U.S. Army Research Laboratory

University of Delaware
Center for Composite Materials

U.S. Army Tank-automotive
and Armaments Command

U.S. Army Aviation
and Missile Command

U.S. Army Soldier and
Biological/Chemical Command

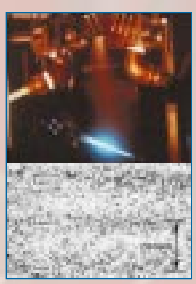
COMPOSITE MATERIALS

ENABLING THE VISION

The U.S. Army Research Laboratory (ARL) plays a lead role in composite materials research and in working with partners throughout industry, academia, and the Defense Department to transition technologies resulting from this research into Army applications. Applying composite materials to emerging weapon system developments is critical to meeting the requirements of the U.S. Army's force transformation and Future Combat Systems — systems that will be more deployable, survivable, lethal, and sustainable with a smaller logistical footprint. The ARL Composite Materials Research Program is developing design, processing, and repair technologies that integrate advanced polymer-matrix and metal-matrix composite materials into new designs of high-performance, lightweight components of weapon systems, including armors, projectiles, munitions, and structures. For mobility and survivability, composite materials are used to make energy-absorbing armor equivalent to steel in ballistic protection but less than one-third the weight. They can also enhance lethality in armament systems through parasitic mass reduction in kinetic-energy tank rounds or through volumetric increases in cargo rounds. Many other applications are possible.

Composite materials consist of two or more physically distinct and mechanically separable materials that are mixed in such a way that the dispersion of one material in the other achieves optimum properties. One of the constituent materials is always a high-stiffness and high-strength reinforcing material that usually consists of fibers but could also be particles. Reinforcing materials, either polymeric or ceramic, have very high strengths and stiffnesses at low densities and allow designers to tailor directional properties exactly where they are needed. The other constituent is a continuous "matrix" material that surrounds the reinforcing material (filling the interstitial space between the fibers or particles) and could be either a polymer, metal, or ceramic material. Heat-based and/or pressure-based processing of the constituent matrix and reinforcing materials using one of a variety of techniques results in a new material with properties superior to the properties of the individual constituents. For example, in polymer-matrix composites the very high-strength but very brittle fibers are combined with chemically resistant but very ductile polymer resin to form a bulk material with a strength and stiffness approaching that of the fibers and with the chemical resistance of the polymer.

Processing Technologies



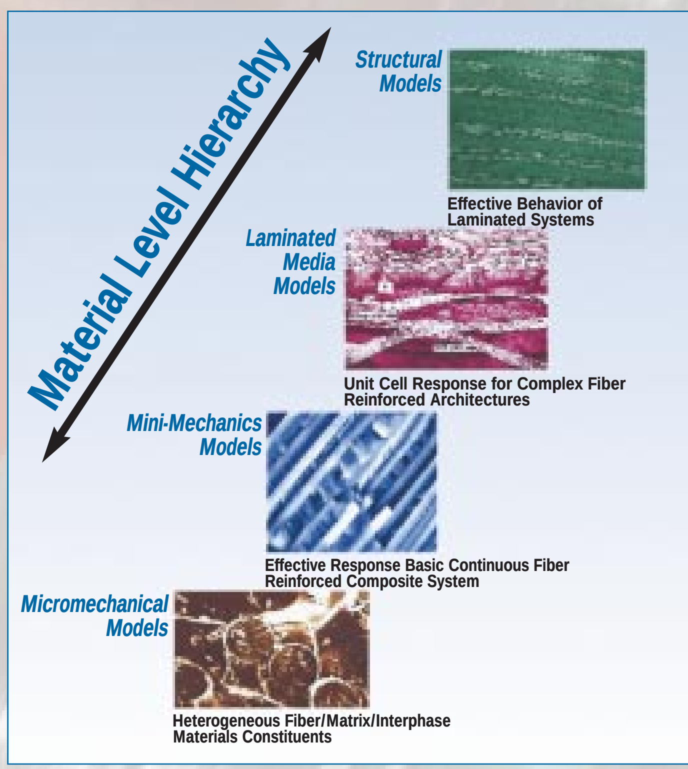
Metal-Matrix Composites

- Pressure-Assisted Casting
- Centrifugal Casting
- Spray Atomization and Codeposition
- Diffusion Bonding

Polymer-Matrix Composites

- Resin Transfer Molding
- Injection Molding
- Autoclave Thermal Curing
- Pultrusion
- Filament Winding
- Induction
- E-beam

Leading-Edge Modeling and Analysis



Virginia Tech University

Tuskegee University

United Defense Limited Partnership

Lightweight Armor

The principal focus of ARL's Composite Armor Program is to develop lightweight high mass-efficiency armor designs for both personnel protection and ground vehicle systems. Multifunctionality is also designed into the armor package to meet specific applications. For example, a new vehicle armor has been designed for ballistic and fragmentation protection, signature management, improved chemical-agent resistance, spall protection, damage detection, and fire, smoke, and toxicity protection built-in to the multifunctional armor package while contributing structurally at a weight reduction of 67% from conventional steel armor/structure. For Future Combat Systems, structural armors are being designed to defeat side, roof, and rear ballistic threats by 2003.

Composite Integral Armors will enable the development of future lightweight combat vehicles.

Advances in composite materials also support developments in lightweight personnel protection.

Lightweight Armaments

Composite materials have proven essential for maximizing the lethality of Army armament systems. The efficiency of composite materials to reduce the weight of sabots for kinetic-energy projectiles was first demonstrated in the development of the M829A1 and M829A2 tank ammunition. While the M829A1 was developed very rapidly using state-of-the-art aluminum sabot technology, the sabot for the M829A2 was designed with graphite fiber-reinforced epoxy material that resulted in a 30% weight reduction in the sabot component. This weight reduction enabled an increased muzzle velocity of approximately 60 m/s, significantly increasing the range and armor-penetration capability of the projectile. The M829A2 is currently in production and is one of the largest users of composite materials in the Defense Department. Composite sabot technology war further developed for the M829E3 program, in which ARL developed improved composite design tools and processing techniques to reduce the weight of the sabot by an additional 30%.

The sabots used in the M829A2 and M829E3 kinetic-energy rounds—fabricated from carbon/epoxy composite—enable significant increases in lethality through reductions in parasitic mass.

Metal-Matrix Composites

The use of metal as a matrix component of a composite material design has great promise for application in weapon systems. Metal-matrix composites have the potential of enabling the development of gun tubes that are 50% lighter than current steel tubes and artillery projectile shell 50% lighter than steel shell and with 17% more cargo capacity than polymer-matrix shell. Metal-matrix composite is the most suitable shell material for emerging and future smart munitions because of its unique combination of light weight and high strength — a metal-matrix shell can withstand three times the load of that of a steel shell at equivalent thickness. Metal-matrix composites also have great potential for application in lightweight ground vehicle structural and ordnance components. Their use as projectile flight control components and pulsed-power materials for electromagnetic guns is also being investigated.

Composite materials are critical to the development of future munitions.

Polymer-matrix and metal-matrix composite cargo shells provide significant logistics savings and lethality improvements compared to standard steel shells.

FOR FURTHER INFORMATION

Dr. Bruce K. Fink

phone: 410-306-0755 • fax: 410-306-0759 • e-mail: bfink@arl.army.mil

Army Research Laboratory
attn: AMSRL-WM-MB
Bldg. 4600
Aberdeen Proving Ground, MD 21005

website: www.arl.army.mil/wmrd
Composite Materials Handbook (MIL 17) Website: mil-17.udel.edu

Composite Materials — Enabling the Vision!