1. Appendix

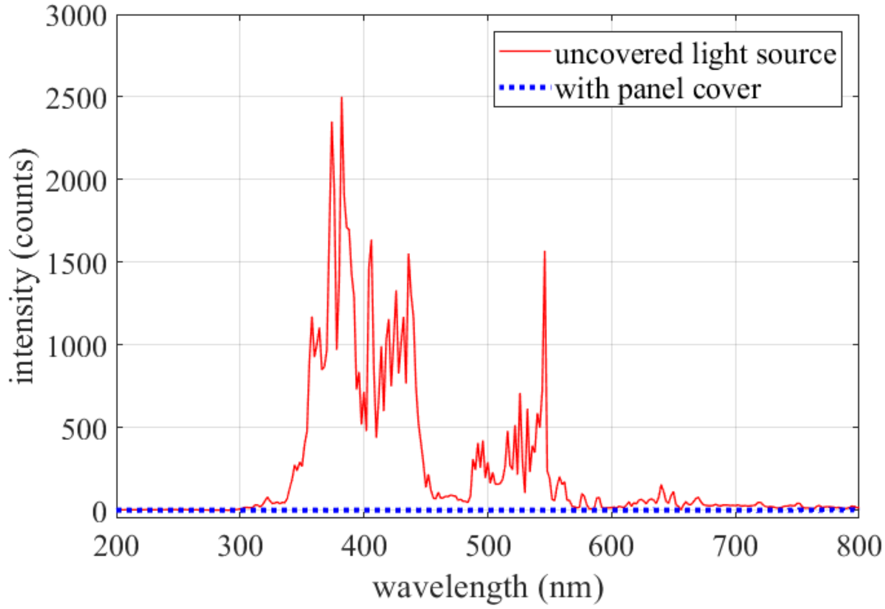

Figure A1. Transmission of ultraviolet and visible light through a typical armor panel covering, using a uniform high intensity light source known as the NIST SPHERE (Simulated Photodegradation via High Energy Radiant Exposure), which is described in [49].

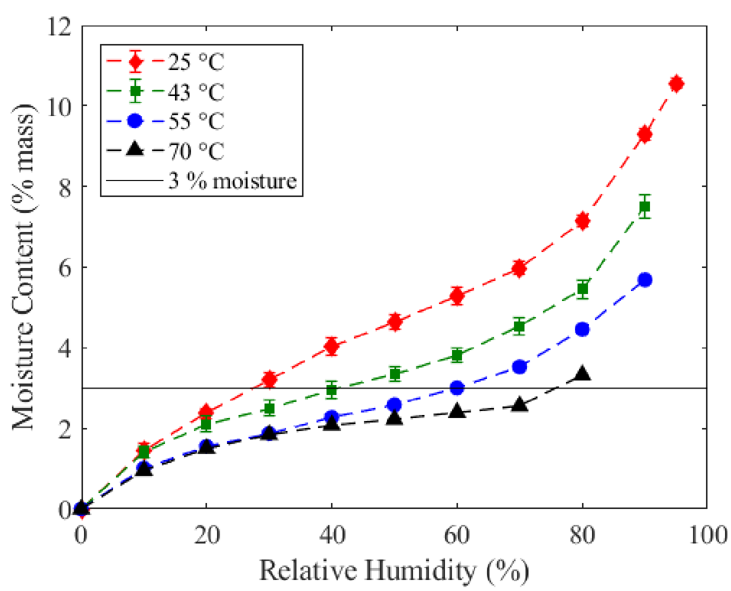

Figure A2 Equilibrium moisture sorption isotherms of Aramid A at four temperatures, with 3 % moisture content indicated by the solid gray horizontal line. The 25 °C and 43 °C curves are the average of four replicates, and the error bars represent the standard deviation of the measurements. Due to experimental difficulties, only one replicate could be measured at each of the 55 °C and 70 °C temperatures, and error bars could not be generated.

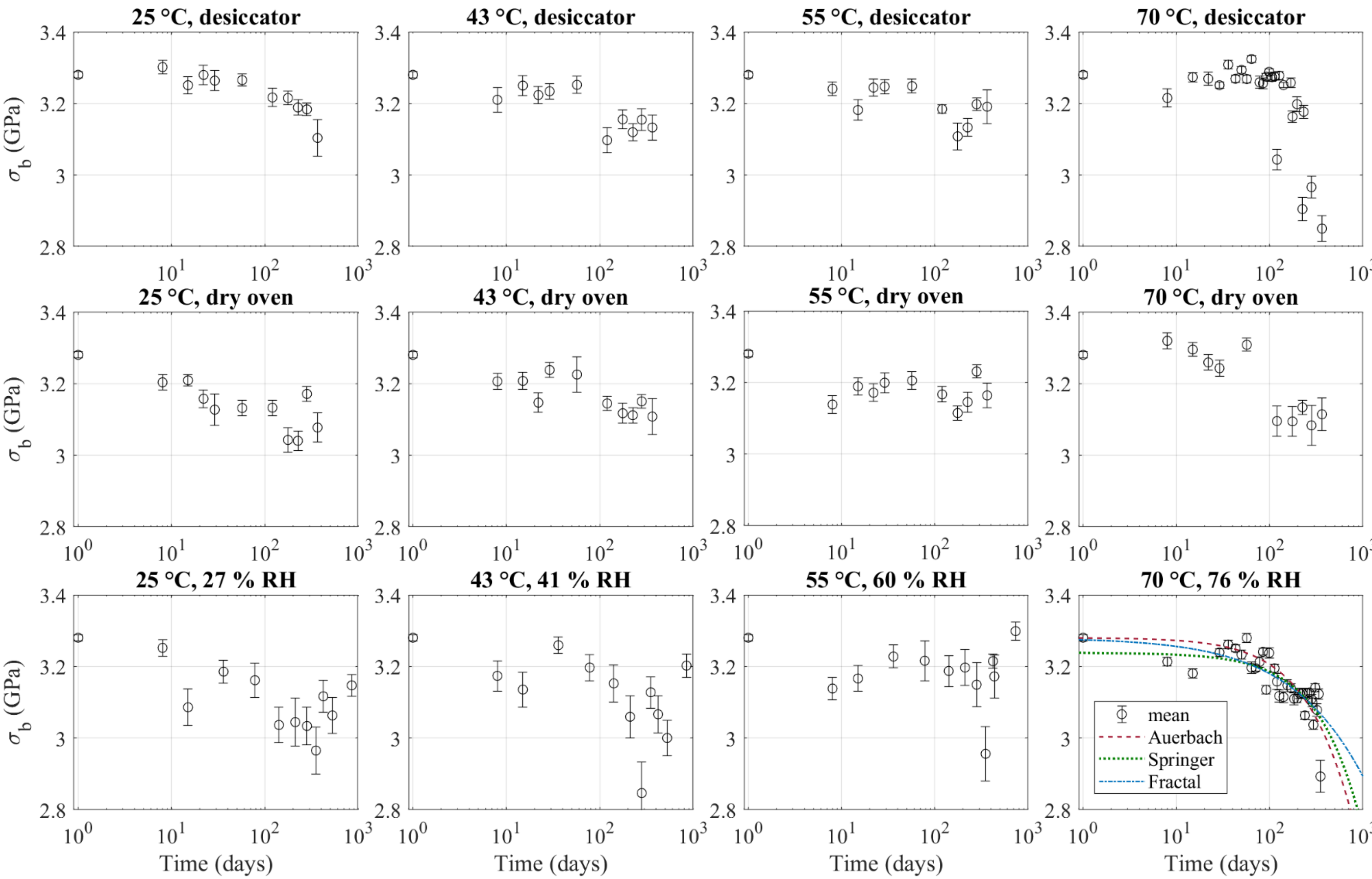

Figure A3 Aramid A mean failure strength values ($\sigma_b(t)$), with error bars of one standard error. The colored lines in the graphs of the rightmost column represent the model fits to the data.

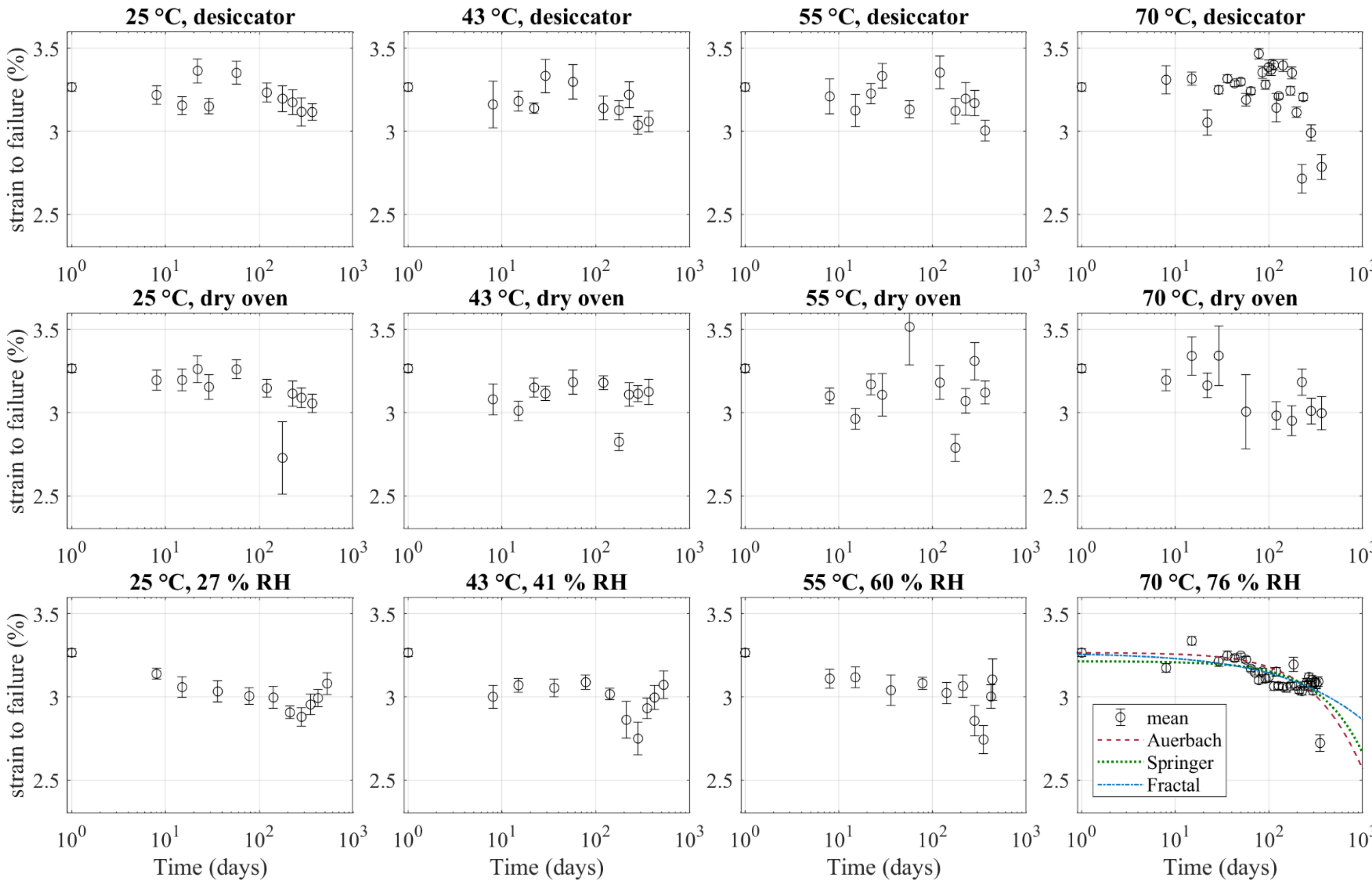

Figure A4 Aramid A mean strain to failure values, with error bars of one standard error. The colored lines in the graphs of the rightmost column represent the model fits to the data.

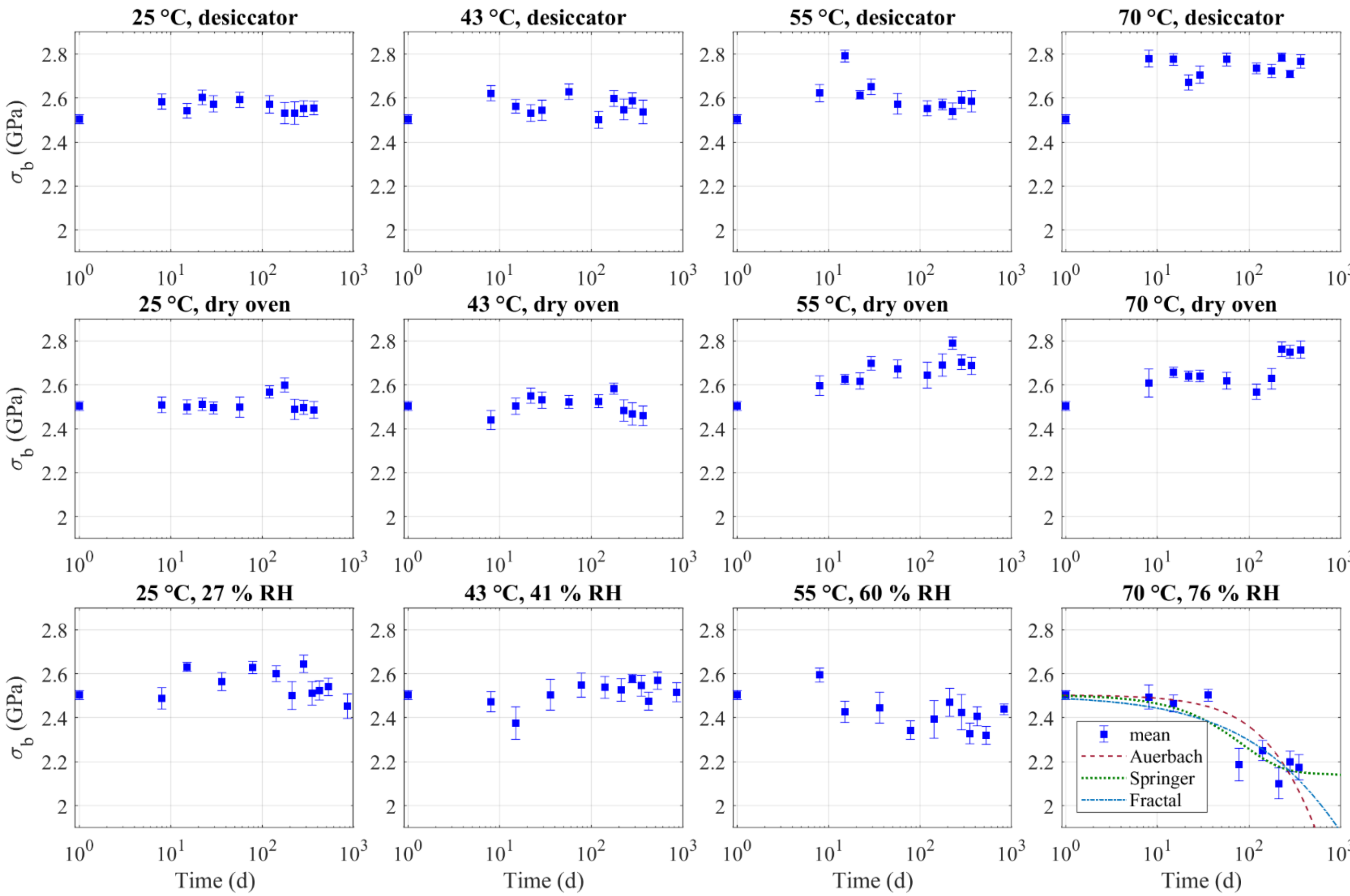

Figure A5 Aramid B mean failure strength values ($\sigma_b(t)$), with error bars of one standard error. The colored lines in the bottom right graph represent the model fits to the data.

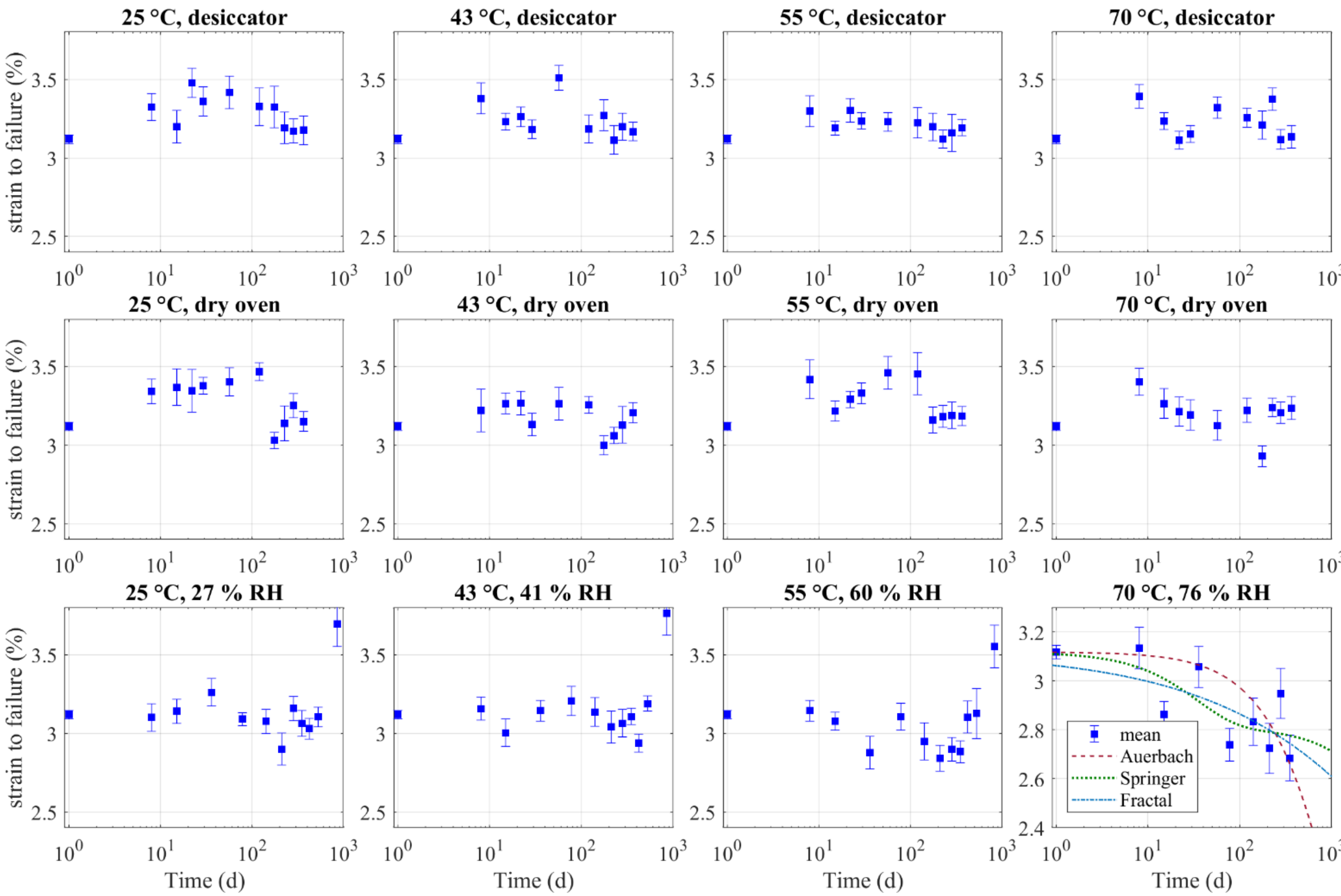

Figure A6. Aramid B mean strain to failure values, with error bars of one standard error. The colored lines in the bottom right graph represent the model fits to the data.

Effects of moisture content on tensile strength

For aramids, tensile strength is dependent on the moisture content. The moisture content, and thus strength, is both dependent on the temperature (lower humidity, higher strength at higher temperatures) and the relative humidity (higher strength at lower humidity). This helps to explain the Aramid B data, as the strength increases after exposure to dry conditions. This strength increase cannot be simply attributed to random error, as the unaged data consists of 84 specimens, while all other datapoints are only the average of at most 15 specimens. The initial moisture content in Aramid B is unknown, and has changed since this study started, but can be inferred based on the strength results after exposure to varying conditions. The 25 °C dry oven condition (with approximately 50 % RH) keeps the material at approximately the same moisture content, resulting in a constant strength. The desiccators drive out moisture, increasing the strength, as do the dry ovens at the higher temperatures where the relative humidity is less.

In the humid conditions for Aramid B, there is a slight overall strength increase at the 25 °C 27 % RH condition after day 10, implying that the initial moisture content in the fibers was more than 3 %. For the yarn exposed to the 43 °C 41 % RH condition, there are no statistically significant strength changes. The yarn exposed to the 55 °C 60 % RH condition exhibited a higher strength after 7 d exposure, but thereafter the strength is always lower than the initial strength, culminating in a decrease to 93 % of the initial strength after 525 d of exposure. The 70 °C 76 % RH condition shows no initial increase in strength and decreased to 87 % of the initial strength after 350 d. One interpretation of these results for Aramid B is that the initial moisture content of the yarn was greater than 3 %. In conditions where the relative humidity is low there is an initial strength increase, as moisture is driven out. At the high humidity, high temperature conditions this strength increase is counteracted by material degradation, which occurs at a faster rate at higher temperatures and humidity.

For Aramid B the strain to failure increased for the desiccator conditions, where moisture is being driven out of the fibers. The yarn exposed to the dry oven conditions exhibit a strength increase in the first 100 d for all conditions. The strain response to the hydrolytic conditions shows no change for yarns exposed to the 25 °C and 43 °C conditions, a decrease of less than 10 % at the 55 °C 60 % condition, and a decrease just over 10 % at the 70 °C 76 % condition. This matches the strength decrease seen for this material.

Under all conditions, Aramid B increases in strength less than 110 %, and this strength increase is a function of humidity and temperature. Aramids A and C had fully acclimated (over several years) to laboratory humidity before the ageing study was started, such that any moisture remaining in the yarns from manufacturing had ample time to dissipate before any testing or ageing began. Since Aramids A and C do not show a tensile strength increase while Aramid B does, it is hypothesized that this effect is due to residual moisture remaining in Aramid B from manufacturing, which is supported by the observed increase in ultimate tensile strength (see Figure A5) for the "desiccator" and "dry oven" conditions. Specimens of Aramid A were placed in the 70 °C desiccator condition for 1 week and 2 weeks and compared using Wide Angle X-Ray Scattering (WAXS) to unaged specimens and the remaining specimen of Aramid A that had been exposed to these conditions at the beginning of the study (in 2012). No changes in the crystal structure or crystal orientation were detected, as seen in Figures A7 and A8. To further investigate this moisture phenomenon, Aramid A was exposed to 25 °C, 80 % RH for 19 weeks, and immediately tested upon extraction. The ultimate tensile strength decreased slightly from 3.28 GPa to 3.24 GPa, which is statistically significant based on a Kolmogorov–Smirnov test for $\alpha = 0.05$.

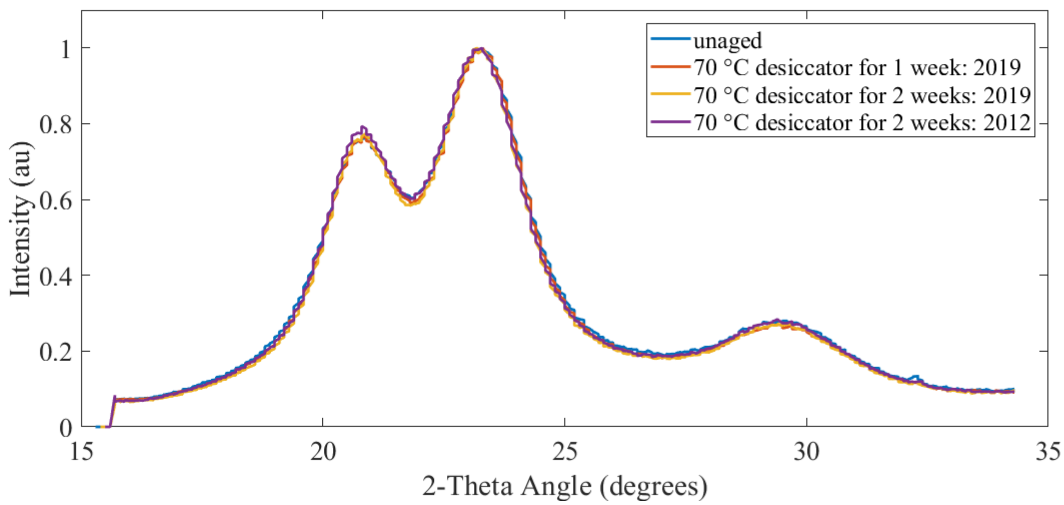

Figure A7 WAXS spectra for Aramid A

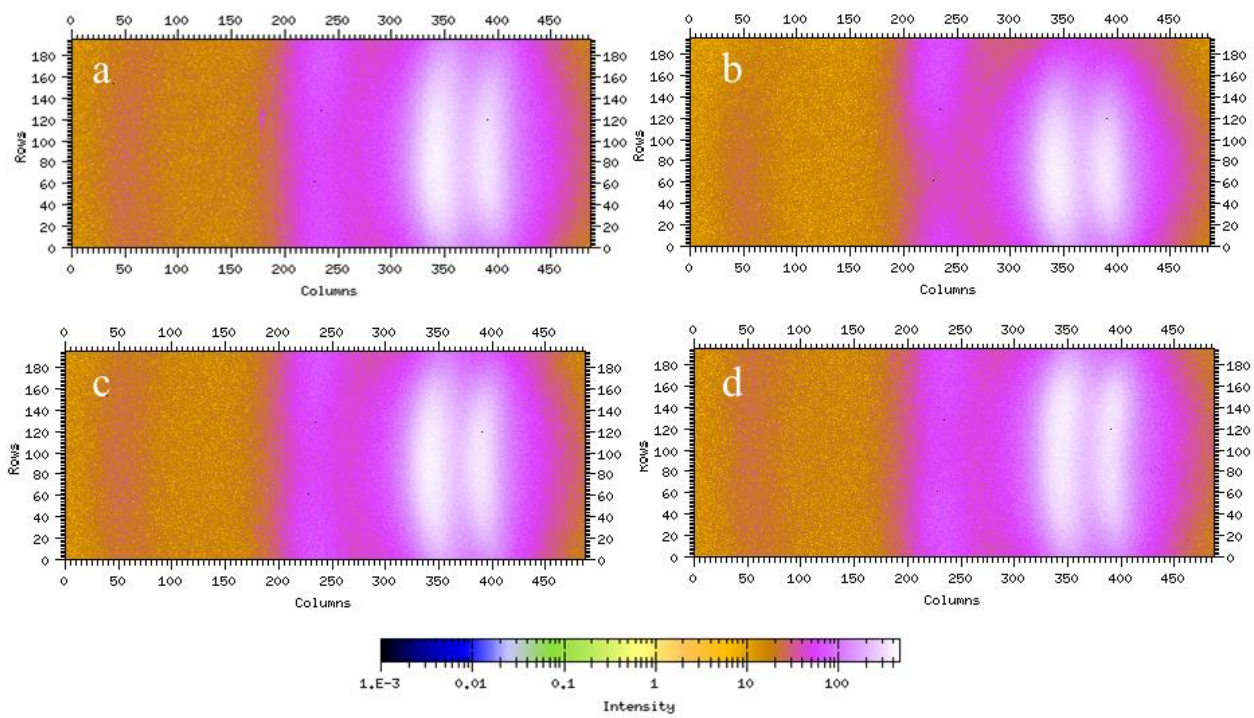

Figure A8 2D WAXS spectra for Aramid A, where a) is the unaged control, b) was aged for 1 week in the 70 °C desiccator in 2019, c) was aged for 2 weeks in the 70 °C desiccator in 2012, and d) was aged for 2 weeks in the 70 °C desiccator in 2019

Table A1 R^2 values for model fits

		Auerbach	Springer	Fractal
Aramid A	strength	0.19	0.22	0.22
	strain to failure	0.08	0.10	0.11
Aramid B	strength	0.29	0.34	0.32
	strain to failure	0.12	0.18	0.17
Aramid C	strength	0.15	0.25	0.24
	strain to failure	0.14	0.16	0.17