Nanotechnology for Building Security

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ABSTRACT

What more can be done to protect building occupants from the threat of terrorist attack? One answer may be nanotechnology, which promises to heighten building security through stronger materials, more powerful sensors, and improved air and water filtration. Access barriers such as walls and windows will benefit from nanocomposite reinforcement, and access control features including biometric devices will be enhanced by advances in micro-electro mechanical systems (MEMS). Nanocomposite reinforcement will also improve building response to explosive blasts and chemical/biological/radiation (CBR) threats. Weapon detection systems are already benefiting from nanosensors capable of detecting some explosives and toxins down to the parts-per-trillion range. Finally, nanofiltration and nanoporous materials will enhance air and water filtration.

Keywords: building security, homeland security, defense, construction, nanosensors

1 NEW THREATS, NEW RESPONSES

Despite increased vigilance and federal anti-terrorism spending exceeding $55 billion per year, building security remains a major concern for most Americans. For those working in large governmental or institutional buildings, fears are particularly acute. What more can be done to protect building occupants from the threat of terrorist attack? What potentially effective strategies, tactics or technologies remain untried? One answer may be nanotechnology. Nanotechnology, the manipulation of matter at the molecular scale, promises to heighten building security and homeland security through the introduction of stronger materials and more powerful sensors. Many of the nanotech innovations now available or in development will have applications for building security. The primary areas of application will be in the strengthening of materials, the advent of nanosensors, and improved air and water filtration.

Aggressors have a variety of weapons and tactics at their disposal, with new ones appearing with alarming frequency. Potential weapons include explosives and incendiaries, stand-off weapons, small arms, and airborne and aqueous toxins. Car bombs, mail bombs, handguns, and chemical/biological/radiation (CBR) threats such as the anthrax used in attacks on the U.S. Congress in 2001, are just some of the current weapons of choice. New technologies mean new threats, including dirty bombs whose nuclear capabilities threaten almost unimaginable destruction and biological bombs like those unleashed in the Tokyo subway attacks of 1995.

Providing physical and psychological security is one of the primary functions of architecture. In order to provide security, buildings must prevent unauthorized entry and harm to occupants. In recent years, the threat of terrorist attack has become the greatest fear of occupants in governmental and institutional buildings. While almost no amount of physical barriers, technology, or protective service can thwart a determined suicide bomber, measures can be taken to protect building occupants, detect intruders, and react effectively in the event of attack. Improving building security can also reduce the threat of attack by making buildings less attractive targets.

2 EMERGING NANOTECHNOLOGIES

Nanotechnology, the understanding and control of matter at the molecular level, is bringing remarkable changes to industries ranging from electronics and medicine to automotive and apparel. Today there are over 700 products on the market using nanotechnology with a value of approximately $13 billion, with sales expected to top $1 trillion by 2015.

Nanotechnology is bringing remarkable changes to the materials and processes of building. Already this new science has brought architectural advances to market including self-cleaning windows, smog-eating concrete, and wi-fi blocking paint.

In the near future, nanotechnology will contribute to building security through stronger materials, nanosensors, and air and water filtration. Access barriers such as walls and windows could incorporate stronger materials benefiting from nano-reinforcement utilizing carbon nanotubes and nanocomposites. Carbon nanotubes can be designed up to 250 times stronger than steel, yet 10 times lighter. Nanotubes are the building blocks for hundreds of applications across many industries, from sports equipment to medication delivery. Nanotubes for reinforcing glass, concrete, masonry and plastics are all in development. The cost of carbon nanotubes is declining and will eventually make nano-reinforced building materials a reality.

As nano-reinforced building materials gain market share, a complementary technology, nanosensors, will also emerge to help improve building security. Nanosensors integrated throughout our buildings and public spaces will collect and transmit a vast quantity of information about our environment and its users. Already, nanosensors smaller than a penny are marketed for detecting airborne toxins such as carbon monoxide and anthrax in and around buildings. These nanosensors will play a growing role in building security and antiterrorism efforts.

Weapon detection systems are also benefiting from commercially available nanosensors capable of detecting some explosives and toxins down to the parts-per-trillion range. Reaction technologies enabling a building to respond to explosive blasts and chemical/biological/radiation (CBR) attack will improve, as structural hardening and shear resistance in building components are enhanced with nanocomposites and nano-reinforcement, leading to blast-resistant building envelopes, sacrificial exterior walls, and shatter-resistant exterior walls and window glass.

Finally, air and water filtration systems are already one of the primary markets for the rapidly developing technologies of nanofiltration and nanoporous materials.

3 DETECTION NANOTECHNOLOGIES

Detection systems are typically deployed at building entry control points to screen individuals and their belongings for hidden firearms, explosives, and other potentially harmful materials. Current detection technologies include imaging devices and sensors for detecting explosives, pathogens and chemicals. The X-ray machines, metal detectors, and explosive detectors found in airport terminals are examples of today's detection technology.

Nanotech-based chemical sensors can provide high sensitivity, low power and low cost portable tools like the "Carbon Nanotube Sensors for Gas Detection" available for licensing from NASA's Ames Research Center [1]. Similarly, the Lawrence Berkeley National Laboratory has "Miniature Airborne Particle Mass Monitors" for monitoring ventilation systems available for licensing [2]. A prototype nanotech-engineered biosensor from Michigan State University could help detect multiple pathogens faster and more accurately than current devices [3]. And a wristwatch-sized device developed at the University of Michigan can detect toxic gasses at the level of 100 parts per trillion, recognizing mustard gas in a building's air supply in just 4 seconds [4].

In the marketplace, Nano-Proprietary is developing a simplified photo acoustic sensor (PAS) platform capable of identifying trace amounts of most gases and vapors, miniaturizing and improving the sensitivity of the PAS sensor down to parts per billion levels [5]. ND Life Sciences, a subsidiary of NanoDynamics, Inc., has received a $738,653 Small Business Innovation Research (SBIR) Award to work with chemical detection specialists ICx-Agentase to speed development of a nano-enabled biocatalytic air monitor capable of detecting hazardous nerve agents at extremely low concentrations in air.

Bioident Technologies Inc., a co-winner in the semiconductor category for the seventh annual *Wall Street Journal* contest for Technology Innovation, produces the PhotonicLab Platform, which enables rapid in-vitro diagnostics, chemical and biological threat detection. NanoSensors, Inc. also markets sensors to detect explosive, chemical and biological agents.

Intrusion detection systems use sensors to detect unauthorized entry or attempted entry by monitoring motion, vibrations, heat, or sound. Closed circuit television (CCTV) is an example of current intrusion detection technology. Applied Nanotech has been awarded a $750,000 contract for a "Dual Sensor Module for Human Detection" from the Homeland Security Advanced Research Project Agency. The company will design, develop and demonstrate a high reliability, low cost, low power chemical sensor with the ability to operate in harsh environments to detect humans [6].

4 NANOTECHNOLOGY FOR REACTION

Reaction technologies include those that improve a building's resistance to terrorist attack, as well as the ability of the building to react and respond. They can be incorporated into structural materials, components, and systems including mechanical and electrical.

4.1 Nanocoatings

Surfaces in buildings can be treated with antimicrobial nanoparticles to kill microbes and bacteria that come in contact with them. These antimicrobial treatments, whether integrated during the manufacturing process or applied to existing surfaces, could reduce the threat of biological attack. Researchers at North Carolina State University have developed a nanocoating that can kill most visuses and bacteria when exposed to visible light. Early tests have shown that it kills 99.9 percent of influenza viruses and 99.99 percent of vaccinia virus [7].

Elsewhere, Yale researchers have discovered that single-walled carbon nanotubes can kill bacteria like the common pathogen E. coli by severely damaging their cell walls, offering the first direct evidence that carbon nanotubes have such powerful antimicrobial activity [8].

NanoViricides is creating special purpose nanomaterials designed to attack viruses and dismantle them. The company is developing nanoviricides to fight bird flu, influenza, HIV, hepatitis C, rabies and dengue fever [9].

4.2 Fire retardants

Both surfaces and structural components like columns and beams can be made more resistant to terrorist attack through improved fire resistance. Plastics are particularly combustible unless they incorporate flame-retardant chemicals. Alternative fire retardants are now being developed in the manufacture of nanocomposite plastics. In nanocomposite, nanoparticles (clay, metal, carbon nanotubes) act as fillers in a matrix [10].

Other research is exploring the synergistic effect of carbon nanotubes and clay for improved fire resistance. Researchers at the University of Warwick have found a way of replacing the soap used to stabilize latex emulsion paints with nanotech sized clay armor that can create a much more hard wearing and fire resistant paint [11].

4.3 Self-healing materials

Eventually, building materials based on nanotechnology may even become self-healing. Researchers at Rensselaer Polytechnic Institute are at work on an epoxy material infused with a wire grid and carbon nanotubes that can detect and repair structural problems in airplanes. When a crack is detected, voltage is increased to the carbon nanotubes, generating heat which melts the epoxy that fills the crack [12].

Leeds NanoManufacturing Institute is designing an experimental house with walls containing nanopolymer particles that will turn into a liquid when squeezed under pressure, flow into the cracks, and then harden to form a solid material. The house walls will also contain wireless, battery-less sensors and radio frequency identity tags that collect data about the building over time [13].

4.4 Nano-reinforced Glass and Concrete

Glass may be strengthened as well in the nano-enabled future. University of Texas at Dallas nanotechnologists have produced transparent carbon nanotube sheets that are stronger than the same-weight steel sheets [14]. And engineers at the Air Force Research Laboratory are testing a new kind of transparent armor made from aluminum oxynitride that could stop armor-piercing weapons from penetrating vehicle windows [15].

In the marketplace, Solutia Inc., the world's largest producer of polyvinyl butyral (PVB) protective interlayer used to manufacture laminated glass, has launched Vanceva Secure, a nanotech-based product [16]. And 3M has created Prestige Ultra Safety & Security transparent window film using polyester nanomaterials [17].

Traditional structural materials like concrete will also eventually benefit from nano-reinforcement. Vanderbilt University assistant professor Florence Sanchez recently won a CAREER Award from the National Science Foundation (NSF) for her research into more durable nano-structured cement. Sanchez is investigating how nanofibers made of carbon could be added to a concrete bridge, allowing it to monitor itself for cracks [18].

4.5 Air Purification Technologies

Building systems, particularly air and water supply, are also vulnerable to attack. A building's heating, ventilating, and air-conditioning (HVAC) systems can become an entry points and distribution system for many hazardous contaminants, including chemical/biological/radiation (CBR) agents like arsine, nitrogen mustard gas, anthrax, and radiation from a dirty bomb. Air filtration systems can protect a building and its occupants from the effects of a CBR attack, and nanotech has already entered the air filtration market.

Commercially available products include the Nano e-HEPA (High Efficiency Particulate Arrest) filtration system from Samsung, which uses a dust filter coated with 8-nanometer silver particles to kill airborne health threats, including 99.7 percent of influenza viruses [19]. Other nanotech-based air filtration products include the Ultra-Web nanofiber media from Donaldson Filtration Systems [20], ConsERV brand energy recovery ventilator products by Dais Analytic Corporation [21], And NanoBreeze room air purifiers [22].

4.6 Water Purification Technologies

Finally, water purification can also benefit from emerging nanotechnologies. Some nanoparticles have a high surface area and reactivity, and can be used to render heavy metals like lead and mercury insoluble, reducing their contamination. Dendrimers, with their sponge-like molecular structure, can clean up heavy metals by trapping metal ions in their pores [23].

Photocatalytic nanomaterials enable ultraviolet light to destroy pesticides, industrial solvents and germs. Titanium dioxide, for example, can be used to decontaminate bacteria-ridden water. When exposed to light, it breaks down bacterial cell membranes, killing bacteria like E. coli [24]. Purification and filtration of water can also be achieved through nanoscale membranes or nanoscale polymer "brushes" coated with molecules that can remove poisonous metals, proteins and germs.

Seldon Laboratories has delivered prototype portable water purification systems to the Air Force for testing

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[25]. Water purification nanotechnologies available for licensing include "Biofunctional Magnetic Nanoparticles for Pathogen Detection," from Hong Kong University of Science and Technology [26].

The complete 100+ page report, "Nanotechnology for Building Security," is available from Green Technology Forum at greentechforum.net/security.

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