TRANSPARENT ARMOR SYSTEMS

Certain transparent materials can provide effective means of ballistic, thermal, and mechanical protection in equipment that requires transmission of light or other electromagnetic radiation. Examples include faceshields, goggles, vehicle vision blocks, windshields and windows, blast shields, radomes, and aircraft canopies. While transparent armors have been applied in a variety of military and civilian (i.e., law enforcement) systems and equipment, the relatively low mass efficiency of the current technology (i.e., sode-lime glass and polycarbonate laminate systems) and the high cost of advanced transparent armor materials have limited their application. The U.S. Army Research Laboratory (ARL) is engaged joint efforts to develop transparent armor systems that can defeat a wider range of ballistic and directed-energy threats at higher mass efficiencies (i.e., reduced weights and thicknesses) and lower costs. Development partners include the U.S. Army Tank-Automotive Research, Development, and Engineering Center (TARDEC), the U.S. Army Soldier and Biological/Chemical Command (SBCCOM), and the U.S. Army Aviation and Missile Command (AMCOM)—responsible for development of ground vehicles, soldier protection equipment, aircraft, and missiles, all of which require the integration of transparent armor systems. Other partners include industry (e.g., Raytheon, O'Gara Hess), universities, and other Government agencies (e.g., Secret Service, National Institute of Justice).

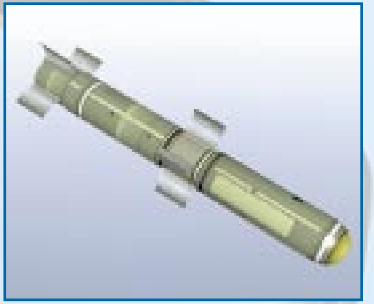
ARL scientists and engineers are investigating advanced ceramic-based and polymer-based systems as transparent armor candidates. Transparent ceramics being researched include single-crystal and polycrystalline materials, such as magnesium aluminate spinel and aluminum oxynitride (i.e., AlON, invented at ARL), which exhibit excellent ballistic resistance, but are very expensive to fabricate. A primary focus is to develop lower cost methods of processing these ceramics into large sections that can be fashioned into specific end items. Less expensive transparent ceramics with varying degrees of ballistic hardness are also being investigated. These include advanced recrystallized glass and high-hardness glass. In addition to ceramics, polymer-based systems are being developed and evaluated. Hybrid composites including a ductile polycarbonate and a hard polymethyl-methacrylate are being optimized with layered configurations for armor systems integration. Novel polymer nanocomposites are being developed and characterized for potential bulk transparent armor applications. The addition of 2 to 5 % nanofillers to the polymers has resulted in significant improvements in physical properties. Characterization of these candidate materials includes structural testing, ballistic testing, and failure analysis. Since most transparent armor systems will require multilayered designs, adhesive bonding materials and techniques are also being studied.

Applications

ELECTROMAGNETIC SPECTRUM	WAVELENGTH	APPLICATIONS
Infrared	700 - 400,000 nm	Radomes and Sensor Windows*
Visible	400 - 700 nm	Face Shields, Windshields Vision Blocks, Blast Shields
Ultraviolet	10 - 400 nm	Radomes and Sensor Windows*

* Tactical and Strategic Missiles
Aircraft, Spacecraft, High-Energy Lasers
Unmanned Vehicles, Battlefield Optics

Soldier Eye/Face Protection



Missile Sensor Windows

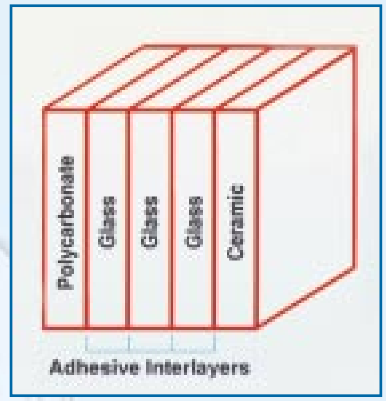
Combat Vehicle Vision Blocks and Sensor Windows

Aircraft Blast Shields and Canopies

Ground Vehicle Windows

Transparent Ceramics for Sensor Windows

ARL-Developed Sapphire-Based Transparent Armor Prototype

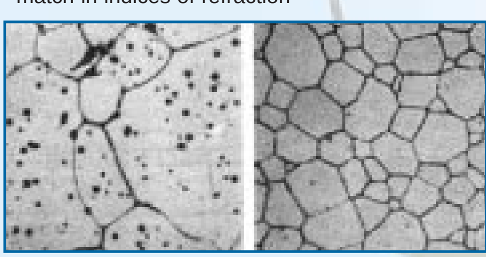


Vehicle Transparent Armor Windshield Laminate System

TRANSPARENT ARMOR CERAMICS AND POLYMERS

What Makes a Ceramic Transparent?

- Microscopic mechanism of light scattering the local refraction at interfaces of 2nd-phase pores or particles
- Degree of transparency depends on size and concentration of pores and particles, and match in indices of refraction



Photomicrographs of Microstructures

OPAQUE

- Pores separated from grain bounderies
- No image transmission (trapped porosity scatters light)

TRANSPARENT

- Minimum porosity
- Clear image transmission
- Optimized processing techniques allow transparency

Transparent Armor Ceramic Candidates

Current Glass/Polycarbonate Laminate Systems

- Soda/lime/silica glass
- Limited change in material design in 25 years

Advanced Single-Crystal and Polycrystalline Materials

- Single-crystal sapphire, AlON, Spinel
- Reduce weight by 30% or more
- Reduce thickness by 40% or more
- Can be fabricated in different shapes and sizes (polycrystalline)
- At present, prohibitively expensive

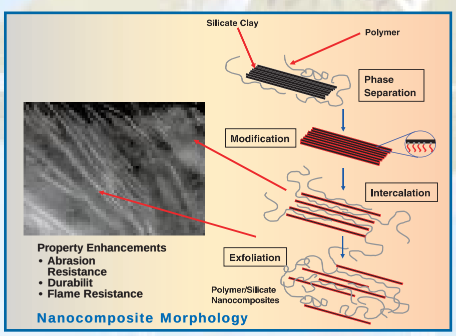
Recrystallized Glass

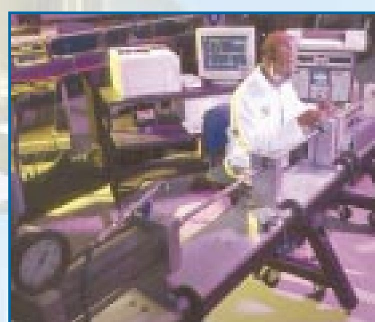
- Effective as aluminum oxide against some threats
- Inexpensive
- Can be fabricated in large sizes
- Limited in thickness, using current processing methods

High-Hardened Glass

- Fused silica, Vycor
- Ballistically superior to soda lime glass
- Could reduce weight and thickness
- Moderately expensive

Novel Transparent Polymers





ARL's Split Hopkinson Bar Facility allows the Mechanical Characterization of Candidate Transparent Ceramics and Polymers

Hybrid hard/ductile nanocomposites are applicable to transparent armor systems that require more robust protection at reduced weights. These novel materials, being developed at ARL, have the potential of providing improved mechanical performance, flame resistance, insensitivity to moisture, barrier properties, thermal robustness, and transparency.

FOR FURTHER INFORMATION

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