Nanocellulose steps up on stage

A one-tonne per day demonstration plant is in the works, and manufacturers are lining up to explore the potential of these tiny particles.

By Carroll McCormick

Canadian researchers and manufacturers are leading the world in learning how to create new uses for nanocellulose, a major component of trees. Industries from aerospace and automotive to pharmaceutical and security are lining up, paying up and teaming up to learn how to use this strong and versatile material to improve existing products and develop new ones.

Canada is "absolutely" on the front of the world stage in the ability to industrialize the production of this material, according to Dr. Richard Berry, a program manager at FPInnovations, a private, not-for-profit Canadian forest research institute. There, he pioneered the effort to liberate nanocellulose in industrial quantities from pulp.

To avoid confusion, FPInnovations coined the term nanocrystalline cellulose (NCC) for the particular form of nanocellulose it makes; the crystallites it produces are uniformly 150-200 nanometres long and 5-10 nanometres in diameter.

"A lot of other people are talking about nanocellulose, but we don't always know what their versions of it are," says Dr. Ron Crotogino, president and CEO of the Canadian Forest Nanoproducts Network. Officially called ArboraNano, it was created last year by Industry Canada's Business-Led Network of Centres of Excellence program. ArboraNano has almost $9 million and a four-year mandate to bring together researchers and industry to develop new products based on forest-based nanomaterials, particularly NCC. Other public and private sources are providing matching funding.

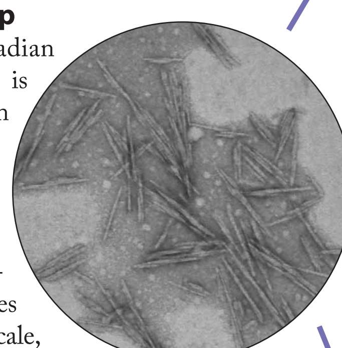
Unlike nanorobots, say, NCC is not a mysterious human invention, purposefully made tiny for working in small places. The crystallites just happen to be vanishingly small. Mother Nature has been using NCC in plants since long before dinosaurs woke up hungry and its tremendous strength is one of the reasons trees can soar as high as 379.1 feet (115.56 metres) — the world record, incidentally — without collapsing on themselves.

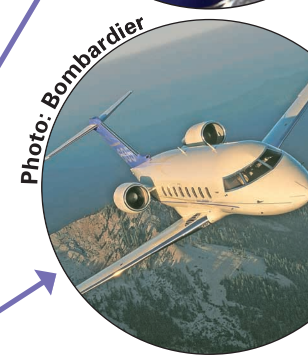
Also called cellulose nanocrystals, the material was first isolated in 1949, according to Berry. The cellulose in pulp is up to 70% NCC, which is a crystalline cellulose, and about 30% amorphous cellulose, give or take. Liberate the crystalline from the amorphous cellulose and, voilà, you have NCC to go.

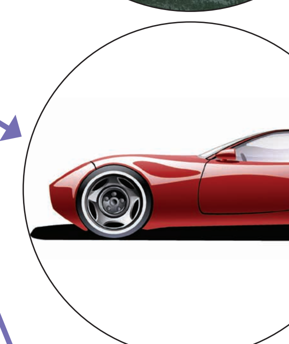
Production scaling up

The nut that Canadian researchers have cracked is how to extract NCC from wood in industrial quantities. At the FPInnovations laboratory in Pointe Claire, Que., a batch process is capable of producing kilogram quantities per day. A commerical-scale, one-tonne per day demonstration plant is now under construction at Domtar's Windsor pulp and paper facility. The $32-million facility is a joint venture between Domtar and FPInnovations, with Natural Resources Canada and Quebec's Natural Resources and Wildlife Ministry contributing $10.2 million each to FPInnovations' portion of the venture.

A whole sack of nuts that FPInnovations and its university and industry partners are busy cracking is how to use NCC and its properties to enhance existing products and contribute to the manufacture of new ones. The National Sciences and Engineering







Nanocrystalline cellulose could be used in a variety of products. (Photo courtesy of FPInnovations)

Research Council lists 18 product areas in which NCC could have applications. Here are some possibilities:

• Add NCC to varnish, perhaps just 3% of its volume. This makes it about three times harder, and more abrasion-resistant than ordinary varnish. This improvement could directly help those in the wood products industry, such as manufacturers of hardwood floors and cabinetry. NCC could also improve the strength of adhesives.

• Add NCC to water-based paint. Just sitting there, in the can, the NCC-enhanced paint will be a bit jelly-like. Agitate it, however, and it becomes liquid — perfect for brushing and rolling. But once applied, the paint will re-gel and not drip from the ceiling onto your glasses.

• Add NCC to a liquid in just the right way, then dry it. The resulting material will have a shimmering iridescent colour. It's not a dye though. Rather, the arrangement of NCC crystals reflects visible light so that we see pretty colours. Possible ways to exploit this property include security marks on paper and pigments for nail polish or lipstick. NCC can also be made to reflect radiation in the ultra-violet and infra-red parts of the electromagnetic spectrum. "We are initiating work with the Institut National d'Optique," Berry says.

• Manipulate the surface of NCC so it bonds with other polymers, and the result, for example, could be stronger plastic. This, plus the possibility of making stronger, possibly lighter cellulose-based car parts, excites manufacturers.

Other potential applications include aircraft, textiles, optics, gels, composites, pharmaceuticals, bone replacement, tooth repair, food additives and electronic products.

Manufacturers are interested

Imagining potential applications of NCC, inspired by its great strength and other known properties, is the easy task. Proceeding to products is a far more complex undertaking. It is impressive then, given the real risk of failure, the amount of private industry interest and money behind the effort to commercialize NCC.

Of the eight funding members of ArboraNano, six — FPInnovations, Bell Helicopter Textron Canada Limited, NanoLedge Inc., Kruger Inc., the Ontario Bioauto Council and NanoQuebec — are from the private sector. Le Fonds québécois de la recherché sur la nature et les technologies (FQRNT) and Alberta Innovated — Bio Solutions provide provincial funding support.

"The wonderful thing that is happening is that every company we visit sees a use for its properties. We have more than 65 companies that we have different levels of relationships with. Even getting to the discussion point in this economy is significant. People's time is precious," says Berry.

"We are putting together joint agreements with manufacturers. Our expertise is making and modifying the materials, and they know best how to formulate their materials in products."

Research is heating up at the university level, says Crotogino, who notes that the exact number of participating universities is a moving target. "As projects are approved, more universities come on board. There are now four universities receiving research funding with four more universities involved in the administration of the network."

In partnership with FQRNT, one of its public funding members, ArboraNano launched a research partnership program. Four grant recipients at the universities of McGill, Sherbrooke, Laval and Quebec (at Trois-Rivieres) now have a total of $965,000 to work on NCC projects in the wood processing and pulp and paper sectors until 2013. Targets of their investigations include wood coatings and composites, improving NCC's compatibility with polymers, applications of its optical properties and its use to improve pulp and paper processes.

Not salvation, but stimulation for the industry

Pulp mills will be involved in the production of NCC, but it remains to be seen, however, what the demand for pulp to produce NCC might be once the nanocellulose market matures. Claims that NCC may be the salvation of the wood products industry are exaggerated. Rather, says Crotogino, "the salvation of the forest products industry is innovation. NCC will be part of this as a key to the development of higher-value forest products. It will not save a paper mill that makes traditional products, but NCC creates new opportunities for the manufacture of innovative, high-value paper products, as well as a new generation of building materials."

Berry adds, "I look at NCC as a way of diversifying the sectors in which wood products are used, rather than turning it back into the industry." What he means by this is that the wood products industry should not think only about making better wood products with NCC. Rather, it should be thinking of totally new applications for the materials harvested from our forests.

"The whole purpose of ArboraNano is to extend these materials into other areas, newer directions, new marketplaces, and get us out of the box we have been living in. We need to look at the full spectrum of possibilities from the components, talk to the companies we have never spoken to before," Berry declares.

Construction on the demonstration plant should be completed in about 20 months, capping 15 years of research by FPInnovations. "We need to have products ready to use NCC by then. We will start with materials that are easier to take to the marketplace. Industrial materials are easier than consumer materials. Wood products are easier than aerospace," Berry explains.

Introducing NCC to products containing water will be the easiest to master, because NCC likes water. Hydrophobic materials will come later. Industrial uses will likely come before consumer products, because of regulatory issues. Automotive applications will precede those in aerospace, with its stringent and lengthy certification processes.

One day, Berry muses, aircraft manufacturers might come full circle to using NCC-enhanced wood products in aircraft again: fancier versions of plywood sheathing and the wooden stringers of old. Call it wild speculation, but perhaps spacecraft will one day be made of nanocrystalline cellulose-containing parts. After all, the registry number for Star Trek's USS Enterprise, the most famous spaceship in the universe, was NCC-1701. **PPC**