armed with his materials engineering training, and 20 years' experience in the nuclear side of the former Ontario Hydro (now Ontario Power Generation), Palumbo saw Integran as an opportunity to take the benefits of materials development in multiple new directions.

Integran bills itself as a metallurgical nanotechnology company whose technologies focus on the engineering of the internal structure of materials on a near-atomic scale to yield "super materials" that meet exacting performance requirements of new products.

The company's core technologies grew from innovative multi-disciplinary research and development carried out at Ontario Hydro's research division in the 1990s. This research was conducted in collaboration with researchers at Queen's University and U of T. The company to this day maintains its strong collaboration with U of T.

In many ways, Palumbo and Integran represent the best of materials engineering and its impact on the development of stronger, more resilient and generally enhanced products across a wide spectrum.

A small souvenir Integran staff offer to guests and visitors–a ping pong ball coated with the company's high-strength Nanovate material (thus rendering it practically indestructible)–makes a simple but convincing statement as to what can be achieved by the careful selection and manipulation of materials.

"One of our core competencies is our ability to design, engineer and manufacture ground-breaking new products based on combining very high strength (nano) metals with polymers and carbon fibre composite materials," says Jonathan McCrea, PhD, P.Eng., Integran's vice president of technology. "These hybrid structures deliver unique properties not achievable with monolithic designs. A good example of this is the Colt hockey stick."

Integran holds one of the first patents in nanotechnology with its work on the Electrosleeve process for repairing CANDU reactors and is now widely used to extend the life span of generators in nuclear power plants.

Because much of Integran's core business involves defense and military industries, the company is limited in how it describes its unique technology. Despite the confidential nature of some of its processes, however, Integran is quite open about its position as a leader in metallurgical nanotechnologies. It is motivated to continually develop lighter, better and cheaper products based on its Nanovate nano-crystalline metal platform.

Not surprisingly, the company's archives are filled with reports of its successes in materials innovation. "We're not a commodity materials producer or supplier, but rather a true materials engineering company," McCrea adds. "We serve leading organizations where advanced materials drive competitive advantage or where existing material solutions fall short. Global 500 companies in aerospace, defense, biomedical and heavy industries turn to us for materials innovations. Our collaborations deliver value by enabling new products, weight savings, cost competitiveness and reduced environmental footprints." Σ