

# MATERIALS SCIENCE FOR NATIONAL DEFENSE

*The armed forces of the United States derive its military strength primarily from its advanced personnel training and its large technological advantage over its adversaries. This advantage is in no small part dependent upon the advancements in materials science enabling stealth technology, improved body armor, and faster more robust electronic systems.*

## Materials for Stealth

Various forms of camouflage have been used throughout history, mainly focusing on lowering the visibility of ground forces within their surroundings. However, with the increased reliance on aerial- and water-based vehicles in warfare and the development of improved detection and tracking methods, camouflage requires improved sophistication. Stealth technology, initiated in the 1950's, focuses on reducing the radar cross-section of a vehicle so it appears smaller. This requires modification to the vehicle's shape, but more importantly required the development of radar absorbent material (RAM) that are applied to the vehicle. RAM has enabled the realization of stealth technology for aircraft, sea-faring vessels and UAVs.



The B-2 Spirit Stealth Bomber and the USS Independence – two examples of stealth technology

**Technology improvement:** Stealth technology enabled by the development of radar absorbent materials (RAMs)

**Benefit to the military:** Enables warships and aircraft to reduce radar cross-section so they appear smaller than their true size to enhance military effectiveness

**Benefit to the economy:** Creates new industries, developing new advanced materials for the military

## Materials for Body Armor

With advancements in firearms, the development of lightweight, bullet-proof vests and body armor was required. The development of the polymer Kevlar in 1965 provided a 5x improvement in tensile strength (in comparison to steel on an equal weight basis), providing a material that is flexible enough to be woven into clothing, while providing the protection of thick steel sheets. Further advancements have enabled ultra high molecular weight polyethylene which is 40% stronger than Kevlar and ceramic carbide plates that provide even further protection against high speed projectiles. Thus, materials research has provided the means for protecting our ground personnel on a daily basis.



Marines being issued modular tactical vests at Camp Foster in Okinawa

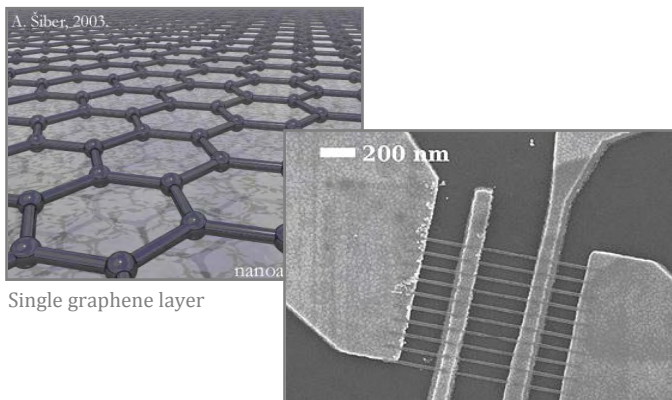
**Technology improvement:** Development of high strength, low weight polymer compounds and ceramics has enabled personal body armor for military personnel

**Benefit to the military:** Drastic reductions in the fatalities for both law enforcement and military service members

**Contribution to the economy:** New fields of polymeric and ceramic materials, creating new industries for both the military and civilian law enforcement

## Materials for the Future

Graphene is a newly realized material made up of single sheets of graphitic carbon. Graphene has many ideal and unique characteristics that not only stretch the limits of current electronic and optoelectronic technology, but also enable completely new applications. Graphene promises high-frequency transistor devices for faster electronics, highly conductive thin films for heads up displays and highly sensitive gas sensors capable of detecting trace quantities of explosives or chemical/biological agents. Single-layer graphene was first fabricated in 2004 and since then multiple avenues for fabrication of graphene materials have been developed. However, large-area, easily manufactured sources of graphene are needed for both device research and mass-production.



Single graphene layer

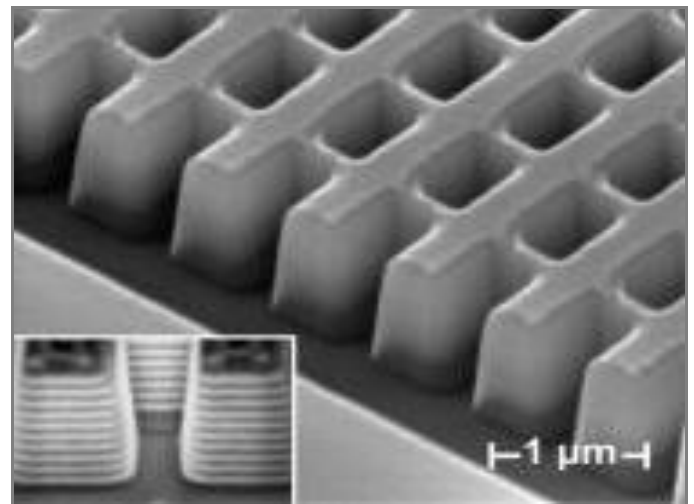
20 nm wide graphene interconnects, fabricated by Georgia Tech

**Potential benefits:** Graphene promises dramatic improvements in integrated circuits, optical emitters and displays, and chemical and biological sensors with improved sensitivity

**Improvement to quality of life:** May lead to higher efficiency and higher speed integrated circuits as well as improved optical and electronic devices

## Metamaterials for Cloaking and Antennae

Scientists and engineers are now demonstrating the ability to create 3-D materials that can bend the path of visible and near-infrared light, making it pass by the material with minimal interaction. This makes the object appear almost invisible to that wavelength of light! These materials could be the basis for revolutionary military technologies – cloaking devices that could render objects invisible to radar or even the human eye, and advanced antenna designs to improve war-fighting capabilities.



Scanning electron microscope image of the first 3-D "fishnet" metamaterial that can achieve a negative index of refraction at optical frequencies, developed by UC Berkeley researchers – the alternating layers form small circuits that can bend light backwards

**Potential benefits:** Materials are being developed that interact with visible and near-infrared light to render objects invisible at that wavelength

**Improvement to quality of life:** New developments are leading to improved resolution imagers, cloaking devices and improved antennas

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## MATERIALS FOR DEFENSE: WHAT IT MEANS TO YOU

*As new materials are developed, new advancements are realized in a wide array of fields. With each such advancement, new industries are created to fabricate the materials, then to manufacture goods based on those materials and eventually to sell those goods to the U.S. government. This process creates jobs for researchers and engineers, as well as factory workers, managers and business leaders. However, this requires federal investment to fund the initial basic research that leads to these developments.*