

Aging effect of Zylon

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Background

High-field magnets call for efficient reinforcement materials. Zylon, a poly-p-phenylene-benzobisoxazole (PBO) fibers, possesses an ultimate tensile strength of 5.8 Gpa and modulus about 180~280 Gpa. The high strength and modulus make Zylon a excellent candidate for internal reinforcement of high-field magnet coils. However, the property stability of Zylon has not been studied in details. We studied aging effect on the tensile strength and structure off Zylon stored up to 8 years.

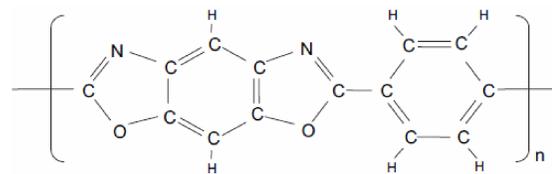
Conclusion

- ❖ Zylon shielded from light remains stable and has no strength degradation after stored 8 years.
- ❖ Light-aging causes surface defects formation and molecular chain scission, and strength degradation in Zylon.
- ❖ The transition from well-oriented crystal structure to random amorphous structure is responsible for the defects formation .

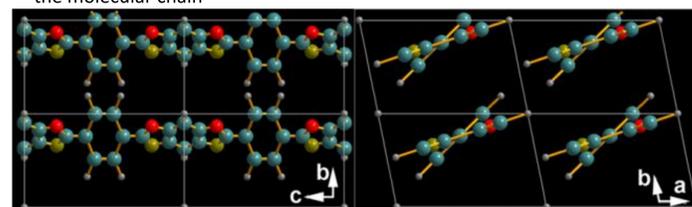
Acknowledgment

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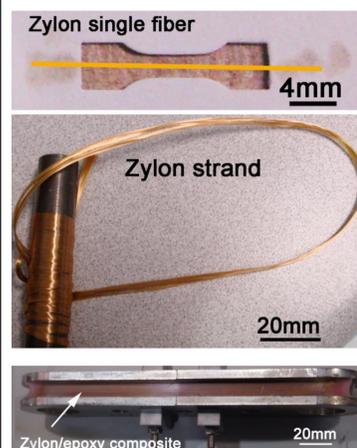
Zylon molecular structure



Chemical structure of poly(p-phenylene-2,6-benzobisoxazole) PBO
Trade mark : Zylon
The excellent tensile properties are determined by the covalent bonds in the molecular chain



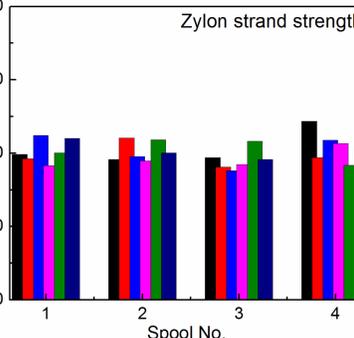
Tensile samples



Zylon stored in dark

Age (year)	Length (mm)	Mass (g)	Calculated cross-section area (mm ²)
Spool #1 8	322	0.0090	0.0179
Spool #2 6	877	0.2875	0.2101
Spool #3 4	169	0.0184	0.0694
Spool #4 1	322	0.0354	0.0704

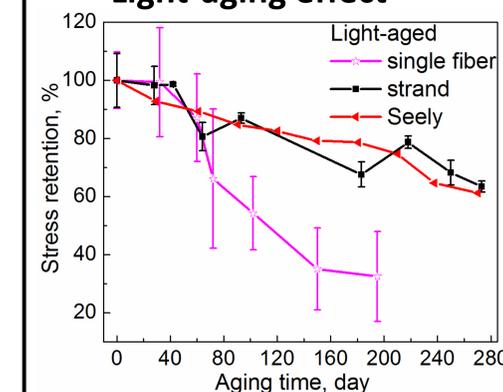
Fracture strength of Zylon strand aged in dark bag. The strength variance from spool #1, #2, #3 and #4 are 7.8%, 6.2%, 7.4% and 9.1%, respectively.



	Aver. Fracture Strength (GPa)	
	In-dark strand	In-dark single Fiber
Spool #1(8-year old)	4.00±0.31	5.55±.62
Spool #2(6-year old)	4.12±.26	5.86±.73
Spool #3(4-year old)	3.86±.27	5.71±.42
Spool #4(1-year old)	4.20±.38	5.38±.39

- No strength degradation
- Single fiber strength appears higher than strand strength, the reasons is that the tensile load is not shared uniformly by Zylon fibers in the wrapped-strand or composites.
- Radius difference between the inner layer and outer layer fibers during surrounding the pin or winding fixture causes outer layer fibers more stretched under tension, and initiates the fracture earlier.

Light-aging effect

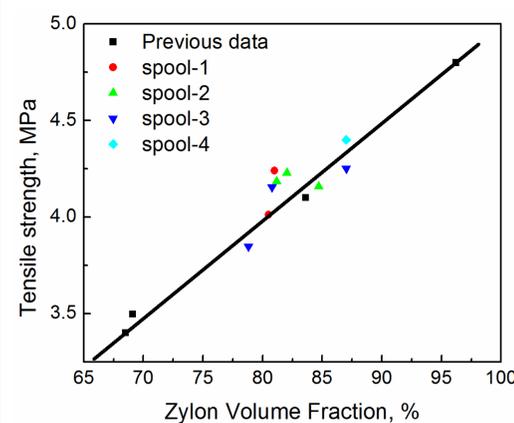


Strand: 6 Month, lost approximately ~ 37%
single fiber: After 80 days, rapid strength degradation

Mechanical Characterization

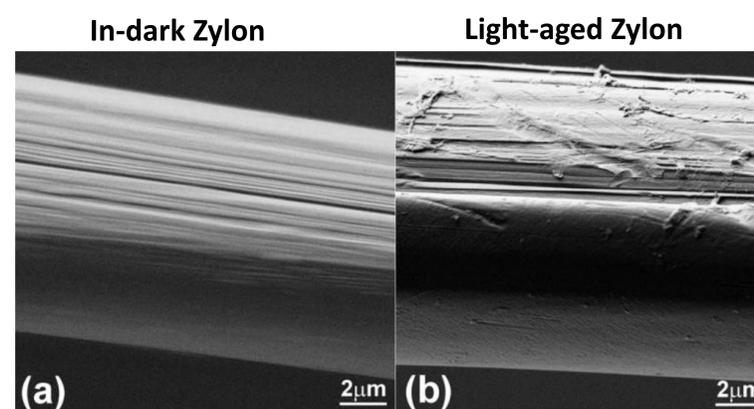
Winding pre-stress (Mpa)	Est Fibre Vol (%)	Ultimate tensile strength (Gpa)
1283	81.00	4.24
1283	80.56	4.15
1283	80.27	3.92
1268	80.56	4.01
1268	79.66	4.11
1268	82.32	4.23
887	81.26	4.43
887	81.82	4.49

Winding per-stress in the range of 887 Mpa~ 1283 Mpa has no effect to increase the fibre volume fraction further.



Higher Zylon volume fraction, higher the ultimate tensile strength

SEM Observation

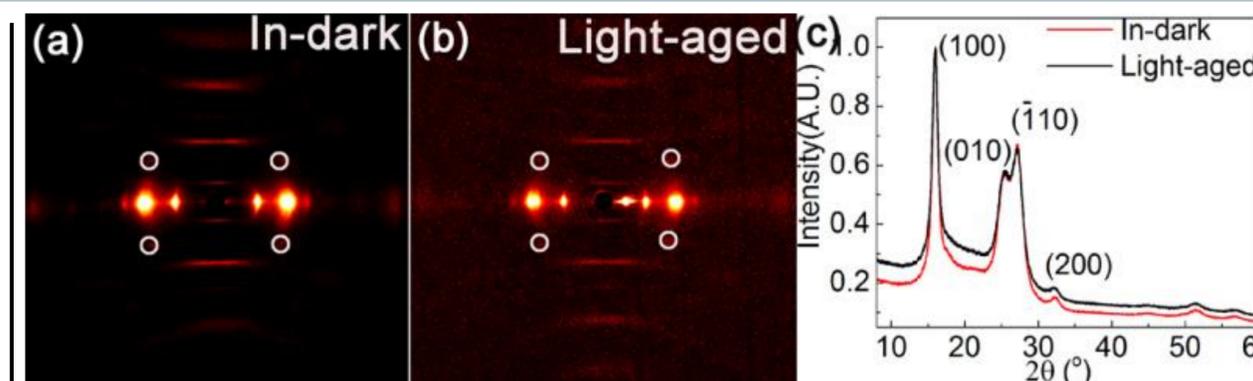


(a) fiber was built up of a parallel array of identical fibrils.

(b) light-aged Zylon, lots of scratch-like defects and debris.

Laboratory lighting lead to chain scission and the ordered molecular chain scission is responsible for the form of defects and debris.

Wide-angle X-ray



Common feature:

- sharp equatorial spots,
- non-periodic layer lines
- off-axis, first order (hkl) reflections.
- The narrow spread of the arcs indicates crystallites are highly oriented along the fibre axes.
- The streak-like layer lines indicate the random axial disorder in the Zylon crystal structure.
- The off-axis, first order (hkl) reflections indicate that there is a level of three-dimensional crystallinity.

Difference: the background of light-aged Zylon is higher than that of the in-dark one.
One of possible reasons may be related to the crystallinity imperfection in Zylon. The poorer the quality of the crystallinity, the higher the background.