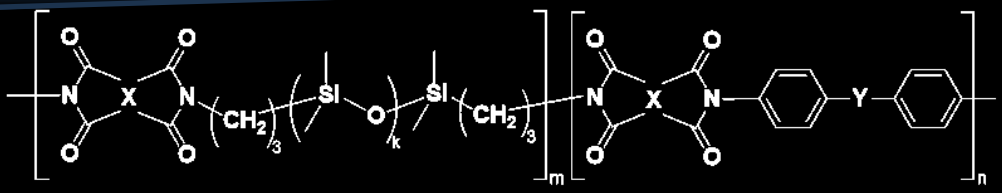
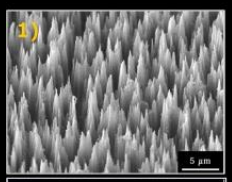
NIPPON STEEL Chemical & Material Co.,Ltd. ChemMat

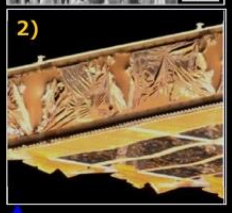
Atomic-Oxygen (ATOX) Tolerant Film "Siloxane Block Polyimide BSF series" for Low and Very Low Earth Orbit Satellite

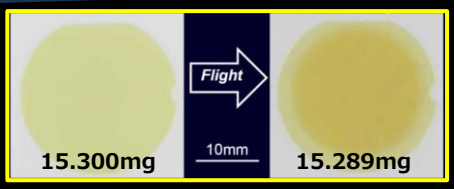
BSF Series Typical Molecular Structure



Atomic-Oxygen Tolerant Mechanism







High-energy UV light

Oxygen molecule (O_2) O O

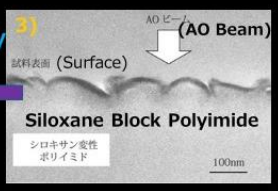
Generation of Atomic Oxygen

O

Atomic Oxygen (AO)

AO is the main component at altitudes of 200~600 km

Satellite Velocity (8km/s)



The case of typical polyimide used on the satellite	The case of BSF series used on the satellite
Decomposition CO_2 CO, etc Erosion Typical Polyimide Typical Polyimide	Generation of SiO_2 Layer & Prevent oxidation by AO Self-Organized & Self-Healing Function Oxidation of Siloxane unit BSF Series SiO_2 Layer (about 10nm) BSF Series

1) H. Shimamura, T. Nakamura, Mechanical properties degradation of polyimide films irradiated by atomic oxygen, Degradation and Stability Volume 94, Issue 9, September 2009
2) B. A. Banks et al., "Issues and Consequences of Atomic Oxygen Undercutting of Protected Polymers in Low Earth Orbit," NASA/TM-2002-211577, 2002
3) MATERIAL STAGE Vol.10, No.10 2011

Self-Organization of AO-tolerance layer

Only Conventional PI	BSF serises	AO tolerance Inorganic coating on conventional PI	AO tolerance silicone coating on conventional PI
Microdebris / Meteoroids AO CO_2 CO PI more erosion	Microdebris / Meteoroids AO SiO_2 layer BSF Regeneration of SiO_2 layer Even if the SiO_2 layer is destroyed, BSF reacts with AO and regenerates the SiO_2 layer .	Microdebris / Meteoroids AO CO_2 CO Inorganic coating Silicone coating PI erosion If the fracture stays within the AO-resistant coating layer, AO resistance is retained, but if the fracture extends beyond the AO-resistant coating layer to the PI layer, erosion proceeds.	

Low & Very Low Earth Orbit Exposure Tests by JAXA

2009 ISS "KIBO"
JEM/MPAC & SEED
(8.5months)

2012 "SDS-4"
Thermal control material
demonstration experiment

2015 "ExHAM"

2017 "SLATS"
Exposure testing of materials
in very-low earth orbit
(attitude : 160km)

Application Example

★ Multi-layer insulation (MLI)
★ Substrate of Solar Panel
★ For anti-debris & deorbit of Satellite

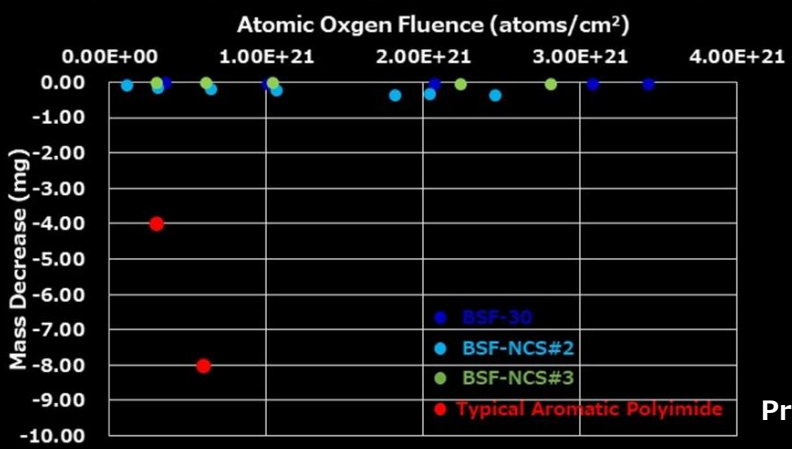
Adapted Product

Drag Sail

Provided by AXELSPACE

Atomic-Oxygen Tolerant Test Results

Results of mass change of PI by AO irradiation



Provided by JAXA

Typical Properties of BSF series

Item	unit	BSF-30	BSF-NCS#2	BSF-NCS#3
Glass transition temp (Tg)	℃	187	176	140
5% Thermal decomposition (Td5)	℃	456	462	456
coefficient of thermal expansion(CTE)	ppm/K	100	68	92
Young's Modulus	GPa	1.4	1.9	1.7
Elongation	%	15	11	45
Tensile Strength	MPa	53	87	59
Cyclic siloxane Outgassing components	–	Contain (D10-D17)	None	None