ATEM OXYGEN: a real threat for spacecraft

In space, solar radiation has enough energy to break apart oxygen (O2) molecules and create atomic oxygen (O). This very abundant particle, particularly present at altitudes from 180 km to 650 km, erodes and damages many materials including most polymers and even some metals including silver.

The lower the altitude, the higher the ATOX density and its effects. Multi-Layer Insulation (MLI) blankets, solar panels and wires and cables located on spacecraft exteriors are all susceptible to this threat. ATOX erosion limits the service life of the components and therefore of the mission. Protection against atomic oxygen is, therefore, a key challenge for the space industry.

Materials used on spacecraft exteriors are exposed to a variety of environmental threats that can cause significant degradation. In Low Earth orbit (LEO), these threats include radiation, ultraviolet (UV) radiation, thermal cycling, micrometeoroids, orbital debris impact, and especially atomic oxygen (ATOX). In order to limit the effects of ATOX which erodes and damages materials including polymer insulated wires and cables, Axon Cable has developed a new electrical insulation system called Radatox™.

Alternative to protective coatings such as aluminized SiOx, ITO or PTFE coated polyimides can offer Intrinsically bulk resistant to ATOX.

Proven by independent laboratories to have superior ITAR-free. Easy to strip.

40% mass saving compared to solutions such as PTFE or PFA.

Twice as flexible as polyimide tapes with similar thickness.

Proven by independent laboratories to have superior ATOMX performance.

10 times more resistant to ATOX compared to typical perfluoropolymers (FEP, PFA, PTFE) which are highly sensitive to the combined effects of ATOX, UV radiation and thermal cycling, limiting their use for long lifetime missions.

100 times more ATOX-resistant than polypyrymes such as Kapton® (1) (Radatox™ ATOX erosion yield: < 2 x 10⁻¹⁰ cm³/atom).

Intrinsically bulk resistant to ATOX. Alternative products based on protective coatings such as aluminized SiOx, ITO or PTFE coated polyimides can offer improved protection, but the whole ATOX resistance can be compromised by the presence of microscopic pinholes or defects in these thin coatings from micro-meteoroids or even during manufacturing or handling stages.

Radatox™ insulated wires and cables have undergone tests including Atomic Oxygen erosion and ageing in space-like simulated conditions (radiation, UV and thermal cycling) led by independent laboratories including ESA ESTEC TEC-QEE lab.

Radatox™ based pressure sensitive tapes (PST) survive the harsh, on-ground evaluation test plan without any noticeable cracking or degradation of properties after 200 Mrad irradiation followed by UV exposure up to 6000 ESH and finally 100 thermal cycles in vacuum between [-150 +150]°C. Thermo-optical properties have also been measured at each of the ageing stages.

How ATOX damages materials

A spacecraft in LEO orbits (Earth at a velocity of about 8 km/sec (nearly 30,000 km/hr)). At such high speed, the collision with atomic oxygen atoms results in erosion by thermo-oxidation due to the high impact energies involved. Eroded particles can further condensate and contaminate functional surfaces of the satellites including optics.

LEO Satellites are not the only ones exposed to this threat. Any satellite designed to fly at any time in low orbits is concerned. This includes missions in Polar orbits (POL), Highly Elliptical Orbit (HEO) and Geostationary Transfer Orbits (GTO).

With the new generation of GEO satellites equipped with electrical propulsion for Electrical Orbit Raising (EOR) from LEO to final GEO altitude, combined radiation and ATOX levels are a real challenge. Very Low Earth Orbits (VLEO) missions with altitudes below 550km are also concerned by this problem as the ATOX density increases.

Atmospheric erosion model

Research has shown that if one assumes a constant solar flux, the ATOX density will reach a steady state at 1.7x10⁻²⁸ cm⁻³/atom m⁻². The erosion rate is then found by solving the following conservation equation.

Erosion velocity field

Erosion of a satellite's surface is the result of the interaction of atomic oxygen with the material. The erosion rate can be described by the following equation:

Erosion yield:

Erosion model:

Erosion is a function of the atomic oxygen concentration and the material's erosion coefficient. The erosion coefficient is defined as the mass of material removed per unit area per unit time.

Erosion cross sections:

The erosion cross sections are determined by the interaction of atomic oxygen with the material. These cross sections can be calculated using various models, such as the Mott cross section or the Gourdin cross section.

Erosion rate:

The erosion rate is the product of the atomic oxygen concentration and the erosion cross section.

Erosion depth:

The erosion depth is the integral of the erosion rate over time.

Materials comparison: Radatox™ at the forefront

Typical LEO mission examples

- Erosion fluence: 1.07x10⁻²² cm⁻²
- Polyimide tape: > 200,000 µm
- Radatox™: 1,000 µm

Estimated end of life ATOX erosion depth

- LEO: 100 µm
- Radatox™: 1,000 µm

Applications & Products

New Radatox™ solutions are already available for round wires and cables. Flat Flexible Cable (FFC) prototypes with Radatox™ protection have also been developed.

Principal potential applications for Radatox™ insulation include wires and cables, antennas, solar array cabling, adhesive tapes and a potential further application in Heli Thin films (725µm) and Pressure Sensitive Tapes (PST). Radatox™ combined with low outgassing space grade adhesives.

Alternative ATOX Resistant Solutions

Radatox™ is an optimized, mass saving solution for spacecraft operating in LEO orbits, particularly those below 600 km. But for missions for which mass saving and material erosion are less critical, Axon Cable also offers ESA qualified wires and cables (ESCC 3901/018 and ESCC 3901/024) which already present some resistance to ATOX. This mainly concerns satellites in higher altitudes where ATOX density is lower or for shorter mission lifetimes (less than 5 years).

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