Solutions for improving vehicle armour and personal protective equipment

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Improving vehicle armour and personal protective equipment

From Kevlar® to polymer composites, from RHA steel to advanced ceramics, vehicle armour and personal protective equipment based on conventional materials are rapidly approaching their performance limits.

▲ Photo: Caporal Marc-André Gaudreault, Section d'imagerie, Garnison Valcartier.
Cover photo: MCpl Kevin Paul, Canadian Forces Combat Camera

It is only through new and advanced material technologies that significant gains in performance will be achieved. That's why the National Research Council of Canada (NRC) has joined forces with Defence Research and Development Canada (DRDC) to launch the Security Materials Technologies (SMT) research program.

The SMT program works directly with Canadian industry and other partners across the security materials supply chain to develop and bring to market advanced armour materials and manufacturing technologies.

Our research team has extensive experience and expertise in manufacturing technologies and in developing advanced materials including nanomaterials, polymers and polymer composites, metals and ceramics. Collectively, NRC and DRDC have experience in developing high performance material solutions and multi-threat protection systems. We can help develop improved and disruptive armour products from concept to full-scale prototyping and evaluation and can offer technical advice and consulting services to accelerate and substantially de-risk product development.

We can help solve complex problems by:

- Improving the performance of conventional armour materials
- Developing new nano-modified or hybrid materials and armour structures
- Developing improved manufacturing and joining methods
- Accelerating development and validation of new products
- Assessing product performance through testing

Benefits of the SMT program's technical advice and consulting services:

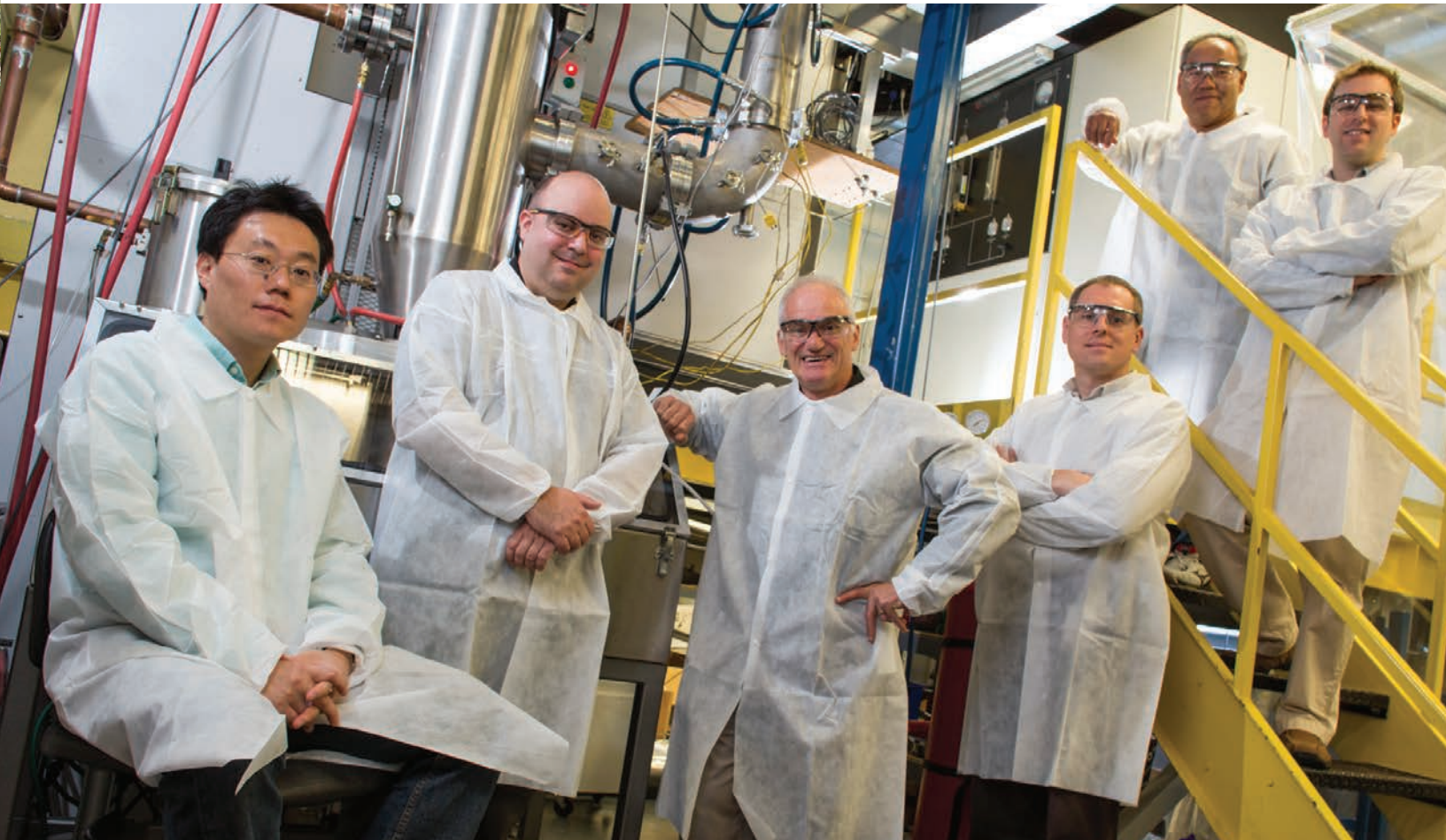
- More effective solutions in shorter time
- More efficient use of your valuable resources and research investments
- Reduced risk and significant cost savings in product development
- Exploitation and transfer of specialized knowledge

Our technical advice and consulting services help our partners succeed by capitalizing on the extraordinary strengths in science and engineering of advanced materials, manufacturing processes, and armour systems resident within NRC and DRDC.

Work with us

- Access extensive scientific knowledge and technical expertise – from constituent materials (nanomaterials, polymers, metals and ceramics) to armour components and systems
- Access critical and world-class research infrastructure from nano-scale to full-scale
- Develop unique customized solutions to maintain and improve your competitive edge

The NRC nanocomposites team that demonstrated the world's first pilot-scale production of boron nitride nanotubes. L to R: Keun Su Kim, Mark Plunkett, Benoit Simard, Chris Kingston, Jingwen Guan, Mike Jakubinek ▼



About composites, hybrids and nano-modified materials

- **Composite material:** A combination of two or more materials with very different properties, producing a new material with characteristics different from the individual components.
- **Nanomaterials:** Nanoscale materials (nanomaterials) have at least one dimension between 1 nm to 100 nm and often exhibit extraordinary mechanical, thermal or other properties. For example, a single-walled carbon nanotube, with a diameter of about 1 nm, is over 100 times as strong as the best steel (by weight).
- **Nano-modified material:** A macroscopic material (e.g., a polymer, metal or ceramic) with at least one constituent being a nanoscale material such as carbon or boron-nitride nanotubes. Nano-modification offers the potential to impart some of the extraordinary properties of nanomaterials to the bulk material, even at relatively low concentrations (e.g., less than 1%).
- **Hybrid material:** A type of composite material with two or more types of constituents with quite different but ideally complementary properties. For example, an aramid/carbon hybrid can combine stiffness and ballistic resistance.

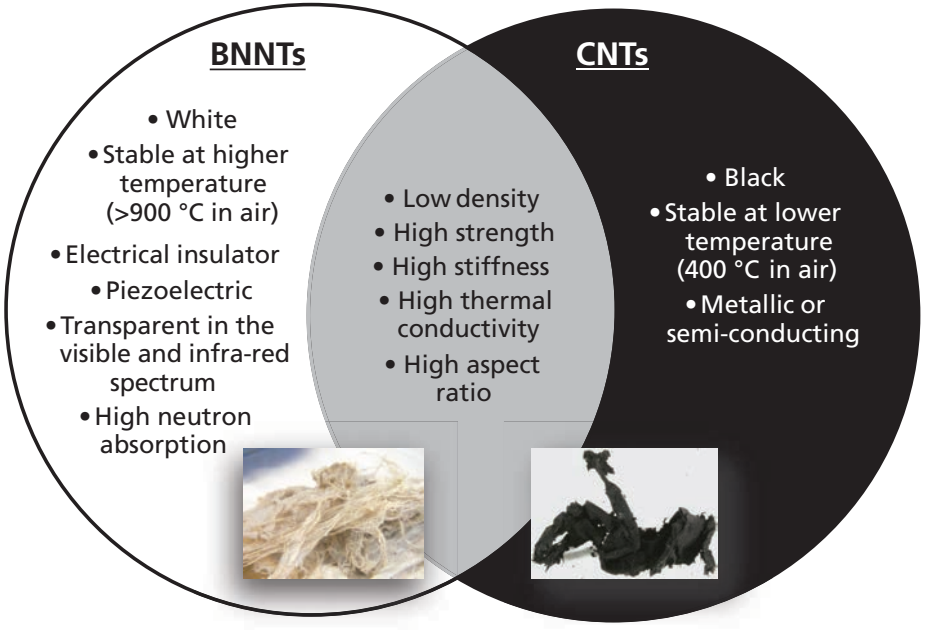
Stronger, tougher, lighter materials

Nanomaterials

Improve and expand the performance of conventional and advanced materials

Nanomaterials, such as carbon nanotubes (CNTs) and boron nitride nanotubes (BNNTs), can enhance the properties and functions of current materials and introduce new functionalities that weren't previously possible, allowing for the creation of new, more efficient and higher-performance material systems.

We have extensive scientific and engineering knowledge and experience in the manufacturing, handling and optimizing the integration of nanomaterials into conventional materials to produce high-performance materials and structures.



Nano-modified materials and hybrids

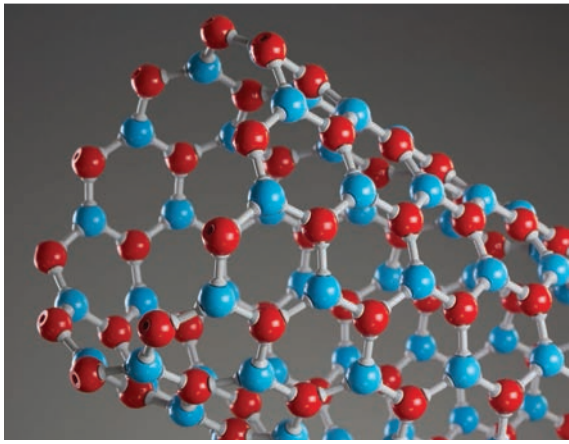
Translating the extraordinary properties of nanomaterials into real-world armour applications requires effective integration into conventional high-performance armour materials. Our materials experts have applied their world-class skill sets in chemistry, physics and process engineering to successfully nano-modify a broad range of materials including polymer adhesives, textiles, advanced composites, metals, ceramics and glasses. The resulting nano-modified engineered materials can show not only improved strength, stiffness and toughness compared to the base material, but can also be designed to improve such properties as flammability or moisture resistance, or even improve electrical properties.

One intriguing example is the use of carbon nanotubes (CNTs) and boron nitride nanotubes (BNNTs) to enhance the toughness of ceramic armour. Our team has grown carbon nanotubes on ceramic fibres to create a "fuzzy mat" ceramic matrix composite, which has been shown to substantially enhance the fracture toughness of the base ceramic. BNNTs are a very exciting reinforcement for ceramic matrices since they are themselves a (transparent) ceramic and, being stable at very high temperatures, are compatible with the high temperature processes required to fabricate armour-grade ceramic materials.

While some nano-modified materials are ready for near-term armour applications, others will require longer-term investments to reach their truly disruptive potential. In many cases, a short-term alternative to nano-modification is hybridization of one or more types of more conventional materials into a material/structure that combines the best properties of both. An aramid/carbon composite hybrid, for example, or a composite with multiple types of fibre architectures, can create a structure with better optimized performance than any one material on its own. Our team possesses the skills in design, materials and processing to develop the perfect hybrid material for your application.

Nanocomposite and hybrid materials can have a big effect on:

- Materials and structures with unique properties possessed by no single natural material
- Functionally-graded materials that transition from one type of property to another
- Materials designed for a specific threat environment
- Multi-functional materials that avoid parasitic weight of multiple layers with different functions
- Ultimately: unmatched armour system performance



Boron nitride nanotubes production capacity

The structural, electronic and optical properties of BNNTs make them promising candidates for nano-modification of polymers, glasses, metals and ceramics. BNNTs are expected to lead to lighter and multifunctional materials for applications including aerospace, automotive, and defence and security. Of particular note is the potential of BNNTs as coatings or for bulk modification of transparent armour.

Despite their extraordinary properties, BNNTs were produced in such small quantities that they were primarily a laboratory curiosity. Recently, however, NRC developed a patented technology that produces these materials over 100 times faster than any earlier method. This game-changing development opens the door to exploration of BNNTs in a wide range of applications.

Flexible, scalable, industrial processes

▲ NRC's hot press

Modelling

Our modelling and simulation capabilities allow modelling and simulation of processing, properties and performance of materials and structures from the nano-scale to full-scale in a wide range of simulated environments. These capabilities can substantially reduce materials and process development time and de-risk product development.

Our modelling tools help to explore a wide range of challenges

- Manufacturing process development
- Environmental durability and degradation
- Damage initiation and propagation
- Translating nano-scale performance to macro-scale structures
- Low to high-speed velocity impacts
- Blast and structure interactions
- Vehicle control and dynamics

Manufacturing

High-quality, repeatable and cost-effective manufacturing processes are critical to successfully transitioning the next generation of high-performance materials into successful armour products. Advanced processing and manufacturing technologies is one of the greatest strengths of the SMT program. It brings together a team with world-class expertise from nanomaterials production and integration to joining technologies, polymers and advanced composites processing, metals and ceramics processing, coatings technologies, non-destructive inspection and additive manufacturing.

We can manufacture a broad range of materials and select the best processing route for combining polymers with reinforcing fabrics depending on the need of a particular structure, including wet and pre-impregnated layups, micro foaming, compression moulding, resin transfer moulding, injection moulding, reaction injection moulding, profile and sheet extrusion, film blowing, continuous fibre reinforcement, filament winding, etc. Whether we add nanoparticles to the polymers or other additives, the end result is a polymer composite in a form that can be shaped into a ballistic insert, vest, visor, or combat helmet.

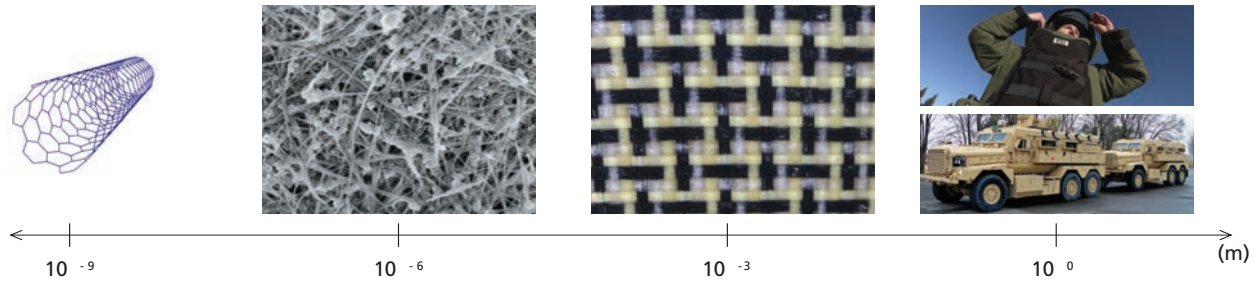
Our new multi-process moulding platform that includes an infra-red oven and an array of features, such as high speed ram movements and rapid heating capabilities, is at the core of our armour products manufacturing capabilities.

Our team has decades of experience developing and transitioning to industry state-of-the-art manufacturing technologies, particularly in the aerospace, automotive and ground transportation sectors. Our experience with a broad range of materials and technologies gives us the ability to work with your team to rapidly identify the best manufacturing route for your product and to develop and demonstrate a process that can be quickly transitioned to your own operation or to your supply chain.

Scale-up production of nano-modified materials

A challenge common to all new materials is scaling from lab-scale demonstrations to industrial production. NRC is expanding its facilities and tools for the production, processing, formulating and integration of nanomaterials and nano-composites to fill this critical gap. Scale-up of these novel nano-modified materials to industrially relevant quantities enables thorough process troubleshooting and optimization in preparation for transfer to full-scale production lines. It also feeds our advanced manufacturing facilities with quantities of nano-modified materials sufficient for large-scale component manufacturing and prototype demonstrations.

From nanomaterials to validated products



NRC's Boucherville facility ▶

Stronger, tougher, lighter and cost-effective

Personal protective equipment

Through the Security Materials Technologies program, we support the development, assessment and adaptation of next-generation materials and manufacturing technologies to enhance the performance and reduce the weight of protective vests, helmets and other personal protective equipment (PPE).

Maximize effectiveness and reduce costs

We are working to develop a range of materials and manufacturing technologies to develop improved, cost-effective PPE components and systems. One example is our work adapting an automotive technology called direct long-fibre thermoplastics (D-LFT) to develop low-cost, high-complexity armour from long discontinuous aramid fibres. Another area of work is the application of our world-leading BNNT technologies to develop improved polymer transparent armour through both more durable surface coatings and bulk material modification. In all cases, whether meeting a short-term client requirement or addressing longer-term challenges, our work is aimed at transitioning advanced armour technologies to Canadian industry.

Vehicle armour products

Modern armoured vehicles are the result of complex system engineering processes that balance mobility, lethality, protection and cost to respond to evolving threats and operational requirements. Rapidly advancing materials technologies and a highly competitive global armour industry makes it challenging for companies to stay on top.

If you manufacture vehicle armour or transparent armour components and systems, or armoured vehicles themselves, and you want to strengthen your position in the marketplace, the SMT team can:

- introduce you to new materials and manufacturing technologies to support your mission;
- identify ways to improve your existing products and manufacturing processes;
- introduce you to the state-of-the-art in computer modeling of ballistic and blast processes, and establish the extent to which they can help you optimize the performance of your products;
- help you establish linkages with key suppliers and partners;
- introduce you to test organizations that can evaluate ballistic or blast performance of your components, products and systems; and
- work with you on ITAR or non-ITAR technologies.

Photo: Sgt Matthew McGregor, ▲
Canadian Forces Combat Camera

Canadian Security Material Technology Roadmap

- Industry-led strategic planning process that will foster collaborative development of innovative materials, armour products and systems to meet future international market demands.
- By identifying industry needs and critical technologies, will help align, plan and coordinate technology development opportunities for Canadian industry and target R&D investments, resulting in a more competitive and innovation-based industry in Canada.

To get involved, contact us:

E-mail: NRC.SecurityMaterials-MaterielSecurite.CNRC@nrc-cnrc.gc.ca
Web: www.nrc-cnrc.gc.ca/eng/solutions/collaborative/smtrm.html/

◄ Corporal Shilo Adamson, Canadian Forces Combat Camera

Research and testing facilities

Our partners have the opportunity to access our innovative research facilities to develop products and get them into the hands of customers better, and faster than before.

- Unparalleled industrial materials processing facilities
- Versatile mechanical testing facilities
- Access fast and cost-effective analytical services

Materials characterization services at a glance	
Mechanical characterization	• Micro- and nano-hardness testers • Adhesion tests such as shock wave • Mechanical test rigs from micro-scale to full-scale
Physical and chemical characterization	• World-class electron microscopy • Chemical analysis • Thermal and electrical properties • Flame resistance
Non-destructive materials testing	• Conventional and laser-ultrasonic, radiographic, photometric, and computed tomography
Environmental conditioning	• Immersion tanks • Envionmental and thermal aging chambers • UV resistance
Non-contact strain measurements	• Advanced digital image correlation (high speed)
Polymer characterization	• Rheological properties • Thermal properties • Morphology
Dynamic structural characterization	• Blast and quasi-static pressure with air cannons, shock tubes, and explosive devices • Low-to-high velocity ballistic impact tests from less than 15 m/s to beyond 3000 m/s with two-stage gas guns, plate impact testers, high-speed recording devices, and enhanced laser velocity systems

Five powerful reasons for collaborating with us

1. **Create competitive armour products** — Keep up with and surpass global competitors.

2. **Get products to market faster** — Shorten the time it takes to integrate new high-performance materials technologies into personal and vehicle armour systems.

3. **Gain access to world-class research infrastructure and unique expertise** — We provide an opportunity to access unique capabilities and facilities.

4. **Enjoy intellectual property terms that match risks and levels of investment** — Our goal is support Canadian defence and security companies in becoming international market leaders and our intellectual property policies supports companies in doing so.

5. **Stay visible and connected within the Canadian defence and security community** — Our program gives companies the chance to interact with peers and influence government investments.

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