book reviews

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Nanotechnology for Chemical and Biological Defense

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In today's world, recognition of the potential applications of a technology and a sense of purpose in exploiting it are far more important than simply having access to it. A relevant example is the tremendous development in biotechnology and its effect on the fundamental security of each country. Defence against chemical and biological weapons currently presents a threat that is difficult to predict and for which traditional solutions are increasingly less effective.

Nanotechnology, like biotechnology, carries the potential for groundbreaking applications as well as the potential for unpredictable harm.

The world is possibly 20 years away from the full impact of nanotechnology on defensive capabilities.

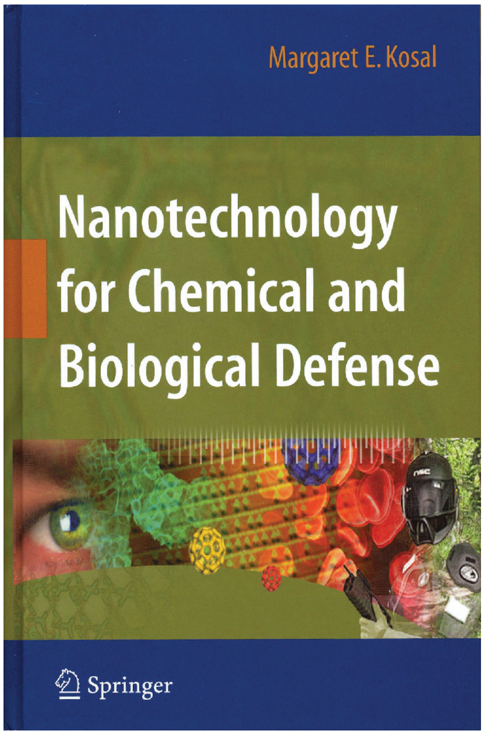
Prediction of possible scenarios in that field is never easy and can many times be dangerous – for these reasons must be driven by strategic concerns. The research underpinning this book and the workshop that was undertaken as part of it was focused on the potential role and impact of nanotechnology on US national defence and international security. The text highlights the findings and conclusions from the study as well as identifies research directions that may provide an overview of the current situation framing the opportunities and the challenges.

Defence against chemical and biological (CB) weapons has been a part of the US national security strategy. This began with the fall of the Soviet Union and was magnified greatly by the events of September 11, 2001, and the shifting nature of technological progress that brings entirely new capabilities.

Therefore, it is necessary to define potential applications of nanotechnology, the factors driving the capabilities, and the relationship between science and national security (p. 1).

In the rapidly changing post-cold war environment, the most technologically advanced military power no longer guarantees national security. Globalization and information revolution have made new technological developments accessible and relatively inexpensive to many nations, so that advanced technology is no longer the domain of the few. In the twenty-first century, both national-states and nonstate actors may have access to new and potentially devastating dual-use technology. Nanotechnology is one such technology that could have dual uses.

Recent advances in biotechnology and information technology have been driven by needs for improved biomedical products, public health, or industrial applications. In some cases, negative or undesirable results from existing experimental data may be harnessed to develop potential weapons. For example, the negative data or undesirable effects that hill healthy cells, however, may provide the seeds for adversaries to identify and develop new unforeseen weapons. The same is true for data derived from nanomaterial experimentation.



Changes in technology can most easily be seen as a decrease in the cost and increase in the availability of technology, tools, and materials. The internet and other communication leaps have led to much greater insight into the availability and potential for technology.

On page 5 are described technological advances enabled by nanoscience. Nanotechnology can be described as technologies resulting from efforts to understand and control the properties and function of matter at the nanoscale. The term nanotechnology also labels a vision first described by Richard Feynman in his classic talk "There's plenty of room at the bottom", where he outlined the potential for new fundamental work at the nanoscale. K. Eric Drexler popularized the concept and terminology in the 1980s and 1990s. At the nanoscale, phenomena are no longer dominated by bulk properties.

Among the first popular descriptions of nanotechnology were nanomachines capable of assembling themselves or spontaneously or by designated signal.

Today, the meaning and application of nanotechnology is much wider. Multiple terms are used to describe and name the fields associated with nanotechnology: nanoscience, nanoengineering materials, bionanotechnology, supramolecular science, and self-assembly. Engineering nanoparticles are currently used in a number of commercial products, including cosmetics, clothes, sunscreens, and electronics.

In medicine, nanotechnology is expected to influence medical diagnostics, drug delivery systems, therapeutics, and vaccines. Applications for all of these are in varying stages of transition from research to the marketplace.

Twenty-first century nanotechnology investment intrinsically traverses national borders (p.7), and, for example, the European Union is now estimated to be investing € 1 billion per year. In 2001, Japan identified nanotechnology as a major research priority and subsequently increased its investment to exceed one billion dollars per year for nanotechnology research. China, South Korea and Taiwan also have robust, federally funded nanotechnology programs. In April 2007, Russia announced plans to invest almost 28 billion rubles between 2008 and 2010 in nanotechnology as part of an intensive effort to make Russia a leading global competitor in nanotechnology. The designers have both military and civilian applications in mind. Traditional and innovative new approaches to nonproliferation and counterproliferation are important policy elements to reduce risk of malfeasant application of nanotechnology.

Chapter 2 describes the possibilities and potential for nanotechnology to impact chemical and biological (CB) defence and proliferation. The goal was to find innovative solutions and strategize potential countermeasures to current CB threats leveraging revolutionary developments in nanotechnology and recommended research directions and priorities to enable the long-term science capabilities for CB defence. This chapter substantially contributed to the development of scenarios on and strategies regarding the potential benefits and threats of nanotechnology for national security.

Applying nanotechnology to revolutionary chemical and biological countermeasures is presented in Chapter 3. This chapter examines the possible technical areas of nanotechnology: physical protection, detection and diagnostics, decontamination and medical countermeasures (p. 29).

Sensor systems are among the many envisioned applications of nanotechnology of substantial interest for defensive weapons and military aspects. For example, semiconducting nanocrystals – often called quantum dots or nanodots – have the potential to detect single molecules of a target substance. They are essentially very small transistors that produce a unique optical signal that can be changed by the addition or removal of an electron. Detectors using quantum dots could better detect solids and liquids with low vapour pressure, such as high explosives and some classes of nerve agents. Nanodots have also been designed for detection of specific biological moieties, which may lead to detection methodologies for infectious diseases.

The current state of knowledge of nanomaterials can be compared with the synthetic chemicals 75 years ago: a host of discoveries and interesting materials – nylon, Teflon, nitrogen compounds, aromatics, pure alcanes. Now, 75 years later, chemists can imagine almost any molecule and then synthesize it in one of the most intellectually challenging pursuits and accomplishments of the human mind.

Moving from advancements in current approaches to sensing and detections, one vision for 2030 is the use of an artificial immune system as a detector (p. 55). Immune system biology for CB defence generally refers to the medical countermeasures, prophylaxis or pretreatments. The immune system is an autonomous cellular network responsible for defeating pathogens and discriminating between self and foreign microbes.

Realization of such a countermeasure will require multidisciplinary work across the fields of molecular biology, biochemistry, and nanotechnology. Information and computer science will be important as well, including new artificial intelligence systems, algorithms, and integration.

Potential malfeasant cooption of nanotechnology is described in Chapter 4. Understanding potential proliferation challenges and threats that may be wielded through application of CB technologies is critical. The development of countermeasures to those threats is a national concern, and a strong defensive capability is also important as a deterrent.

Chapter 5 describes strategic research priorities and directions. A number of basic research directions are needed to successfully design nanomaterials with structures and functions that both enable revolutionary CB countermeasures and that are appropriate for use in these applications.

Nanomaterials have shown a number of novel physical and chemical properties and functions that are different from those of bulk substances (p. 105).

A cornerstone for all 2030 countermeasures is the ability to understand the relationship between the structure and the function of nanomaterials – whether bionanomaterials, inorganic nanomaterials, or hybrids. Their mechanical, electrical, optical, magnetic, chemical, and thermodynamic properties are very important.

A revolutionary research goal is the low-cost, high volume self-driven production of a nanomaterial or nanodevice (p. 112). Self-recognition technique is a high priority to enable damage-tolerant nanomaterials and systems.

Nanotechnology holds great promise and presents potential threats for US as well as for other countries' efforts in CB defence. Chapter 6 focuses on institutional factors – domestic, international and disciplinary – and policy recommendations. The current technical limitations of nanotechnology are such that the present threat is low (p. 129).

Now is the time to develop and establish strategic approaches and policy to limit or neutralize potential state or terrorist uses, rather than when such research applications appear inevitable. At the end of book, there are four appendices describing the roles and missions of CB defence organizations, attendees at the workshop on nanotechnology for CB defence, workshop programme and acronyms and abbreviations.

This book should be recommended to all those dealing with nano- or biotechnology, as well as to those who are responsible for national defence and homeland security in today's world.

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