

RF Guidance Sensor Windows for High-Speed and Hypersonic Air Vehicles

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PROBLEM STATEMENT

Missile nosecones must withstand very hostile conditions and yet be transparent to the electronics placed behind them. Successful materials have been made from Pyroceram (a material much like CorningWare cookware), fused silica (good thermally and electrically, but soft) and composite materials (carbon-carbon). These have been fine for past generations of slower missiles, but the Pyroceram is no longer available and the fused silica and composites will not survive Mach 4-6 long duration flight conditions so there has been a focus on the design and develop low-cost electromagnetic window/radome concepts that are capable of protecting guidance sensors at speeds of Mach 4-6 at altitudes above 40 kft at cruise for 15 minutes.

The heating effects of a high-speed/hypersonic vehicle (stagnation temperatures up to 2,700°F) associated with high-speed/hypersonic flight pose a difficult environment for sensors. The interface surface or window material must be able to withstand the high temperatures while affording transparency in the sensor's electromagnetic spectrum of operation. Furthermore, the window may need to offer the sensor thermal insulation, cooling or protection from the vehicle's external environment. Lastly, terminal homing seekers tend to have a forward-looking field-of-view, requiring an ogive-shaped window or radome that must endure the high stagnation temperature of these speeds, and the high dynamic pressures (2000-12000 lbs/sq ft). Given the altitudes and speeds that hypersonic vehicles encounter, RF sensors are deemed the most reasonable to perform as guidance sensors. The platforms, which this technology can be used, include legacy and next generation air-to-air, surface-to-air and air-to-ground supersonic/hypersonic missiles.

WHO CAN BENEFIT?

A robust extended range (ER) anti-air missile with engage-on-remote capability is key to providing flexible firepower throughout the battle space using a variety of targeting platforms.

In addition there is ongoing development of missiles designed to counter supersonic maneuvering anti-ship missiles, utilizing larger, more powerful rocket motors for increased range and agility, as well as upgraded aerodynamics using strakes and skid-to-turn in an effort to better protect ships from attacking missiles, aircraft and surface threats.

Launch and leave, air combat missiles that use passive infrared (IR) energy for acquisition and tracking, which can be employed in near beyond visual range (NBVR) and within visual range (WVR) arenas and tactical, air-to-surface missiles designed to home in on electronic transmissions coming from surface-to-air radar systems could benefit from this technology.

BASELINE TECHNOLOGY

The baseline technology, currently used by the Navy, includes fused silica and silicon nitride type radomes. Silicon nitride radomes are expensive with a dielectric constant on the high side (7), and fused silica has low strength at high temperatures making it unsuitable for high speed and high temperature applications. Fiber-reinforced barium aluminosilicate is a low cost alternative to the baseline technology for high-speed radome application.

TECHNOLOGY DESCRIPTION

Advanced Cerametrics, Inc (ACI) has developed a new ceramic material to compete directly with the very high priced reaction bonded silicon nitride (RBSN) and obsolete Pyroceram radomes. ACI has built on earlier work done by NAVSEA to develop a repeatable and inexpensive process to produce radomes from barium aluminosilicate (BAS) using high temperature eutectic BAS fiber as a reinforcement for the BAS matrix ceramics and then, in order to make a sandwich structure, backfilling with an aluminum phosphate coating for erosion resistance and dielectric enhancement.

FAB Table

Feature	Ceramic fiber composite for reinforcement to enhance strength.
Advantage	High temperature capabilities (up to 1500C) with stable and low dielectric properties.
Benefit	Low cost of manufacturing and readily scalable.

Comparison Table

Property	Fused Silica	Pyroceram 9606	Silicon Nitride	BAS
Max. Use Temperature (°C)	1000	1093	1200	1550
Dielectric Constant	3.3	5.5	8	6.5
Dielectric Loss	2x10 ⁻⁵	3x10 ⁻⁴	8x10 ⁻³	3x10 ⁻⁴
Toughness (Mpa-m ^{0.5})	0.8	2.5	3.5-5.0	1.8
Four-Point MOR (MPa)	48	300	620-1100	110
CTE (x10 ⁻⁶ °C ⁻¹)	0.6	5.7	3.0-3.4	2.3
T. Conductivity (W/m °K)	0.8	3.3	9-30	1.5-2
Cost	Low	High	High	Low

CURRENT STATE OF DEVELOPMENT

Raytheon is conducting high temperature tests of BAS coupons and this data will be used to design the initial test radomes using BAS fiber reinforced coated BAS for the first round of evaluations in this program.

The accomplishments so far in this effort include:

- Successfully produced 100% monoclinic thermal shock resistant BAS suitable for radome application.
- Manufactured of BAS fibers for radome reinforcement.
- Developed a process to manufacture fiber composite radomes.
- Evaluated preliminary mechanical and dielectric properties.
- Successfully built demonstration sized ogive shaped BAS fiber reinforced BAS radome prototypes.

Currently the technology is at a TRL 5.

To be accomplished:

- Compositional study to improve strength and reduce dielectric constant
- Dielectric and mechanical property tests
- Specialized impact tests
- High temp mechanical & dielectric property tests

The aforementioned milestones should bring the technology to a TRL 6.

