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Effects of Ultraviolet-C Germicidal Irradiation on Aircraft Cabin Interior Materials

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16. Abstract

As a result of the coronavirus disease 2019 (COVID-19) public health emergency, aircraft owners and operators may find it necessary to increase the frequency with which they disinfect aircraft interiors. The disinfectant procedures included conventional chemical liquid disinfectants and Ultraviolet-C (UV-C) germicidal irradiation. In the first two phases of this project, we evaluated the effects of liquid chemical disinfectants on materials used in aircraft seats and other interior applications. In the third phase of this project, long-term exposure to UV-C irradiation on various aircraft cabin interior materials has been investigated. In this study, eight different materials typically used in aircraft interiors, including seats, were considered. Three UV-C irradiation configurations with peak emissions at 222 nm, 253.4 nm, and 280 nm were selected. The test materials were subjected to accelerated UV-C aging tests at multiple cumulative dosage configurations, representing a single daily exposure over a time period of one, four, and eight years. Post the UV-C exposure, the materials were evaluated for change in weight, color, flammability performance, and mechanical properties.

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Acronyms

Acronym	Definition
ASTM	American Society for Testing and Materials
AVET	Advanced Virtual and Engineering Testing Laboratories
CFR	Code of Federal Regulations
CMH-17	Composite Materials Handbook-17
DUV	deep-UV
DIC	digital image correlation
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
LED	light-emitting diode
NIAR	National Institute for Aviation Research
SAE	Society for Automotive Engineers
UV-C	ultraviolet-C
UVGI	ultraviolet germicidal irradiation

Executive summary

The outbreak of a novel coronavirus disease (COVID-19) in December 2019 resulted in a pandemic bringing operations across the globe to a halt. To reduce virus transmissions during air travel, the aviation industry implemented additional cleaning and disinfectant procedures along with existing standard practices. However, the frequent and extensive use of disinfectant products established a need to understand the long-term effects of disinfectant procedures on aircraft interiors. This study explores the impact of long-term exposure to Ultraviolet-C (UV-C) irradiation on various aircraft cabin interior materials.

With the support of SAE Aircraft Seat and SAE Cabin Interior committees, the researchers identified materials typically used in aircraft seating and cabin interiors such as plastics, honeycomb, and composites. The plastics considered were Kydex 6565, Boltaron 9815E, Lexan XHR, Boltaron 9815N, ULTEM™ 9075, and ULTEM™ 9085. Honeycomb material consists of Nomex® core with fiberglass/phenolic resin as the face sheet. The composite material considered was Fiberglass G-10/FR4. This project evaluated three UV-C irradiation configurations with peak emissions at 222 nm, 253.4 nm, and 280 nm. The virus inactivation dose was determined based on the literature review and varied for each wavelength configuration. With the virus inactivation dose required for single UV-C treatment as the baseline dosage, three cumulative dosages were computed representing one treatment per day everyday for one year, four years, and eight years. The materials were then subjected to accelerated aging tests using 222 nm, 253.4 nm, and 280 nm UV-C lamp sources at various cumulative dosage configurations. Post the UV-C exposure, the materials were evaluated for change in weight, color, and mechanical properties.

Plastic materials were evaluated for the effects of UV-C irradiation on tensile properties, honeycomb materials were evaluated for flexure properties, and fiberglass materials for short-beam strength properties. The first batch of specimens consisting of Kydex 6565, Lexan XHR, Boltaron 9815N, and Boltaron 9815E, when exposed to 253.4 nm light at a 1-year cumulative dose, did not present a significant change in color and mechanical properties when compared to the pristine specimens. Hence, for the 222 nm and 280 nm configurations, the plastic specimens were not subjected to a 1-year cumulative dose and were only subjected to the 4,380 mJ/cm^2 (4-year) and 8,760 mJ/cm^2 (8-year) cumulative dose configurations.

Table 1 summarizes the percentage difference in average yield stress and average tensile strength between pristine and UV-C aged plastic specimens. Compared to pristine specimens, Kydex 6565 aged at 222 nm - 8,760 mJ/cm^2 dosage configuration, presented a reduction between 10% to 15% in average yield stress. From the average tensile strength comparison, the specimen configurations that showed a reduction between 10% to 20% are Kydex 6565 at both dosages of

222 nm and the second and third dosages of 253.4 nm, the first dosage of Lexan XHR and the second dosage configuration of Boltaron 9815N.

Table 2 summarizes the percentage difference in mechanical properties between pristine and UV-C aged honeycomb and fiberglass specimens. Honeycomb specimens at 253.4 nm - 14,600 mJ/cm^2 (1-year) showed a reduction between 5% to 10% in average maximum load, while the 4-year and 8-year configurations resulted in less than 5% reduction when compared to pristine specimens. Due to the limited sample count, further conclusions could not be made on this variation. Additional research should be performed to better understand this behavior. Fiberglass specimens at all the wavelength and dosage configurations showed less than a 5% reduction in average short-beam strength properties compared to their pristine counterparts.

Table 1. Results summary – Plastics

Percentage Difference Compared to Pristine Specimens – Yield Stress (Avg.)								
Wavelength Configuration	Cumulative Time (years) - One dose/day	Cumulative Dosage (mJ/cm^2)	Kydex 6565	Boltaron 9815E	Lexan XHR	Boltaron 9815N	Ultem 9075	Ultem 9085
Avg. Pristine (psi)	N/A	N/A	7548.1	5521.3	10328.4	6636.3	11776.0	10496.1
222 nm	Four	4,380	-4.12	2.16	-4.24	-8.39	4.59	3.69
	Eight	8,760	-10.39	1.88	1.25	-9.61	3.87	3.62
253.4 nm	One	14,600	-2.61	2.45	2.10	-3.97	N/A	N/A
	Four	58,400	-5.53	4.06	0.80	3.46	4.65	3.29
	Eight	116,800	-5.04	5.54	1.52	-2.15	4.27	6.01
280 nm	Four	54,750	-3.90	2.63	1.72	-1.71	4.12	4.39
	Eight	109,500	-4.51	3.26	-1.09	-1.90	4.05	4.37

Percentage Difference Compared to Pristine Specimens – Ultimate Tensile Strength (Avg.)								
Wavelength Configuration	Cumulative Time (years) - One dose/day	Cumulative Dosage (mJ/cm^2)	Kydex 6565	Boltaron 9815E	Lexan XHR	Boltaron 9815N	Ultem 9075	Ultem 9085
Avg. Pristine (psi)	N/A	N/A	6680.5	5180.4	10147.8	5263.5	9722.5	8748.4
222 nm	Four	4,380	-16.49	-9.25	-10.47	-9.66	9.27	4.59
	Eight	8,760	-16.55	-6.24	0.04	-12.33	12.22	9.79
253.4 nm	One	14,600	-4.36	-3.14	-3.72	-2.49	N/A	N/A
	Four	58,400	-13.28	-6.79	0.70	-2.07	-1.65	5.42
	Eight	116,800	-19.20	-6.67	-2.18	-7.16	11.11	8.74
280 nm	Four	54,750	-9.12	0.26	-5.21	-6.42	7.78	4.26
	Eight	109,500	-9.40	-0.37	-7.09	-6.18	12.89	8.62

Percentage difference compared to pristine specimens

< 5%

< between 5% to 10%

> 10%

Table 2. Results summary – Honeycomb & Fiberglass

Percentage Difference Compared to Pristine Specimens				
Wavelength Configuration	**Cumulative Time (years) - One dose/day**	**Cumulative Dosage (mJ/cm^2)**	**Honeycomb – Maximum Load (lbs.)**	**Fiberglass – Short Beam Strength (psi)**
Avg. Pristine	**N/A**	**N/A**	152.4	9250.1
222 nm	**One**	**1,095**	-2.45	-0.91
	Four	**4,380**	-2.75	-0.16
	Eight	**8,760**	-0.22	-0.75
253.4 nm	**One**	**14,600**	-9.66	-0.56
	Four	**58,400**	-1.28	-0.80
	Eight	**116,800**	-0.24	-0.23
280 nm	**One**	**13,687.5**	5.52	-2.21
	Four	**54,750**	-3.47	-0.91
	Eight	**109,500**	-0.74	-0.26

Percentage difference compared to pristine specimens

< 5%

< between 5% to 10%

> 10%

1 Introduction

In December 2019, an outbreak of a new type of coronavirus was identified in the province of Hubei, China. Since that time, the outbreak has reached most countries worldwide (Panait, 2020). To contain the virus transmissions during air travel, Centers for Disease Control and Prevention (CDC) recommended guidelines for airline operators with respect to disinfecting airplane interiors (CDC, 2022; FAA, 2020). This resulted in the airline industry implementing meticulous and frequent interior disinfection procedures to give passengers confidence that they would not contract the virus while in an aircraft. However, the requirement for excessive use of disinfectants raised concerns about its potential negative impacts on the performance of cabin materials, thus leading to this research. Without the existence of proper guidance on methodologies to identify the potential impact of disinfectants on aircraft interiors, it became an urgent issue to determine what materials to test, what disinfectants to consider, how to prepare the test articles, and finally, how to perform the test. Using engineering judgement and airline background information assumptions, the collaborative research team rapidly developed a methodology.

1.1 Overview

This research aimed to identify and evaluate the effects of long-term disinfection procedures on the mechanical and physical properties of aircraft interiors. The disinfection procedures evaluated in this research program include chemical and UV-C disinfection techniques. The first phase of this study focused on evaluating the effects of chemical disinfectants on aircraft seating interiors. In this phase, 17 aircraft seating materials were considered and evaluated for the effects of 5 liquid disinfectants on their mechanical and physical properties (Olivares, et al., 2021).

This report presents the findings from the third phase of the study carried out with a focus on the effects of UV-C disinfection procedures. Current efforts were focused on the materials used in aircraft seats and cabin interiors. The materials were selected in conjunction with the SAE Aircraft Seat Committee and SAE S-9 Cabin Safety Provisions Committee. Selected materials were subjected to accelerated aging using UV-C. The material properties, color, and weight change obtained from aged specimens were then compared and analyzed against control specimens. The total UV-C exposure dosage represents one treatment per day, for one year, four years, and eight years.

This report discusses the methods used to age the test specimens with various UV-C wavelength configurations, followed by the discussion on physical and mechanical properties changes. The results of this work may be used by SAE Committees, other standards organizations, design approval holders, operators, or regulators to create guidelines on the use of UV-C disinfection and application procedures that would minimize the impact on the mechanical characteristics of aircraft interior components.

1.2 Material selection

The materials selected for this study are typical aircraft seat and cabin interior materials. Table 3 presents the materials evaluated in this project and their application in aircraft interiors. These materials were chosen based on the potential targeted surfaces for disinfection in aircraft cabin interiors. Only polymer materials from phases one and two were selected for phase three because they are most likely affected by UV exposure.

Table 3. Materials evaluated and their application in aircraft interior

Material Type	**Application in Aircraft Interior**	**Material Name**	**Test Method and Standard**
Plastics	Armrests and shrouds	Kydex 6565	Tensile – ASTM D638
		Boltaron 9815E	
		Lexan XHR	
		Boltaron 9815N	
		ULTEM™ 9075	
		ULTEM™ 9085	
Honeycomb	Floor, ceilings, kitchen walls, cabinets	Nomex® core with fiberglass/phenolic resin	Flexure – ASTM D7249
Composite	Used as face sheets in honeycomb sandwich structures such as floors, ceilings, kitchen walls, cabinets	Fiberglass G-10/FR4	Short-beam shear – ASTM D2344

1.3 UV-C irradiation configurations

Three different wavelength configurations evaluated in this study are 222 nm, 253.4 nm, and 280 nm. They were chosen based on the current and potential future applications in UV-C germicidal irradiation (UVGI). UV-C light sources with peak emissions at 253.4 nm is the conventionally used UV-C disinfection technique. There are several commercially available 253.4 nm UV-C systems that are used for aircraft disinfection (Honeywell, 2022; Aero HygenX, 2022). The second configuration chosen was far UV-C 222 nm which has gained increased attention since the Covid-19 outbreak. Available data suggests that unlike the 253.4 nm light source, the 222 nm light source could inactivate viruses without causing DNA lesions, erythema, photo-keratitis, and other associated effects of 253.4 nm light to biological tissue (Boeing, 2022). The third configuration chosen was the UV-C light source with peak emissions at 280 nm. This technology is currently used in aviation, automotive, and other residential and commercial applications (AquiSense, 2022).

1.4 Preparation of test articles

Raw materials (plastics, honeycomb, and composite) were machined following their respective test standards. Before the specimen's exposure to UV-C light, the weight and color of each specimen were documented. The specimens were then subjected to accelerated aging tests using different light sources for 222 nm, 253.4 nm, and 280 nm configurations. Specimens were exposed to UV-C light with varying dosages and, consequently, different durations. Three cumulative dosage configurations were considered representing a single treatment of UV-C dose every day for one year, four years, and eight years. The single treatment of UV-C dose depends on the dose required to inactivate the virus and varies based on the wavelength configuration. Detailed information regarding the baseline dose, cumulative doses, UV-C light sources, intensity, and exposure time are presented in Section 4.

2 Material information

In this investigation, three different material types used for aircraft seating and cabin interior were selected. These materials included six plastics, one honeycomb, and one fiberglass laminate, as shown in Figure 1. All the materials treated with UV-C exposure were evaluated for mechanical properties, change in weight, and color.

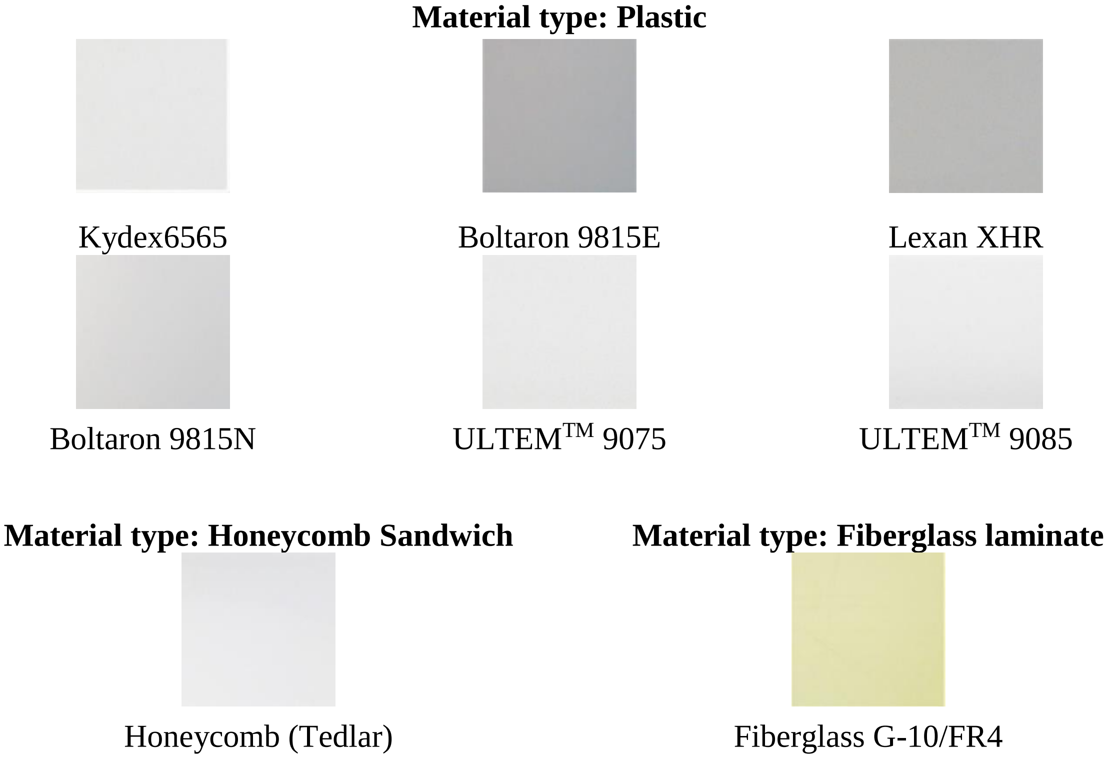

Figure 1. Materials evaluated for accelerated aging tests with UV-C exposure

3 Ultraviolet-C dosage configurations

This study considered three different UV-C wavelengths with varying configurations of dosage. The three UV-C wavelengths of interest are 222 nm, 253.4 nm, and 280 nm. The efficiency of UV-C radiation to inactivate microbes depends on the ultraviolet dosage. This dosage varies based on the UV-C wavelength configuration and was determined based on the literature review. According to the International Ultraviolet Association (IUVA), at 253.4 nm wavelength, the UV-C dose necessary to inactivate the virus on flat and ideal surfaces should at least be 40 mJ/cm^2 (IUVA, 2022). Based on this baseline dosage, test specimens were exposed to three different cumulative dosages, as presented in Table 4. The cumulative dosages were computed to represent one treatment per day every day for one year, four years, and eight years.

UV-C lamps with emissions at wavelengths such as 222 nm and 280 nm are also in-use for germicidal inactivation (U.S. Food & Drug Administration, 2022) (Inagaki, Saito, Sugiyama, Okabayashi, & Fujimoto, 2020). The literature research conducted to determine the appropriate UV-C dosage levels at 222 nm was concluded to be 3 mJ/cm^2. This dosage level was observed to effectively inactivate 99.7% of the virus on surfaces (Kitagawa, et al., 2020). Based on this baseline dosage, the impact of 222 nm UV-C light on test specimens would be evaluated for three different cumulative dosages, as shown in Table 4.

The light sources available for 280 nm wavelength are UV-C light emitting diodes (LEDs). Because of their novel functionality in surface disinfection, there is limited research available in the public domain. The study conducted to determine the effects of wavelength on the disinfection of human coronavirus (HCoV-OC43) reported an irradiation dose of 6-7 mJ/cm^2 for 3-log inactivation at 279 nm (Gerchman, Mamane, Friedman, & Mandelboim, 2020). The virus evaluated in this study was the human coronavirus HCoV-OC43 which was considered a surrogate for SARS-CoV-2. Another research publication discusses the rapid inactivation of SARS-CoV-2 with deep-UV (DUV) LED irradiation (Inagaki, Saito, Sugiyama, Okabayashi, & Fujimoto, 2020). This study evaluated the antiviral efficacy of irradiation by DUV-LED at a wavelength range of 280±5 nm. The SARS-CoV-2 virus was considered for this study. The virus was irradiated for 1, 10, 20, 30, and 60 seconds with each dosage time corresponding to an irradiation dose of 3.75, 37.5, 75, 112.5, and 225 mJ/cm^2. A 99.9% inactivation rate was reported for the dosage time beginning at 10 seconds. Due to the evaluation of SARS-CoV-2 and the higher dosage configuration that can be considered conservative in this study, the dosage value for the 280 nm configuration in the present research was chosen as 37.5 mJ/cm^2. Three cumulative dosages corresponding to one, four, and eight years at one treatment per day are evaluated as presented in Table 4.

Table 4. UV-C wavelength and their representative cumulative dosages

UV-C Wavelength (nm)	**Baseline Treatment Dose (mJ/cm^2)**	**Cumulative Time (Years)**	**Cumulative Dosage at one treatment/day (mJ/cm^2)**
222	3	One	1095
		Four	4380
		Eight	8760
253.4	40	One	14600
		Four	58400
		Eight	116800
280	37.5	One	13687.5
		Four	54750
		Eight	109500

4 UV-C test setup

This section discusses the UV-C test setup, light sources, their irradiance, and the exposure duration for the three wavelength configurations. Test specimens were subjected to accelerated aging experiments under UV-C exposure based on the cumulative dosages discussed in Section 3. Each test configuration was employed with light sources that emit peak emissions at the intended wavelength. Based on the intensity of the UV-C light source and the predetermined cumulative UV-C dosage, the exposure duration was computed using Equation 1. Light intensity was measured with a UV-C radiometer placed at the same location as the specimens.

$$\text{UV Dose (mJ/cm}^2\text{)} = \text{UV Intensity (mW/cm}^2\text{)} \times \text{Exposure Time (seconds)} \quad (1)$$

4.1 Wavelength configuration: 222 nm

Care222 B1 Illuminator modules acquired from Ushio (Ushio, 2022) were used for the accelerated aging tests at 222 nm UV-C configuration. Care222 B1 illuminator module is a filtered 222 nm UV-C light source with excimer lamps intended for microbial inactivation applications. The module is equipped with a band-pass filter which filters out harmful wavelengths above 230nm. In this study, four illuminator modules were used for the specimen aging, as shown in Figure 2.

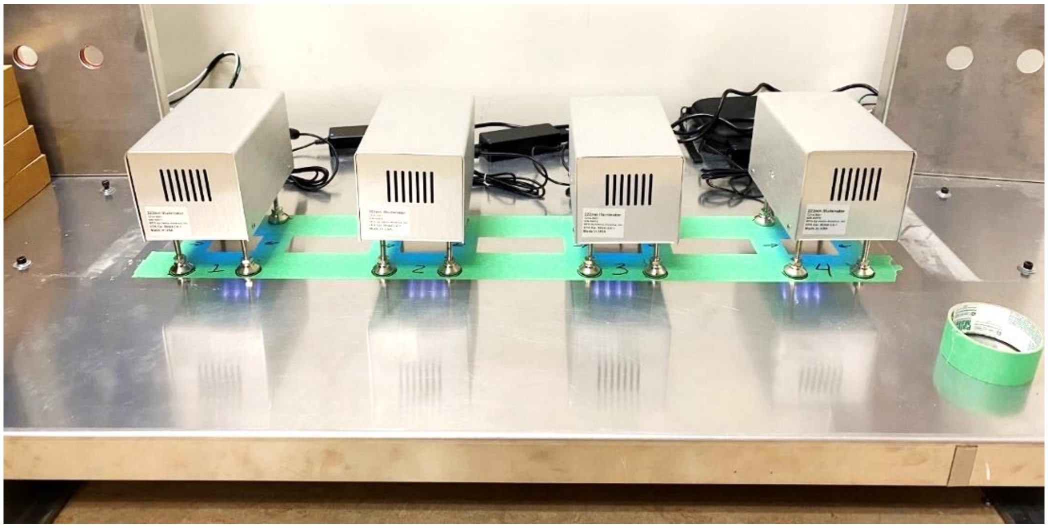

Figure 2. UV-C test setup with Ushio Care222 nm lamps

A UV-C radiometer was used to record irradiance at four different points within the exposure area of each module. Based on the average irradiance obtained and the cumulative UV-C doses, each configuration's exposure duration was computed and presented in Table 5.

Table 5. UV-C exposure parameters: 222 nm

Average Intensity (mW/cm^2)	**Cumulative Dosage (mJ/cm^2)**	**Exposure Duration (minutes)**
0.78	1,095	23.5
	4,380	94
	8,760	188

The first batch of specimens consisting of Kydex 6565, Lexan XHR, Boltaron 9815N, and Boltaron 9815E, when exposed to 253.4 nm light at a 1-year cumulative dose, did not present a significant change in color and mechanical properties when compared to the pristine specimens. Hence, for the 222 nm configuration, the plastic specimens were not subjected to a 1-year cumulative dose and were only subjected to the 4,380 mJ/cm^2 (4-year) and 8,760 mJ/cm^2 (8-year) cumulative dose configurations. However, honeycomb and composite specimens were exposed to all three cumulative dose configurations.

4.2 Wavelength configuration: 253.4 nm

For the 253.4 nm configuration, while the first batch of specimens was subjected to UV-C exposure using the Rayonet reactor (Rayonet, 2022), the second batch of specimens was aged using LightTech lamps (LightTech LightSources, 2022). Plastic specimens such as Kydex 6565, Lexan XHR, Boltaron 9815N, and Boltaron 9815E were aged using the Rayonet reactor with support from Honeywell Aerospace (Honeywell Aerospace, 2022). ULTEM™ 9075, ULTEM™ 9085, honeycomb sandwich, and composite specimens were aged with 253.4 nm lamps from LightTech with support from Aero HygenX (Aero HygenX, 2022).

The first batch of test specimens subjected to UV-C exposure at 253.4 nm was aged in a Rayonet reactor. A Rayonet reactor is a photochemical reactor equipped with mercury vapor UV-C lamps along the circumference of the reactor barrel, as shown in Figure 3. The reactor base consists of a fan that maintains the temperature during exposure within 10° C of room temperature. A UV-C radiometer placed at the same distance as the specimens was used to measure the light intensity. Measurements were recorded all around the circumference to obtain an average intensity value.

Based on the average intensity value and the predetermined UV-C dosage, the exposure durations were computed using Equation 1 and are presented in Table 6.

253.4 lamps inside the Rayonet reactor barrel

Test specimens taped to the pipe and suspended into the reactor barrel

Figure 3. UV-C test setup with 253.4 nm lamps – Rayonet Reactor

Table 6. UV-C Exposure Parameters: 253.4 nm – Rayonet Reactor

Average Intensity (mW/cm^2)	**Cumulative Dosage (mJ/cm^2)**	**Exposure Duration (minutes)**
13.2	14,600	18.4
	58,400	73.6
	116,800	147.2

During the setup, test specimens were taped on the surface of a PVC pipe and placed at the center of the reactor barrel as shown in Figure 3. The distance between the surface of the pipe and the lamps was approximately two inches. The aging began with the lamps emitting light at 253.4 nm wavelength with the gradual rotation of the pipe to ensure all the specimens reached the desired dosage levels. Taping the specimens on the pipe only allows one surface of the specimens to be exposed to UV-C irradiation while leaving the other surface unexposed. To have the entire specimen aged, the specimens were flipped after the first treatment and followed with another treatment to complete the aging process.

The second batch of specimens (ULTEM™ 9075, ULTEM™ 9085, honeycomb sandwich, and composite) were aged using 253.4 nm lamps from LightTech LightSources. Two lamps were used for the aging process, with the specimens placed 12 inches below the lamps on a table. The test setup is shown in Figure 4. The irradiance was measured at four different points in the exposure area using a UV-C radiometer to obtain an average irradiance value. The average irradiance, dosage, and corresponding exposure duration are presented in Table 7.

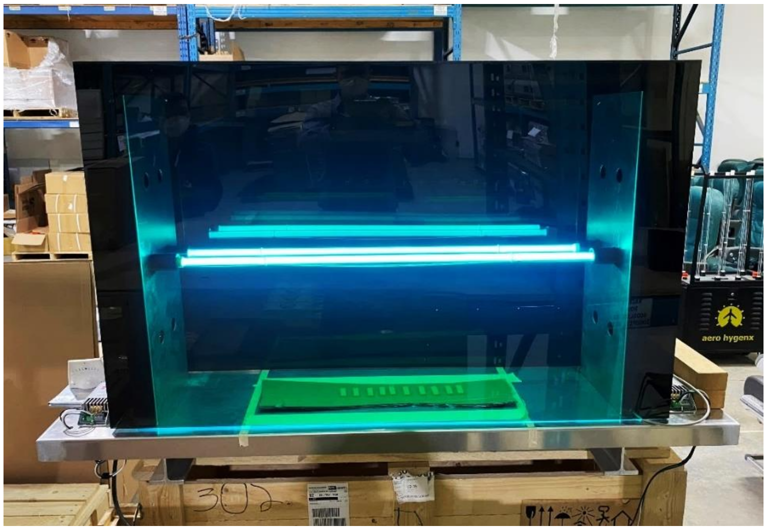

Figure 4. UV-C test setup with 253.4 nm lamps – LightTech

Table 7. UV-C exposure parameters: 253.4 nm – LightTech

Average Intensity (mW/cm^2)	Cumulative Dosage (mJ/cm^2)	Exposure Duration (minutes)
5.28	14,600	46
	58,400	184
	116,800	368

To be conservative, in the initial phase of the research study, the plastic materials were subjected to UV-C exposure on both the faces of the specimen. However, in real-world applications, generally only one face of the interiors would be exposed to disinfection while the other face remains unexposed to surface contamination. Following this approach, only one face of honeycomb and fiberglass specimens was exposed to UV-C light.

At a cumulative dose of 14,600 mJ/cm^2, the first batch of plastic specimens aged using the Rayonet reactor showed no significant discoloration or change in mechanical properties compared to their pristine counterparts. Hence, ULTEM™ 9075 and ULTEM™ 9085 were only aged under cumulative doses of 58,400 mJ/cm^2 and 116,800 mJ/cm^2. Honeycomb sandwich and composite specimens were subjected to all three cumulative dosage configurations.

4.3 Wavelength configuration: 280 nm

Aquisense 24G UVinaire lamp module units were used for the accelerated aging tests at 280 nm UV-C configuration (AquiSense, 2022). UVinaire lamps are UV-C disinfection systems equipped with LEDs. In this study, four lamp modules were used for the specimen aging as shown in Figure 5. Average irradiance was computed using a UV-C radiometer with measurements from four different locations within the exposure area of each unit. The average irradiance, cumulative UV-C doses, and the corresponding exposure duration for each configuration are presented in Table 8. Similar to the 222 nm wavelength configuration, the plastic specimens were only exposed to cumulative doses of 54,750 mJ/cm^2 (4-year) and 109,500 mJ/cm^2 (8-year) for the 280 nm configuration. However, honeycomb and composite specimens were exposed to all three cumulative dose configurations.

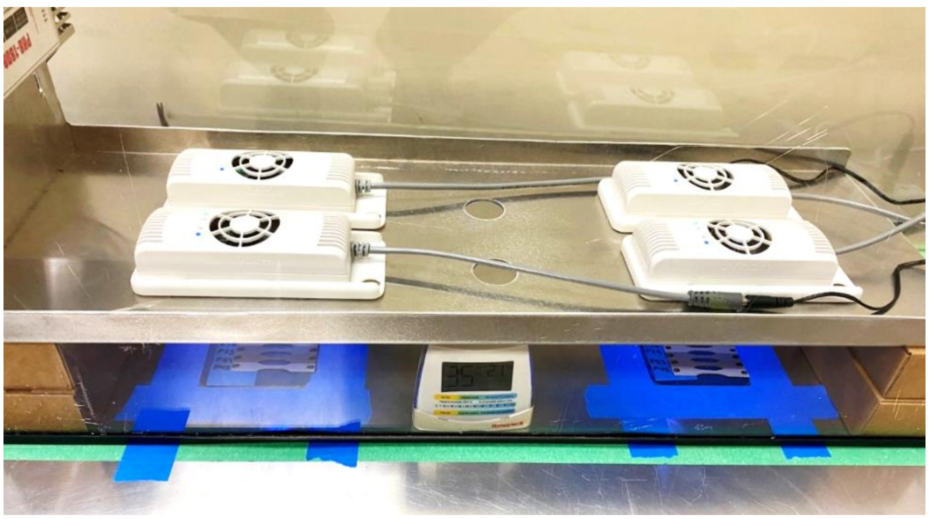

Figure 5. UV-C test setup with Aquisense 24G UVinaire 280 nm LED lamp modules

Table 8. UV-C Exposure Parameters: 280 nm

Average Intensity (mW/cm^2)	**Cumulative Dosage (mJ/cm^2)**	**Exposure Duration (minutes)**
10.14	13,687.5	22.5
	54,750	90
	109,500	180

5 Mechanical properties

A variety of mechanical tests were conducted to understand the effects of UV-C irradiation on the mechanical properties of the selected cabin interior materials. The details of the test methods and experimental observations are discussed in this section.

5.1 Plastics

Test matrix

Uniaxial tension tests were conducted on six different plastic types following ASTM D638 (ASTM International, 2014). Three specimens were tested per wavelength and cumulative time for each plastic type, as shown in Table 9.

Table 9. Tensile test matrix – Plastics

Plastic Type	**Test Standard**	**Wavelength Configuration**						
		253.4 nm			**222 nm**		**280 nm**	
		Cumulative Time (Year)						
		One	**Four**	**Eight**	**Four**	**Eight**	**Four**	**Eight**
Kydex 6565	ASTM D638	x 3	x 3	x 3	x 3	x 3	x 3	x 3
Boltaron 9815E		x 3	x 3	x 3	x 3	x 3	x 3	x 3
Lexan XHR		x 3	x 3	x 3	x 3	x 3	x 3	x 3
Boltaron 9815N		x 3	x 3	x 3	x 3	x 3	x 3	x 3
ULTEM™ 9075		-	x 3	x 3	x 3	x 3	x 3	x 3
ULTEM™ 9085		-	x 3	x 3	x 3	x 3	x 3	x 3

5.1.1 Specimen dimensions and nomenclature

Specimens were manufactured from bulk plastic sheets in accordance with ASTM D638 (ASTM International, 2014). Based on the thickness of the plastic sheets, specimen Type V was selected, as shown in Figure 6. Nominal dimensions for the same are summarized in Table 10. Dimensions were measured for all the specimens and summarized in Appendix A.

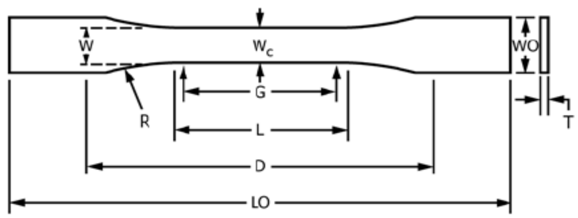

Figure 6. Plastic tension specimen geometry

Table 10. Plastic tension test specimen nominal dimensions, type V

Length Overall [LO], in	2.500
Length of Narrow Section [L], in	0.375
Gage Length [G], in	0.300
Width Overall [WO], in	0.375
Width Narrow Section [W], in	0.125
Distance Between Grips [D], in	1.000
Radius of Fillet [R], in	0.500

To facilitate specimen identification and traceability, this study used the following nomenclature [Client ID – Test Method ID – Plastic Type ID – UV Cumulative Dosage ID – Specimen #]. **Error! Reference source not found.** summarizes specimen identification nomenclature used for ifferent materials.

Table 11. Specimen ID nomenclature for strength characterization - Plastics

Client ID	FAA	FAA
Test Method ID	ASTM D638 – Tension	T
Specimen Type	Kydex 6565	P1
	Boltaron 9815E	P2
	Lexan XHR	P3
	Boltaron 9815N	P4
	ULTEM^{TM} 9075	P5
	ULTEM^{TM} 9085	P6
UV-C Dosage [253.4 nm]	One year	D6
	Four years	D7
	Eight years	D8
UV-C Dosage [222 nm]	Four years	D9
	Eight years	D10
UV-C Dosage [280 nm]	Four years	D11
	Eight years	D12

5.1.2 Test setup

Tests were conducted at room temperature under displacement control at a nominal displacement rate of 0.05 in/min. A non-contact strain measurement technique, Digital Image Correlation (DIC), was employed to measure longitudinal strains, as shown in the test setup in Figure 7. All tests were conducted at room temperature until failure. The test apparatus used was an MTS Electrodynamic testing load frame with a static load capacity of 450 lbs.

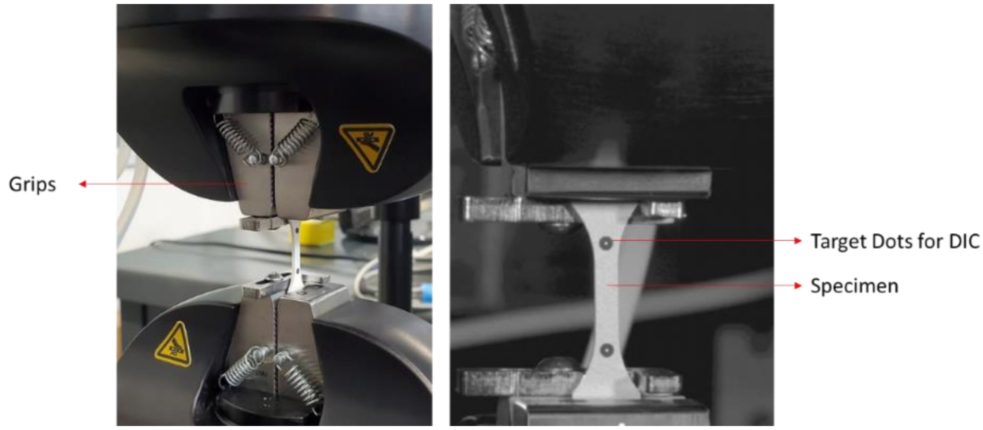

Figure 7. Tensile test setup - Plastics

5.1.3 Test results

Six different types of plastic specimens, pristine and UV-C aged, were tested for tensile properties following the ASTM D638 test standard and the test matrix detailed in Table 9. Figure 8 through Figure 19 present the stress-strain data for each material type, as well as comparisons between the mechanical properties such as yield stress, ultimate tensile strength, and failure strain between pristine and UV-C aged specimens. Post-test failure pictures of all the specimens are presented in Appendix B.

The stress-strain data of Kydex 6565, pristine and specimens exposed to accelerated UV-C aging tests at various dosages under 222 nm, 253.4 nm, and 280 nm wavelengths, is presented in Figure 8. Figure 9 compares yield stress, ultimate tensile strength, and failure strain between pristine and UV-C exposed specimens. The specimens exposed to 222 nm - 4,380 mJ/cm^2 presented less than a 5% reduction in average yield stress compared to their pristine counterparts. The second dosage configuration at 8,760 mJ/cm^2 showed a 10% reduction when compared to average pristine specimen data. For the 253.4 nm configuration, the first dosage configuration showed a reduction of less than 5%, the second and third dosage configurations presented a reduction between 5% to 10% compared to the average yield stress of pristine specimens. For the 280 nm configuration, both dosage configurations showed less than a 5% reduction in average yield stress.

The average ultimate tensile strength comparison presented a 15% to 20% reduction for both the 222 nm dosage configurations. For the 253.4 nm wavelength configuration, the first dosage showed less than a 5% reduction in average ultimate tensile strength, the second dosage showed a 13% reduction, and the third dosage configuration presented a 19% reduction in average ultimate tensile strength when compared to pristine specimens. Both the 280 nm dosage configurations presented less than a 5% reduction in average ultimate tensile strength compared to pristine specimens. The failure strain was noticed to be highly variable for most of the specimen configurations. The high variability could be noticed even within the pristine specimen data.

The stress-strain data of Boltaron 9815E test specimens, pristine and specimens exposed to accelerated UV-C aging tests at various dosages under 222 nm, 253.4 nm, and 280 nm wavelengths, is presented in Figure 10. Figure 11 compares yield stress, ultimate tensile strength, and failure strain between pristine and UV-C exposed specimens. Reduction in average yield stress was less than 5% for all the UV-C aged specimens compared with their pristine counterparts. The average ultimate tensile strength comparison presented a 5% to 10% reduction for both the 222 nm dosage configurations. For the 253.4 nm wavelength configuration, the first dosage showed less than a 5% reduction in average ultimate tensile strength. The second and third dosage configurations showed a reduction between 5% to 10% compared to pristine specimens. Both the 280 nm dosage configurations presented less than a 5% reduction in average ultimate tensile strength compared to pristine specimens.

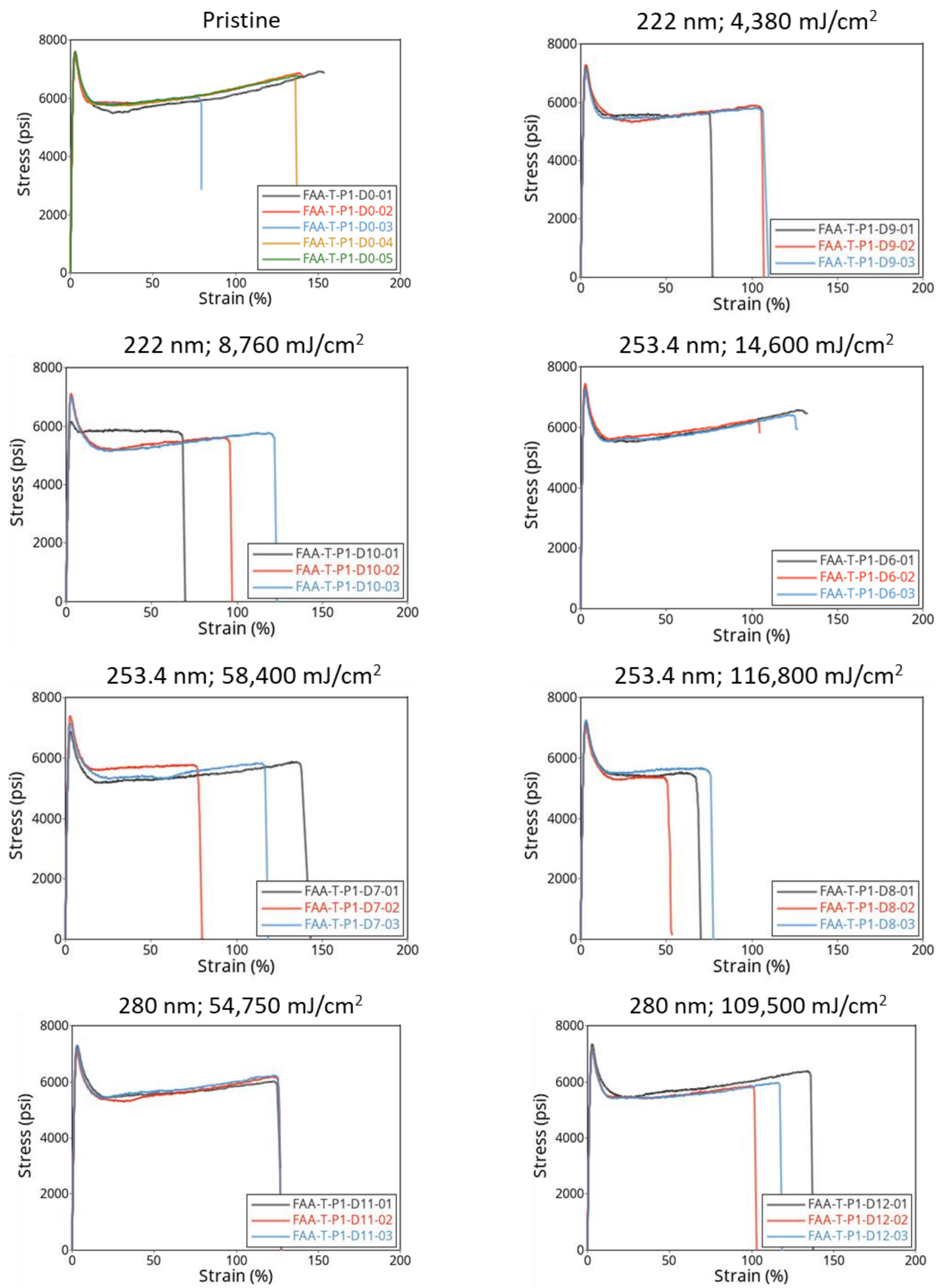

Figure 8. Longitudinal stress-strain response – Kydex 6565

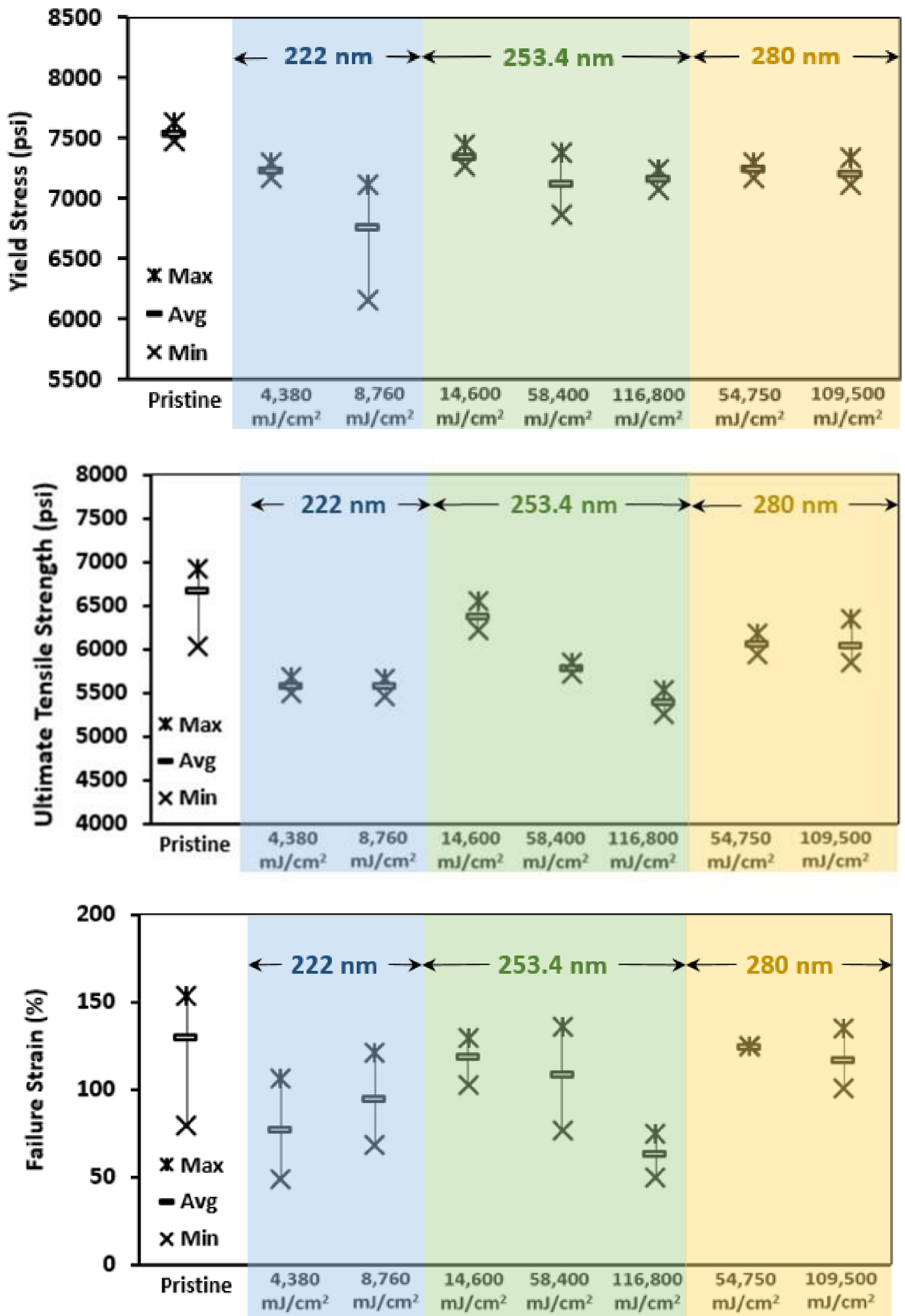

Figure 9. Yield stress, ultimate tensile strength, and failure strain – Kydex 6565

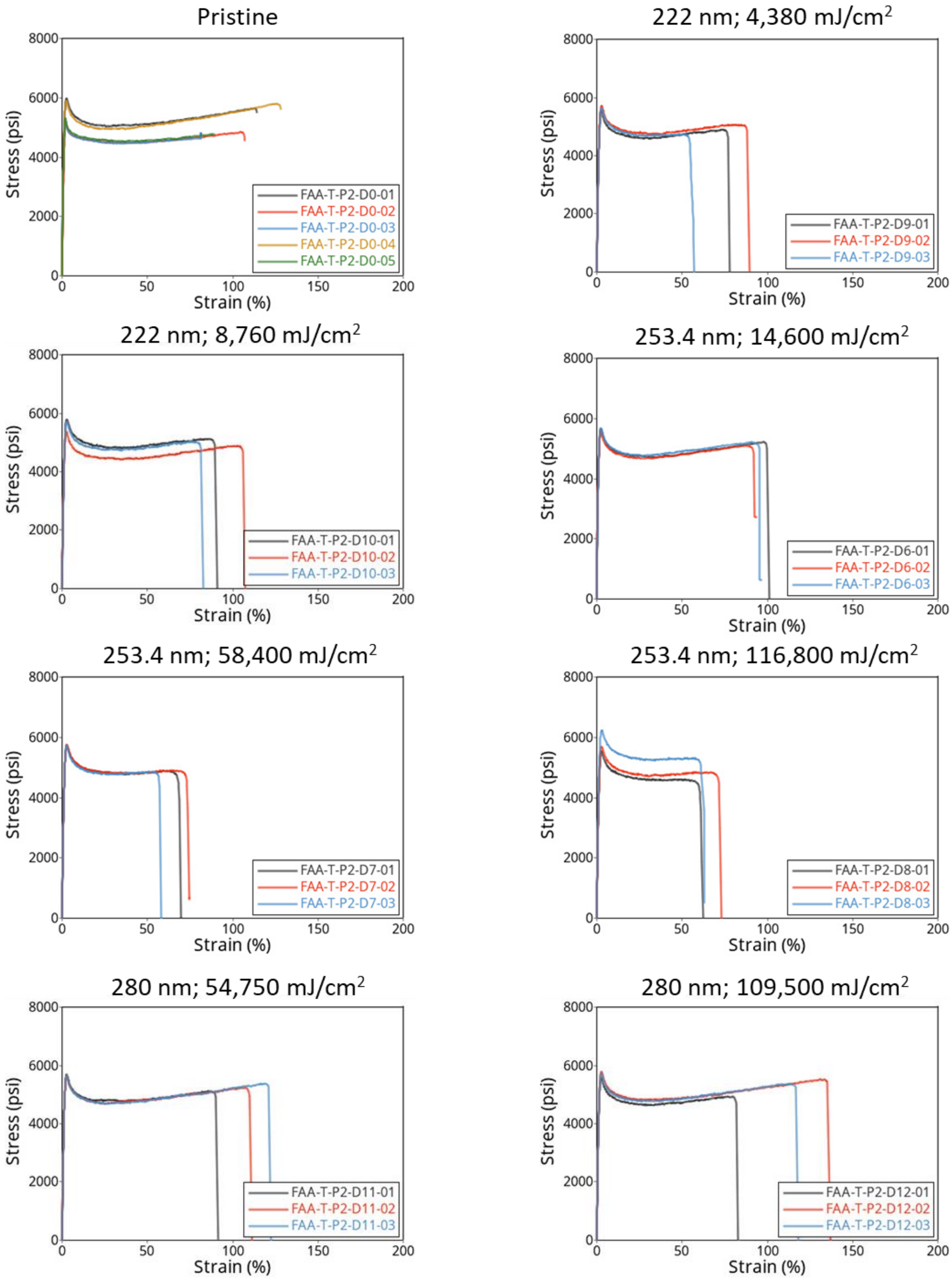

Figure 10. Longitudinal stress-strain response – Boltaron 9815E

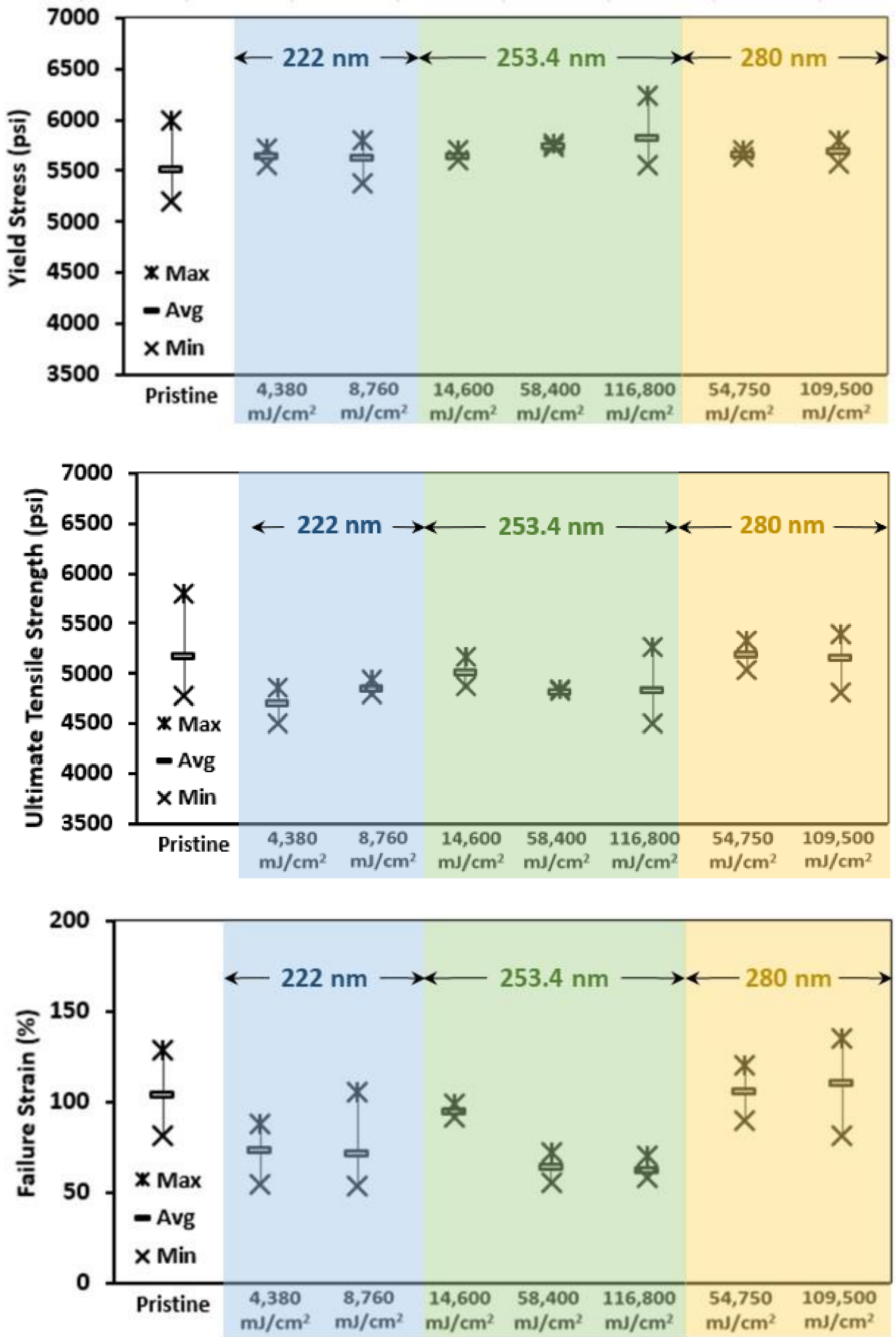

Figure 11. Yield stress, ultimate tensile strength, and failure strain – Boltaron 9815E

The stress-strain data of Lexan XHR test specimens, pristine and specimens exposed to accelerated UV-C aging tests at various dosages of 222 nm, 253.4 nm, and 280 nm wavelengths, is presented in Figure 12. Figure 13 compares yield stress, ultimate tensile strength, and failure strain between pristine and UV-C exposed specimens. Reduction in average yield stress was less than 5% for all the UV-C aged specimens compared with their pristine counterparts. For the 222 nm - 4,380 mJ/cm2 configuration, a 10% reduction in average ultimate tensile strength was observed. For the 253.4 nm wavelength configuration, all three dosage configurations showed less than a 5% reduction in average ultimate tensile strength compared to pristine specimens. Both the 280 nm dosage configurations showed a reduction between 5% to 10% in average ultimate tensile strength.

The stress-strain data of Boltaron 9815N test specimens, pristine and specimens exposed to accelerated UV-C aging tests at various dosages of 222 nm, 253.4 nm, and 280 nm wavelengths, is presented in Figure 14. Figure 15 compares yield stress, ultimate tensile strength, and failure strain between pristine and UV-C exposed specimens. Reduction in average yield stress was between 5% to 10% for the specimens aged with 222 nm dosages. For all the other dosage configurations at 253.4 nm and 280 nm wavelengths, the reduction in yield stress was less than 5% compared with their pristine counterparts. For the 222 nm - 8,760 mJ/cm2 configuration, the reduction in average ultimate tensile strength was observed to be between 10% to 15%. For the 253.4 nm wavelength configuration, the first and second dosage configurations showed less than a 5% reduction in average ultimate tensile strength. The third dosage configuration presented a reduction in average ultimate tensile strength between 5% to 10%. Both the 280 nm dosage configurations showed a reduction between 5% to 10% in average ultimate tensile strength.

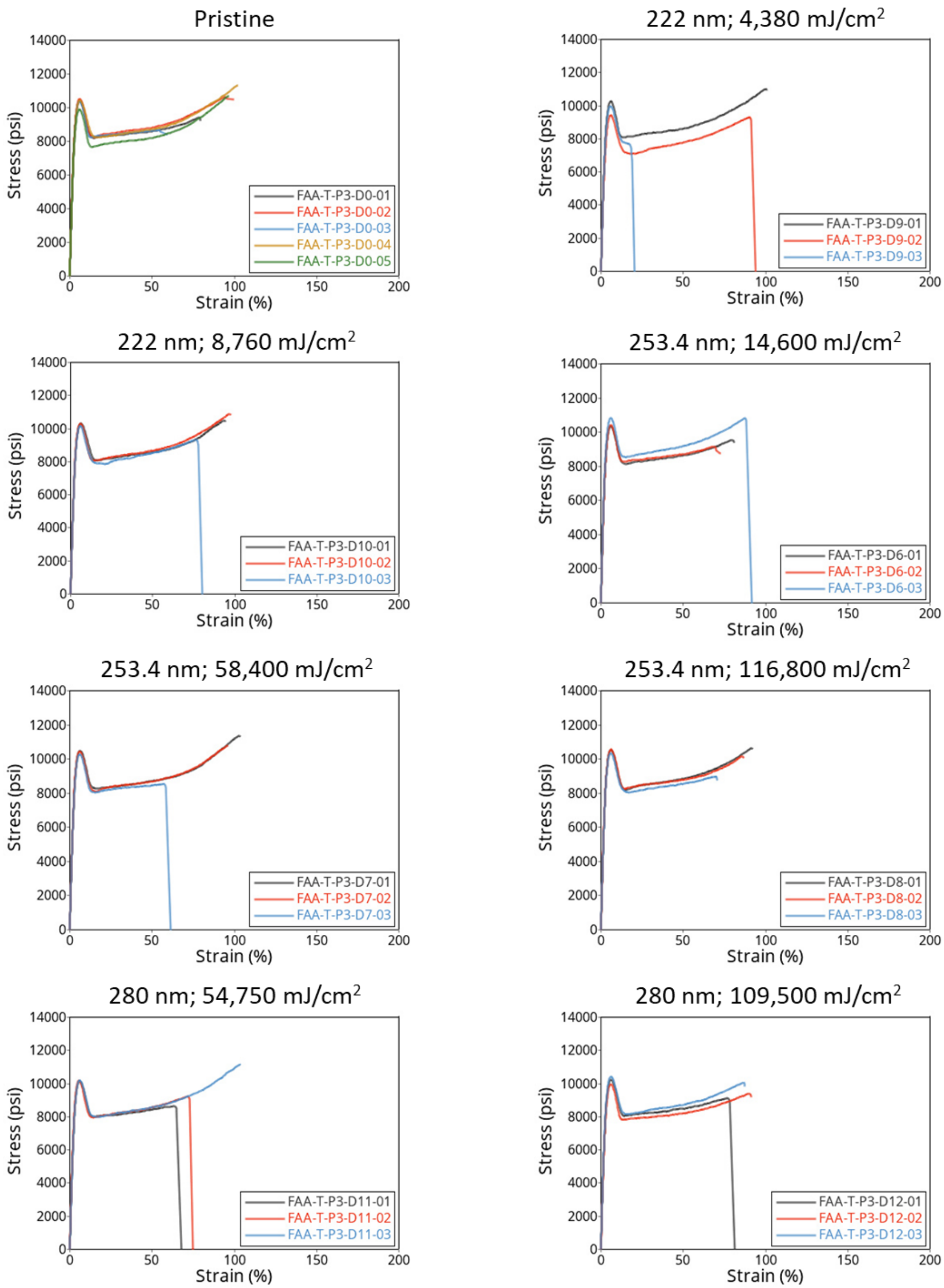

Figure 12. Longitudinal stress-strain response – Lexan XHR

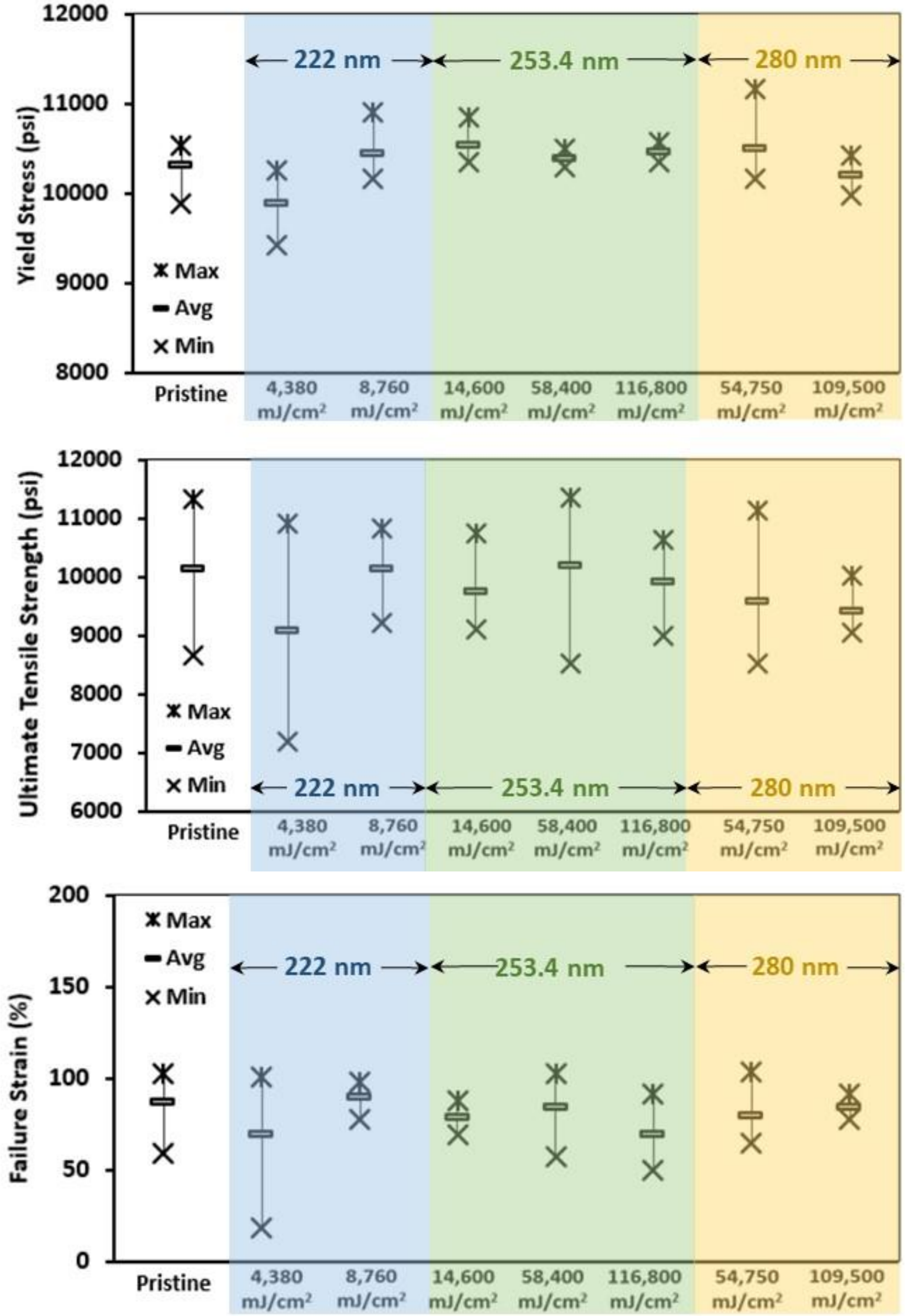

Figure 13. Yield stress, ultimate tensile strength, and failure strain – Lexan XHR

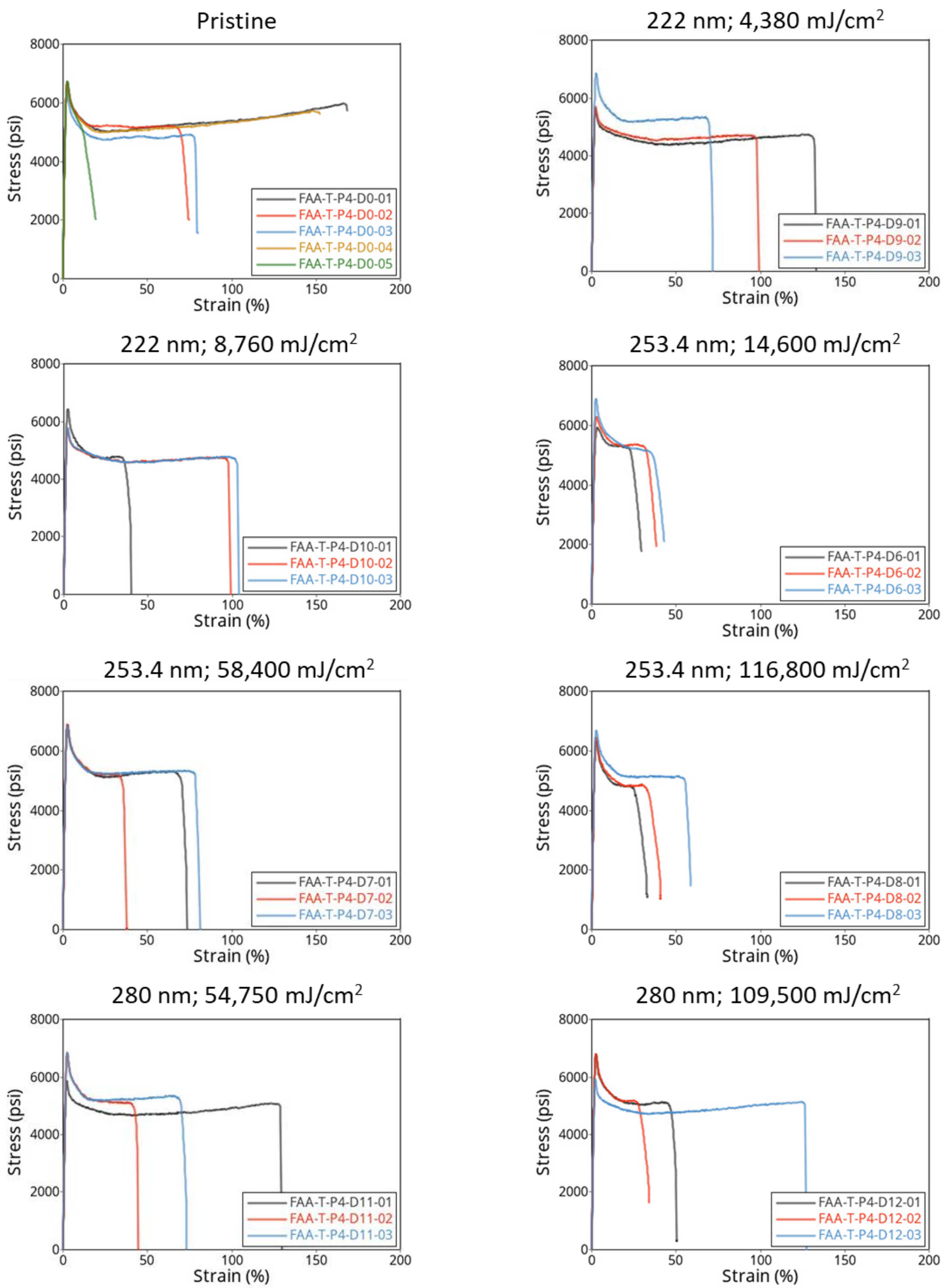

Figure 14. Longitudinal stress-strain response – Boltaron 9815N

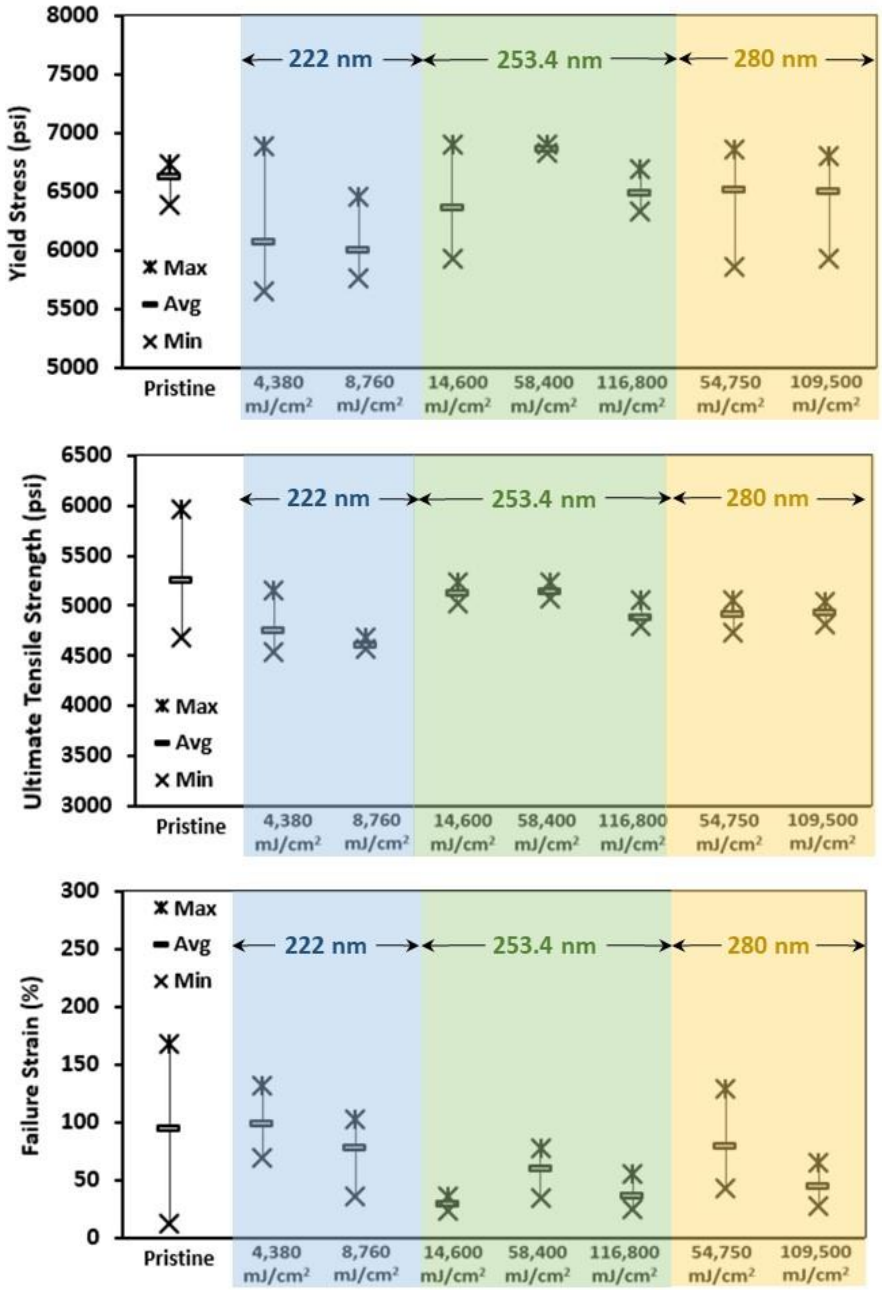

Figure 15. Yield stress, ultimate tensile strength, and failure strain – Boltaron 9815N

The stress-strain data of ULTEM^{TM} 9075 test specimens, pristine and specimens exposed to accelerated UV-C aging tests at various dosages under 222 nm, 253.4 nm, and 280 nm wavelengths, is presented in Figure 16. Figure 17 compares yield stress, ultimate tensile strength, and failure strain between pristine and UV-C exposed specimens. For all the specimen configurations, no reduction in average yield stress, average tensile strength, and average failure strain was observed when compared with pristine specimens. However, an increase in tensile properties of aged specimens in comparison to the pristine specimens was observed. This behavior needs to be further evaluated in future work.

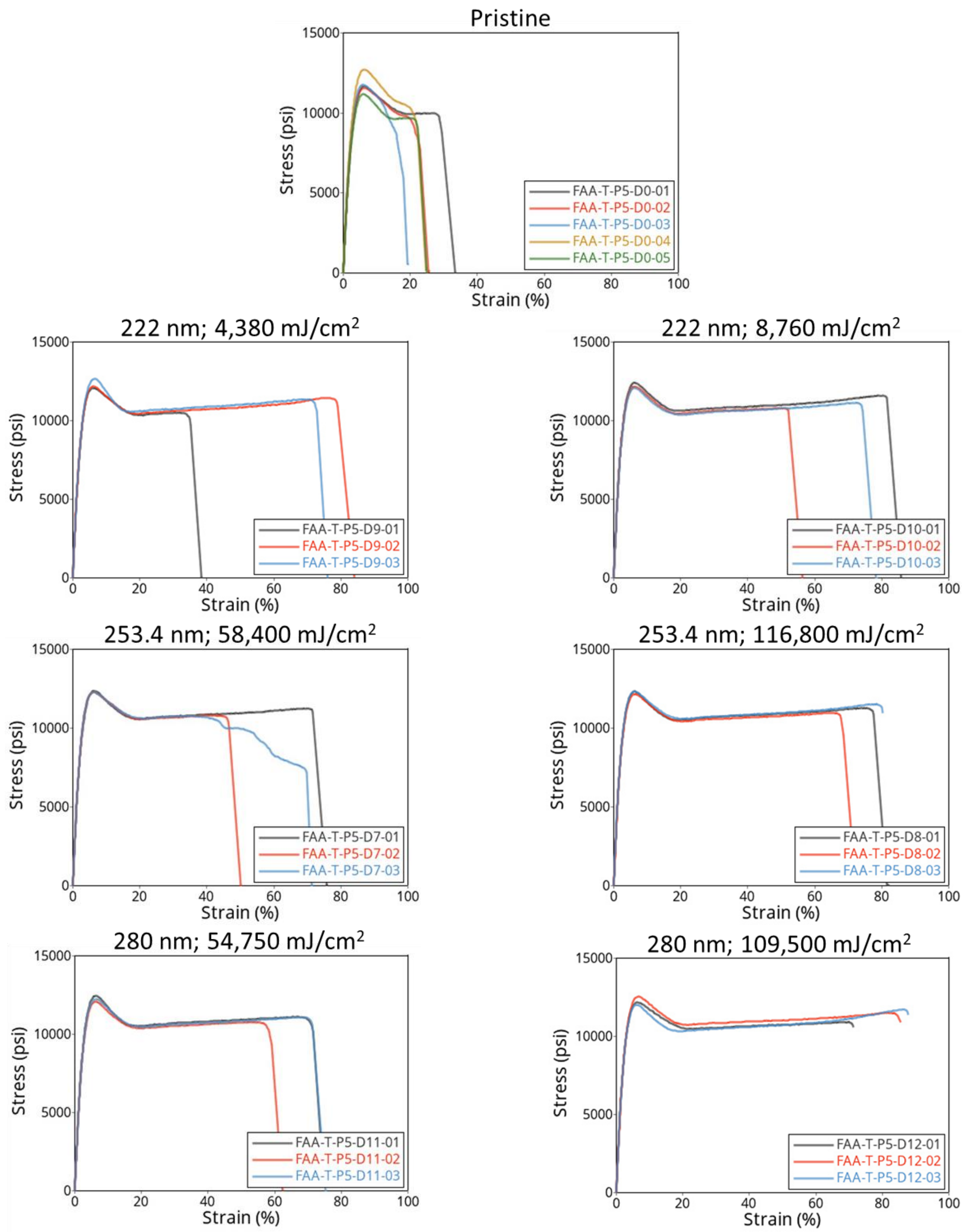

Figure 16. Longitudinal stress-strain response – ULTEM™ 9075

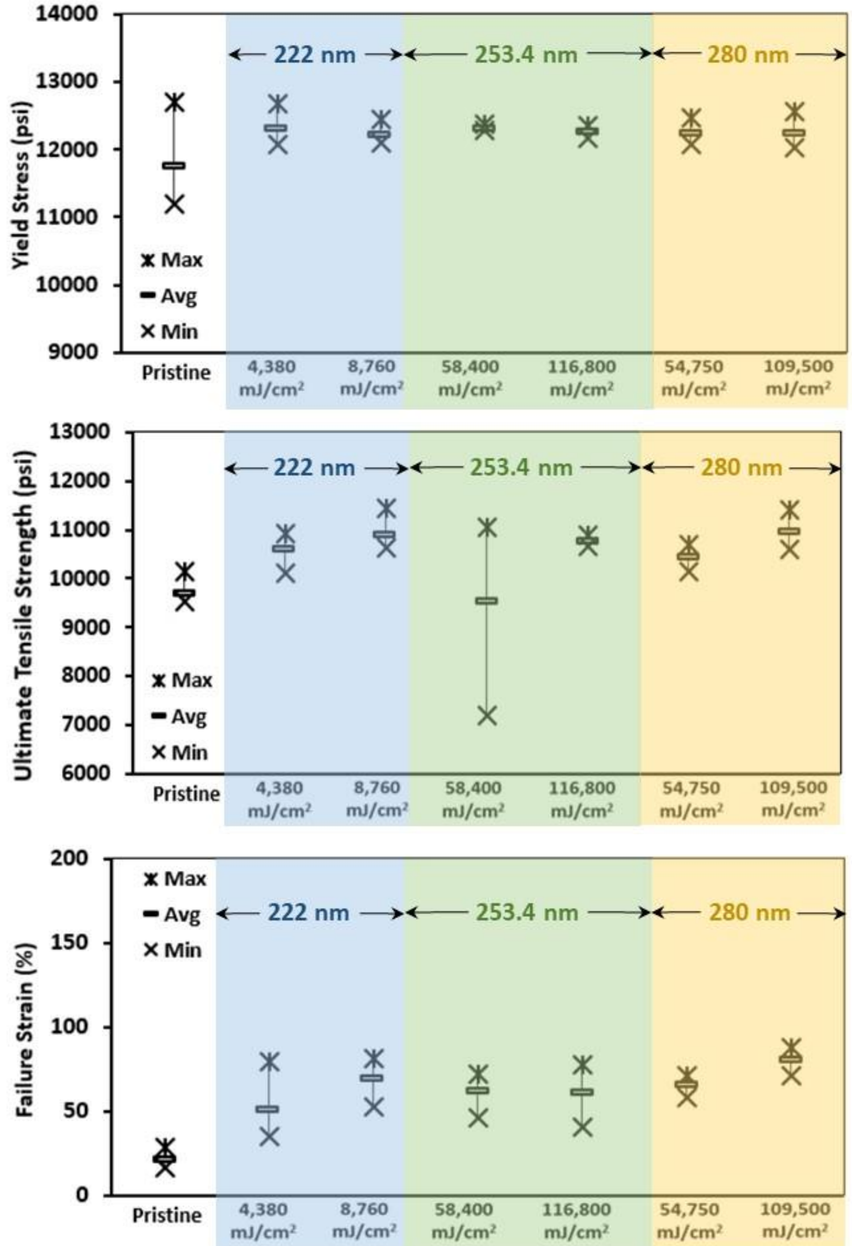

Figure 17. Yield stress, ultimate tensile strength, and failure strain – ULTEM^{TM} 9075

The stress-strain data of ULTEM^{TM} 9085 test specimens, pristine and specimens exposed to accelerated UV-C aging tests at various dosages under 222 nm, 253.4 nm, and 280 nm wavelengths, is presented in Figure 18. Figure 19 compares yield stress, ultimate tensile strength, and failure strain between pristine and UV-C exposed specimens. For all the specimen configurations, no reduction in average yield stress, average ultimate tensile strength, and average failure strain was observed when compared with pristine specimens. Similar to Ultem™ 9075, an increase in tensile properties of aged specimens in comparison to pristine specimens was observed for Ultem™ 9085. This behavior needs to be further evaluated in future work.

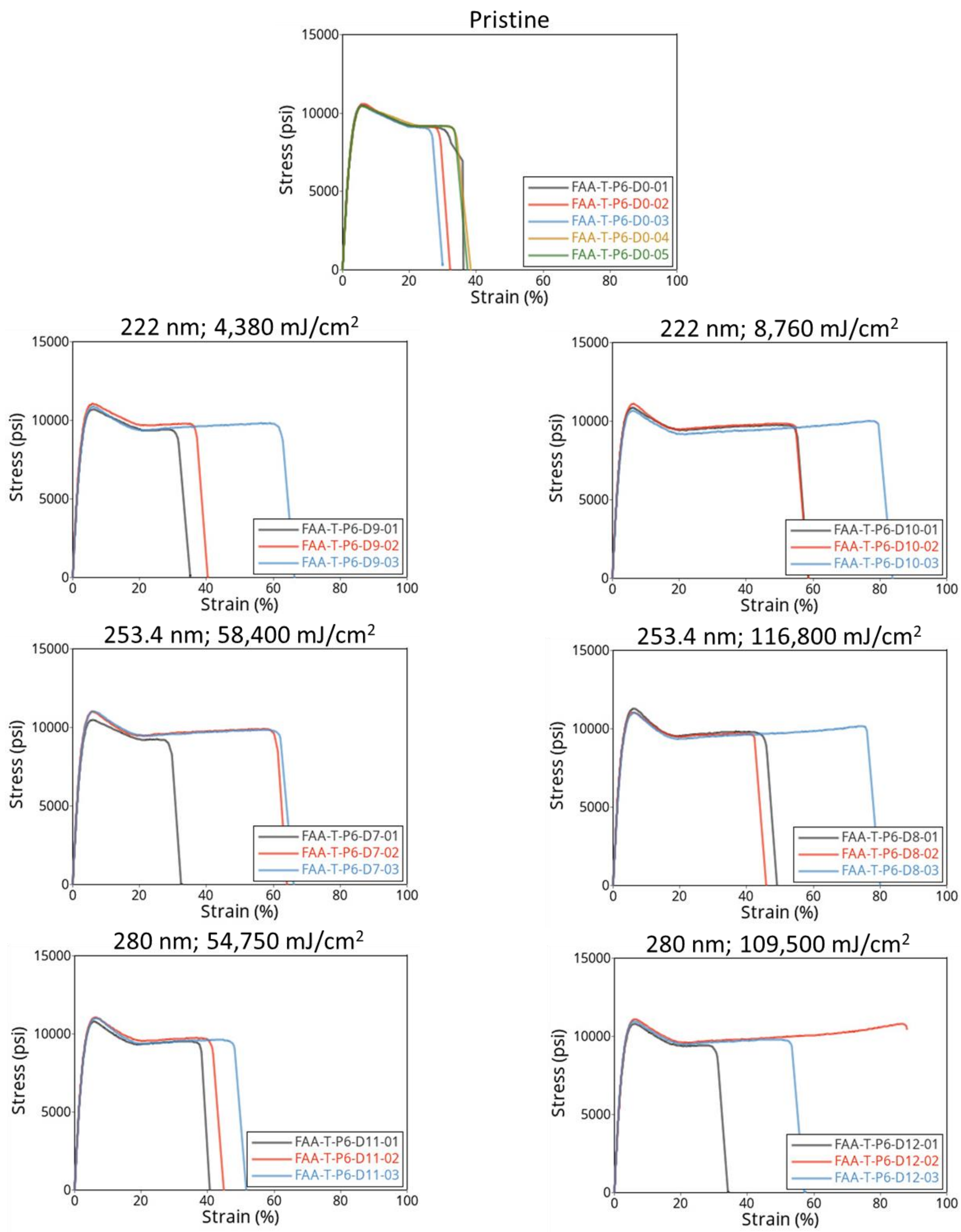

Figure 18. Longitudinal stress-strain response – ULTEM™ 9085

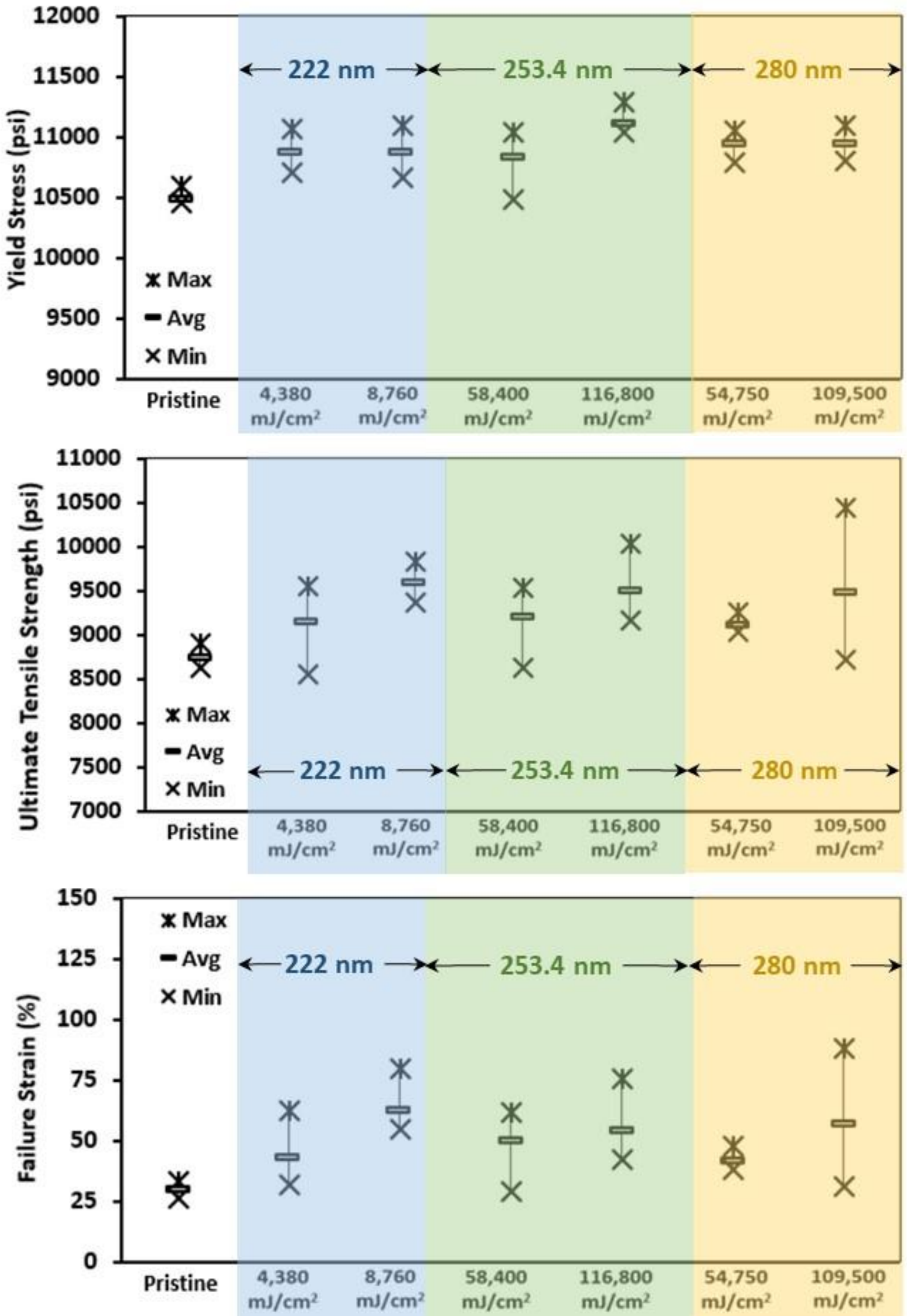

Figure 19. Yield stress, ultimate tensile strength, and failure strain – ULTEM^{TM} 9085

5.2 Honeycomb

5.2.1 Test matrix

Honeycomb specimens were subjected to accelerated UV-C aging tests at three different cumulative dosages per wavelength configuration. Test specimens were then evaluated for the effects of UV-C irradiation on the mechanical properties through long-beam flexure experiments. The tests were conducted following the ASTM D7249 (ASTM International, 2020). Five specimens were tested per configuration, as shown in Table 12.

Table 12. Long-beam flexure test matrix - honeycomb

Honeycomb Type	**Test Standard**	**Wavelength Configuration**								
		222 nm			**253.4 nm**			**280 nm**		
		Cumulative Time (Year)								
		One	**Four**	**Eight**	**One**	**Four**	**Eight**	**One**	**Four**	**Eight**
Honeycomb type A	ASTM D7249	x 5	x 5	x 5	x 5	x 5	x 5	x 5	x 5	x 5

5.2.2 Specimen dimensions and nomenclature

Test specimens were manufactured from honeycomb sandwich panels in accordance with ASTM D7249 (ASTM International, 2020). Nominal specimen geometry and dimensions are summarized in Figure 20 and Table 13. Dimensions of all the test specimens have been summarized in Appendix B.

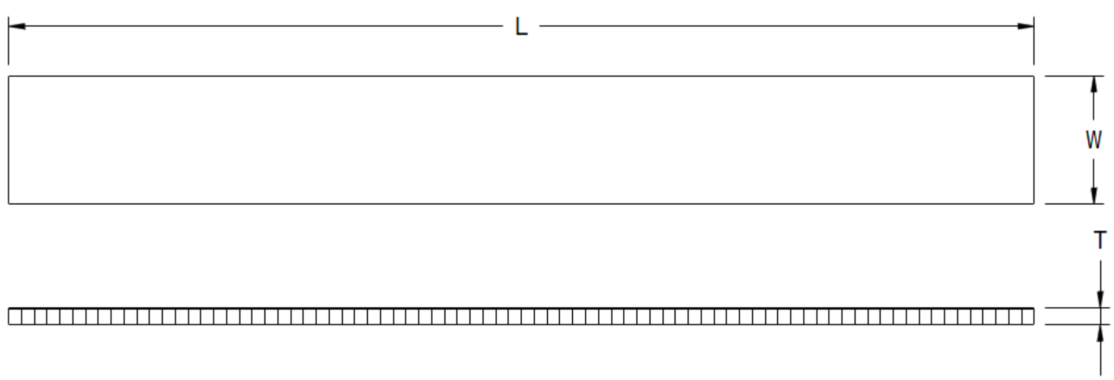

Figure 20. Long-beam flexure specimen geometry

Table 13. Nominal dimensions of long-beam flexure test specimen

Overall length [L], in	24.0
Overall width [W], in	3.0
Panel thickness [T], in	0.4

To facilitate specimen identification and traceability, the following nomenclature was used [Client ID – Test Method ID – Honeycomb Type ID – UV Cumulative Dosage ID – Specimen #] in this study. Table 14 summarizes the nomenclature used for honeycomb test specimens.

Table 14. Specimen ID nomenclature for honeycomb test specimens

Client ID	FAA	FAA
Test Method ID	ASTM D7249 – Flexure	F
Honeycomb Type	Honeycomb Type A	H1
UV-C Dosage [253.4 nm]	One year	D6
	Four years	D7
	Eight years	D8
UV-C Dosage [222 nm]	One year	D13
	Four years	D9
	Eight years	D10
UV-C Dosage [280 nm]	One year	D14
	Four years	D11
	Eight years	D12

5.2.3 Test setup

Long-beam flexure tests were conducted under displacement control at a nominal displacement rate of 0.25 in/min. MTS Servo-Hydraulic test frame with a load capacity of 22,000 lbs. was used to conduct the experiments. All the experiments were conducted at room temperature until specimen failure. DIC was employed to record displacement data during the experiments. The test setup along with the camera used for DIC measurements is presented in Figure 21.

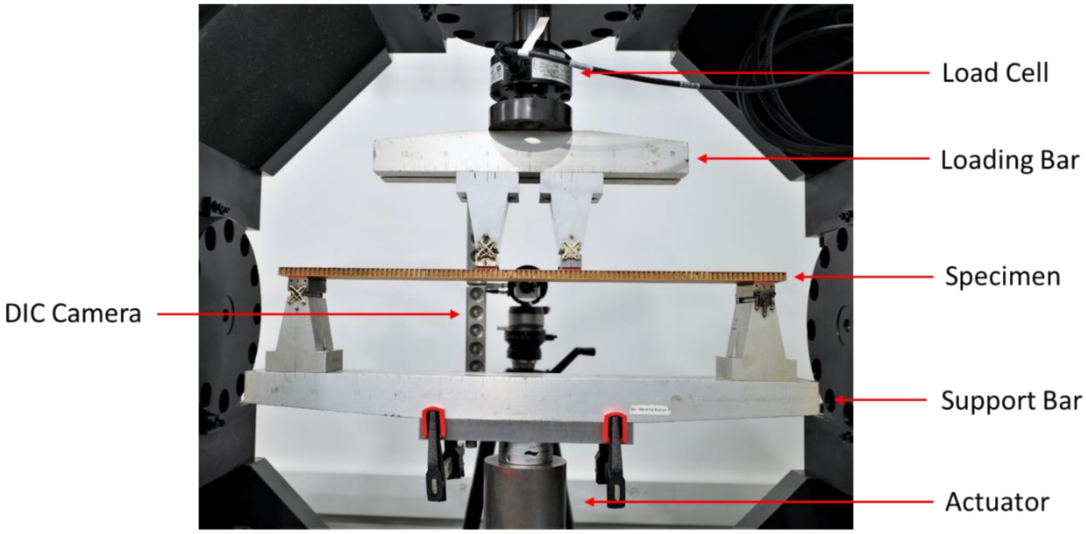

Figure 21. Long-beam flexure test setup

5.2.4 Test Results

Honeycomb specimens, pristine and UV-C aged, were subjected to long-beam flexural tests following the ASTM D7249 test standard and the test matrix detailed in Table 12. Load-displacement data of each specimen configuration is presented in Figure 22. The maximum load data compared between pristine and UV-C aged specimens is presented in Figure 23. Post-test failure pictures of all the specimens are presented in Appendix E.

For the 253.4 nm - 1-year configuration, the reduction in average maximum load was observed to be between 5% to 10% but the second (4-year) and third (8-year) cumulative dosage configurations showed the reduction in average maximum load to be less than 5% when compared to pristine specimens. It must be noted that all the test specimens for the one-year dosage configuration showed similar failure modes. Due to the small sample count, any further conclusions could not be made on this reduction in maximum load. Additional research should be performed before using this material-UV disinfection combination in service. For all other specimen configurations at 222 nm and 280 nm, the reduction in average maximum load was less than 5% compared with their pristine counterparts.

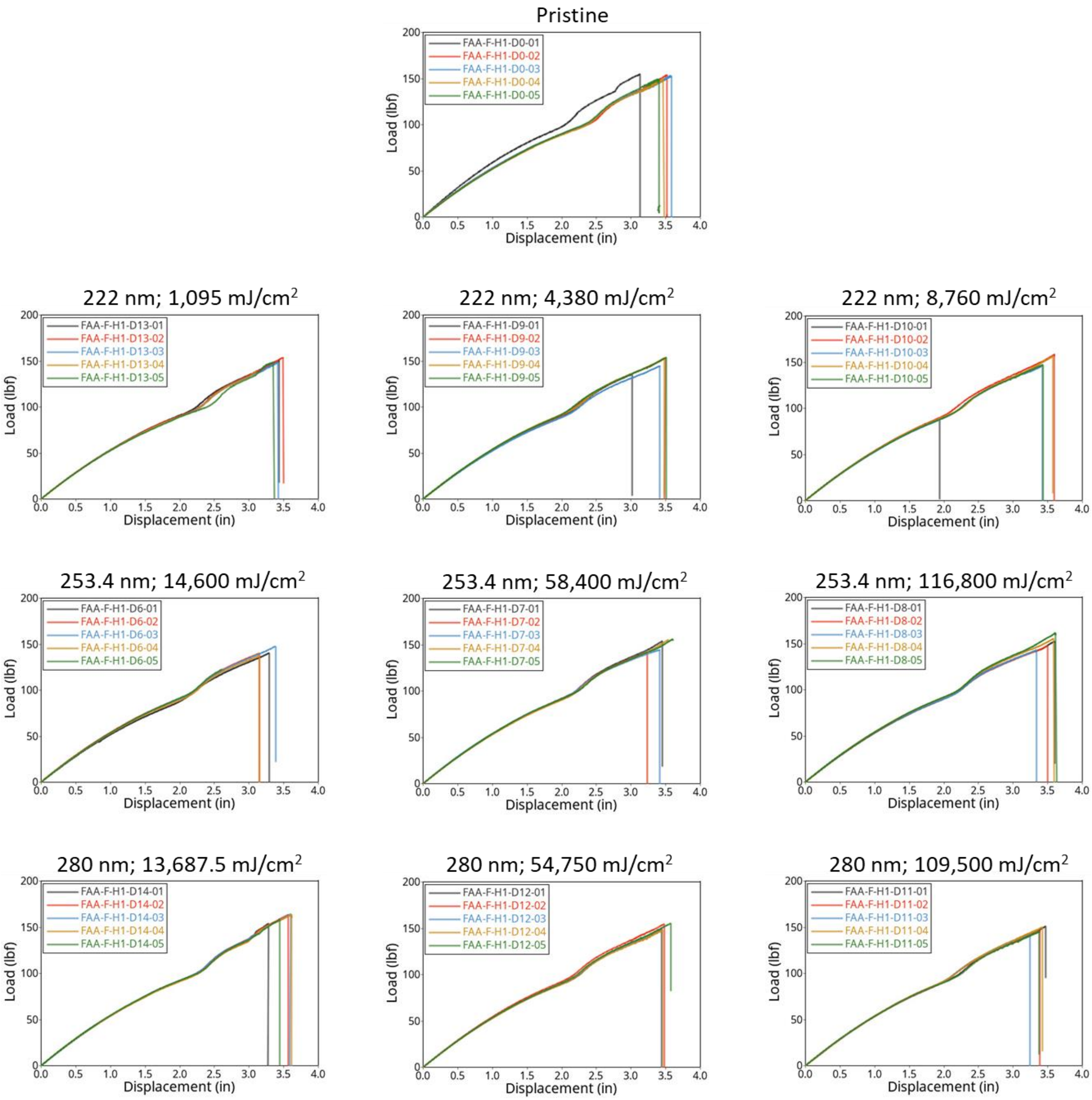

Figure 22. Load-displacement response – Honeycomb type A

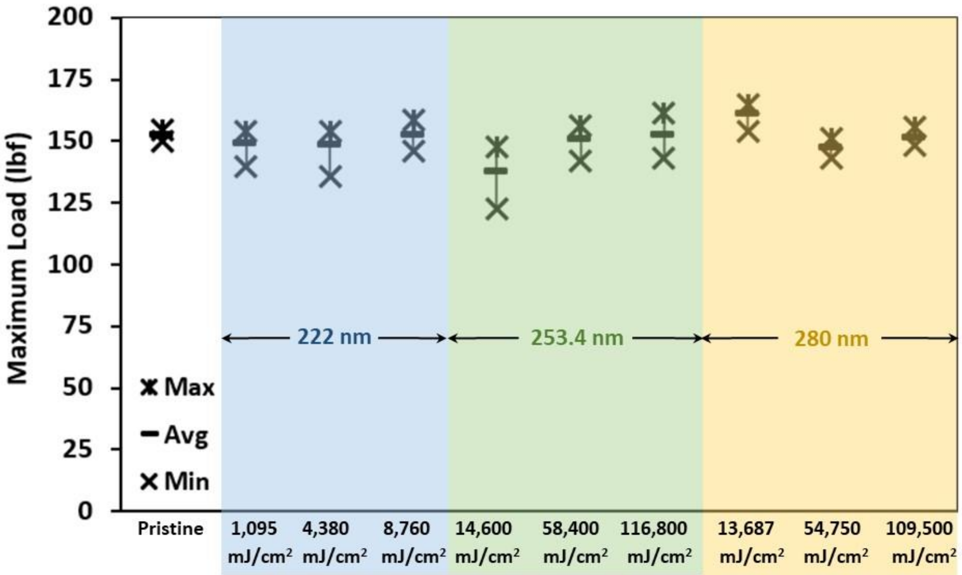

Figure 23. Maximum load comparison – Honeycomb type A

5.2.5 Statistical data evaluation

Statistical analysis of honeycomb test data was conducted following the Composite Materials Handbook (CMH-17) guidelines (Polymer matrix composites: guidelines for characterization of structural materials, 2012). For the acceptance of the material properties from any batch of specimens, it must be shown that the properties obtained from the current batch are "equivalent" to the qualification batch; i.e., the batch data meets the material specification limits (Polymer matrix composites: guidelines for characterization of structural materials, 2012). This study treats material properties obtained from unaged honeycomb specimens as the qualification batch. The equivalency of the maximum load of specimens aged with UV-C is shown in Table 15. The standard equivalency method typically evaluates larger sample batches from multiple data sets. Due to the small sample batch considered in this study, the modified Coefficient of Variation (CV) of 6% method was utilized for equivalency criteria. This method is in accordance with Section 8.4.4 of CMH-17-1G (Polymer matrix composites: guidelines for characterization of structural materials, 2012). Honeycomb specimens pass equivalency criteria for maximum load with a modified CV of 6% for all the wavelength and dosage configurations.

Table 15. Statistical data analysis - Honeycomb

Maximum Load (lbf)	222 nm						253.4 nm						280 nm					
	1,095 mJ/cm^2		4,380 mJ/cm^2		8,760 mJ/cm^2		14,600 mJ/cm^2		58,400 mJ/cm^2		116,800 mJ/cm^2		13,687.5 mJ/cm^2		54,750 mJ/cm^2		109,500 mJ/cm^2	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data as measured	Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data	
Mean Maximum Load (lbf)	152.4	148.6	152.4	148.2	152.4	152.0	152.4	137.6	152.4	150.4	152.4	152.0	152.4	160.8	152.4	147.1	152.4	151.2
Standard Deviation	2.257	5.536	2.257	7.953	2.257	6.086	2.257	9.308	2.257	6.591	2.257	7.157	2.257	4.569	2.257	3.281	2.257	3.625
Coefficient of Variation %	1.481	3.725	1.481	5.368	1.481	4.003	1.481	6.762	1.481	4.382	1.481	4.709	1.481	2.842	1.481	2.231	1.481	2.397
Minimum	149.7	139.4	149.7	135.7	149.7	146.1	149.7	137.0	149.7	142.0	149.7	143.1	149.7	154.1	149.7	143.0	149.7	148.2
Maximum	154.7	154.0	154.7	153.8	154.7	158.4	154.7	147.9	154.7	156.0	154.7	161.6	154.7	164.5	154.7	150.8	154.7	155.4
Number of Specimens	5	5	5	5	5	4	5	4	5	5	5	5	5	5	5	5	5	5
RESULTS	**FAIL**		**FAIL**		**FAIL**		**FAIL**		**FAIL**		**FAIL**		**PASS**		**FAIL**		**PASS**	
Minimum Acceptable Equiv. Sample Mean	150.4		150.4		150.2		150.2		150.4		150.4		150.4		150.4		150.4	
Minimum Acceptable Equiv. Sample Min	146.6		146.6		146.8		146.8		146.6		146.6		146.6		146.6		146.6	
MOD CV RESULTS	**PASS with MOD**		**PASS with MOD**		**PASS with MOD**		**PASS with MOD**		**PASS with MOD**		**PASS with MOD**		**PASS with MOD**		**PASS with MOD**		**PASS with MOD**	
Modified CV%	6.000		6.000		6.000		6.000		6.000		6.000		6.000		6.000		6.000	
Minimum Acceptable Equiv. Sample Mean	144.6		144.6		143.4		133.4		144.6		144.6		144.6		144.6		144.6	
Minimum Acceptable Equiv. Sample Min	129.2		129.2		129.8		120.7		129.2		129.2		129.2		129.2		129.2	

5.3 Fiberglass laminate

5.3.1 Test matrix

Fiberglass specimens were subjected to accelerated UV-C aging tests at three different cumulative dosages per wavelength configuration. Test specimens were then evaluated for the effects of UV-C irradiation on the mechanical properties through short-beam shear experiments. The tests were conducted following the ASTM D2344 (ASTM International, 2016). Five specimens were tested per configuration, as shown in Table 16.

Table 16. Short-beam shear test matrix - fiberglass

Fiberglass Laminate Type	**Test Standard**	**Wavelength Configuration**								
		222 nm			**253.4 nm**			**280 nm**		
		Cumulative Time (Year)								
		One	**Four**	**Eight**	**One**	**Four**	**Eight**	**One**	**Four**	**Eight**
Fiberglass G-10/FR4	ASTM D2344	x 5	x 5	x 5	x 5	x 5	x 5	x 5	x 5	x 5

5.3.2 Specimen dimensions and nomenclature

Test specimens were manufactured from fiberglass laminates following the ASTM D2344 guidelines (ASTM International, 2016). Nominal specimen geometry and dimensions are summarized in Figure 24 and Table 17. Dimensions of all the test specimens have been summarized in Appendix C.

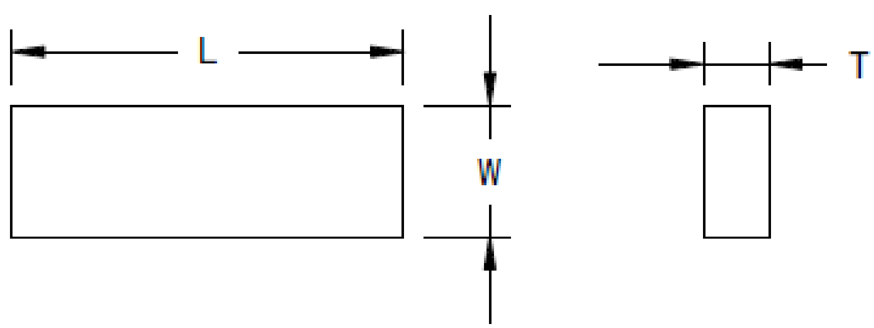

Figure 24. Short-beam shear specimen geometry

Table 17. Nominal dimensions of a short-beam shear specimen

Overall length [L], in	1.50
Overall width [W], in	0.50
Panel thickness [T], in	0.25

To facilitate specimen identification and traceability, the following nomenclature was used [Client ID – Test Method ID – Fiberglass Laminate Type ID – UV Cumulative Dosage ID – Specimen #] in this study. Table 18 summarizes the nomenclature used for short-beam shear test specimens.

Table 18. Specimen ID nomenclature for short-beam shear test specimens

Client ID	FAA	FAA
Test Method ID	ASTM D2344 – Short-beam shear	S
Fiberglass Laminate Type	Fiberglass G-10/FR4	FG1
UV-C Disinfectant Dosage [253.4 nm]	One year	D6
	Four years	D7
	Eight years	D8
UV-C Disinfectant Dosage [222 nm]	One year	D13
	Four years	D9
	Eight years	D10
UV-C Disinfectant Dosage [280 nm]	One year	D14
	Four years	D11
	Eight years	D12

5.3.3 Test setup

Short-beam shear tests were conducted under displacement control at a nominal displacement rate of 0.05 in/min. MTS Servo-Hydraulic test frame with a load capacity of 22,000 lbs. was used to conduct the experiments. All the experiments were conducted at room temperature until specimen failure. The test setup is presented in Figure 25.

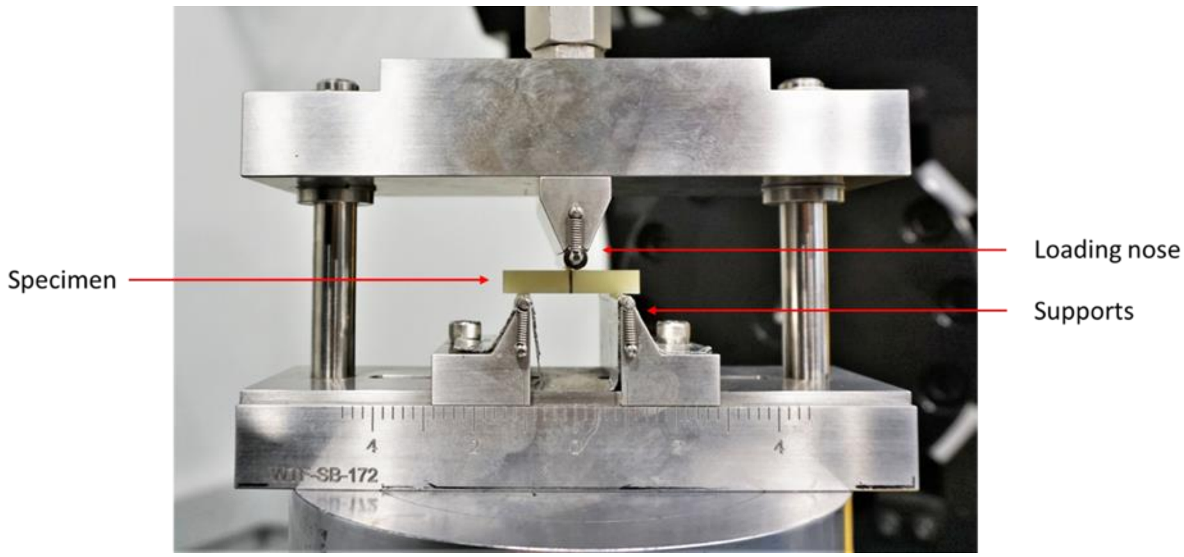

Figure 25. Short-beam shear test setup

5.3.4 Test results

Fiberglass specimens, pristine and UV-C aged, were subjected to short-beam shear tests following the ASTM D7249 test standard and the test matrix detailed in Table 16. Post-test failure pictures of all the specimens are presented in Appendix F. Load-displacement data of each specimen configuration is presented in Figure 26. As shown in Figure 27, the reduction in average short-beam shear strength was less than 5% for all the UV-C aged specimens compared with their pristine counterparts.

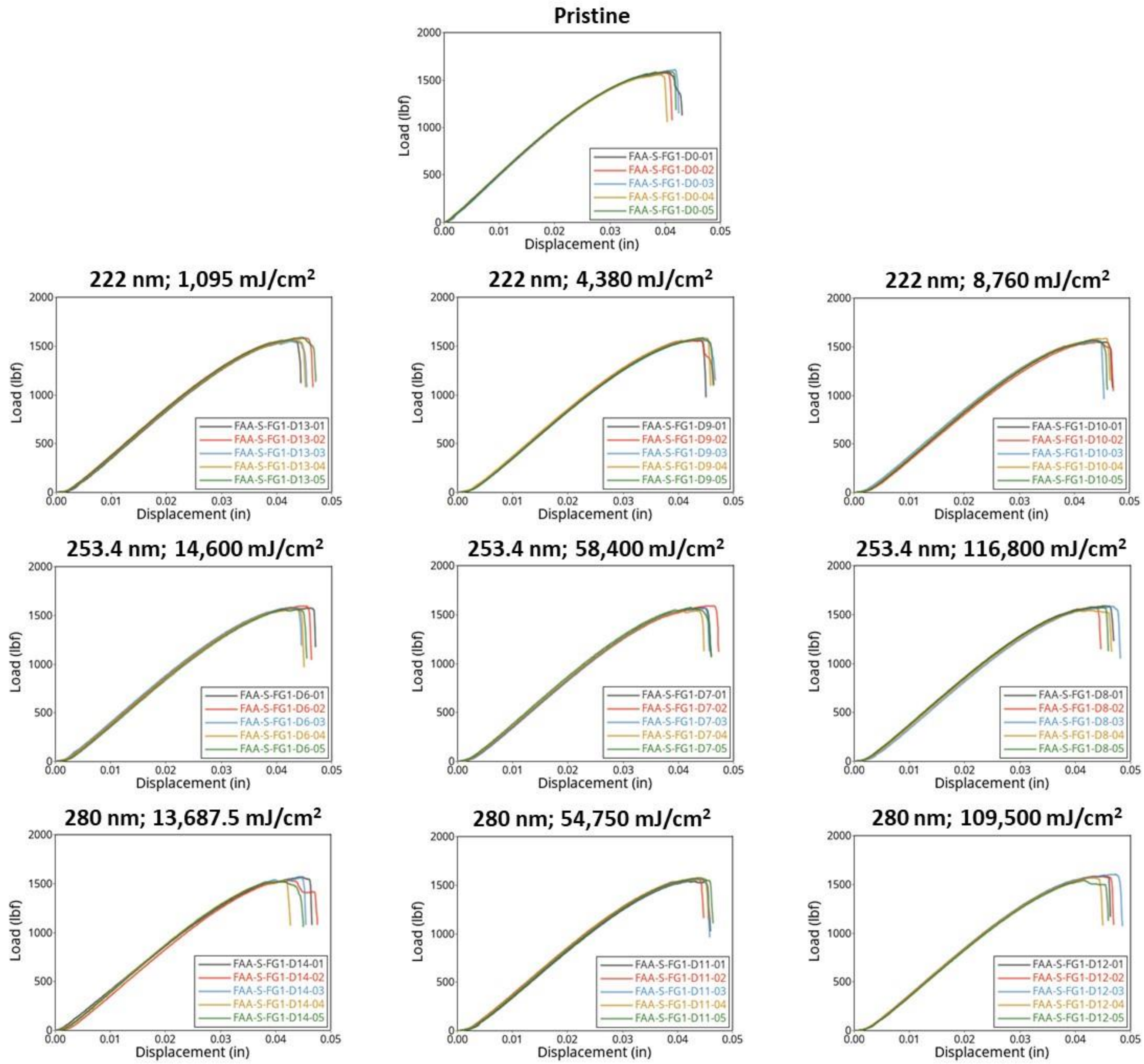

Figure 26. Load-displacement response – Fiberglass G-10/FR4

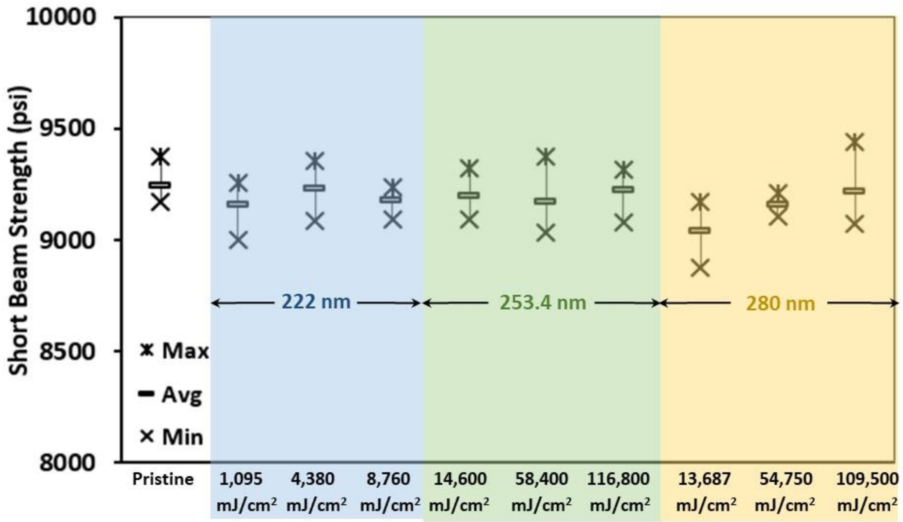

Figure 27. Short-beam strength comparison – Fiberglass G-10/FR4

5.3.5 Statistical data evaluation

Statistical analysis of short-beam shear test data was conducted following the CMH-17 guidelines (Polymer matrix composites: guidelines for characterization of structural materials, 2012). For the acceptance of the material properties from any batch of specimens, it must be shown that the properties obtained from the current batch are “equivalent” to the qualification batch; i.e., the batch data meets the material specification limits (Polymer matrix composites: guidelines for characterization of structural materials, 2012). The current study treats material properties obtained from unaged fiberglass specimens as the qualification batch. The equivalency of the short-beam strength of specimens aged with UV-C is shown in Table 19. The standard equivalency method typically evaluates larger sample batches from multiple data sets. Due to the small sample batch considered in this study, the modified Coefficient of Variation (CV) of 6% method was utilized for equivalency criteria. This method is in accordance with Section 8.4.4 of CMH-17-1G (Polymer matrix composites: guidelines for characterization of structural materials, 2012). For all the wavelength and dosage configurations, fiberglass specimens pass equivalency criteria for short-beam strength with a modified CV of 6%.

Table 19. Statistical data analysis - Fiberglass G-10/FR4

Short-Beam Strength (psi)	222 nm						253.4 nm						280 nm					
	1,095 mJ/cm^2		4,380 mJ/cm^2		8,760 mJ/cm^2		14,600 mJ/cm^2		58,400 mJ/cm^2		116,800 mJ/cm^2		13,687.5 mJ/cm^2		54,750 mJ/cm^2		109,500 mJ/cm^2	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data as measured	Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data		Insufficient Data	
Mean Maximum Load (lbf)	9,250.1	9,166.1	9,250.1	9,235.1	9,250.1	9,180.8	9,250.1	9,197.9	9,250.1	9,175.7	9,250.1	9,228.6	9,250.1	9,045.3	9,250.1	9,165.7	9,250.1	9,226.3
Standard Deviation	85.831	99.396	85.831	101.480	85.831	53.708	85.831	97.255	85.831	124.052	85.831	92.700	85.831	114.868	85.831	43.474	85.831	137.433
Coefficient of Variation %	0.928	1.084	0.928	1.099	0.928	0.585	0.928	1.057	0.928	1.352	0.928	1.004	0.928	1.270	0.928	0.474	0.928	1.490
Minimum	9,172.4	8,998.3	9,172.4	9,088.4	9,172.4	9,093.9	9,172.4	9,093.2	9,172.4	9,036.0	9,172.4	9,078.4	9,172.4	8,877.3	9,172.4	9,104.7	9,172.4	9,070.6
Maximum	9,376.3	9,256.3	9,376.3	9,353.2	9,376.3	9,239.2	9,376.3	9,320.1	9,376.3	9,374.1	9,376.3	9,315.1	9,376.3	9,173.6	9,376.3	9,208.5	9,376.3	9,436.8
Number of Specimens	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
RESULTS	FAIL		PASS		PASS		PASS		FAIL		PASS		FAIL		FAIL		PASS	
Minimum Acceptable Equiv. Sample Mean	9,176.9		9,176.9		9,176.9		9,176.9		9,176.9		9,176.9		9,176.9		9,176.9		9,176.9	
Minimum Acceptable Equiv. Sample Min	9,033.0		9,033.0		9,033.0		9,033.0		9,033.0		9,033.0		9,033.0		9,033.0		9,033.0	
MOD CV RESULTS	PASS with MOD		PASS with MOD		PASS with MOD		PASS with MOD		PASS with MOD		PASS with MOD		PASS with MOD		PASS with MOD		PASS with MOD	
Modified CV%	6.000		6.000		6.000		6.000		6.000		6.000		6.000		6.000		6.000	
Minimum Acceptable Equiv. Sample Mean	8,776.9		8,776.9		8,776.9		8,776.9		8,776.9		8,776.9		8,776.9		8,776.9		8,776.9	
Minimum Acceptable Equiv. Sample Min	7,846.7		7,846.7		7,846.7		7,846.7		7,846.7		7,846.7		7,846.7		7,846.7		7,846.7	

6 Physical properties

This study evaluated the effects of UV-C exposure on the weight and color of different materials. The details of the test methods and the findings are discussed in this section.

6.1 Change in weight

Before and post the accelerated UV-C exposure, the weight of each test specimen was measured to an accuracy of 0.01g. The weight measurements recorded for the test specimens are summarized in Table 20 to Table 22. No significant weight change was observed for any material type when aged with UV-C exposure.

Table 20. Change in weight - Plastics

Plastic Type	Average Recorded Weight (g)													
	222 nm Wavelength				253.4 nm Wavelength						280 nm Wavelength			
	4,380 mJ/cm^2		8,760 mJ/cm^2		14,600 mJ/cm^2		58,400 mJ/cm^2		116,800 mJ/cm^2		54,750 mJ/cm^2		109,500 mJ/cm^2	
	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)
Kydex 6565	0.79	0.80	0.80	0.78	0.81	0.77	0.80	0.79	0.78	0.79	0.79	0.79	0.80	0.79
Boltaron 9815E	0.91	0.89	0.90	0.90	0.90	0.91	0.89	0.89	0.91	0.92	0.91	0.88	0.92	0.88
Lexan XHR	1.00	0.99	1.00	0.99	0.99	0.99	1.00	1.01	1.00	1.01	0.99	0.98	0.99	0.97
Boltaron 9815N	0.88	0.84	0.86	0.86	0.84	0.85	0.86	0.84	0.84	0.85	0.86	0.86	0.87	0.85
ULTEM™ 9075	1.96	1.91	1.96	1.96	-	-	1.96	1.93	1.98	1.93	1.95	1.95	1.98	1.99
ULTEM™ 9085	1.94	1.94	1.90	1.91	-	-	1.93	1.97	1.91	1.97	1.93	1.96	1.93	1.95

Table 21. Change in weight - Honeycomb

Honeycomb Type	Average Recorded Weight (g)					
	222 nm; 1,095 mJ/cm^2		222 nm; 4,380 mJ/cm^2		222 nm; 8,760 mJ/cm^2	
	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)
Honeycomb Type A (H1)	96.02	96.06	95.24	95.31	95.21	95.30

Honeycomb Type	Average Recorded Weight (g)					
	253.4 nm; 14,600 mJ/cm^2		253.4 nm; 58,400 mJ/cm^2		253.4 nm; 116,800 mJ/cm^2	
	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)
Honeycomb Type A (H1)	94.86	94.95	94.45	94.46	95.15	95.23

Honeycomb Type	Average Recorded Weight (g)					
	280 nm; 13,687.5 mJ/cm^2		280 nm; 54,750 mJ/cm^2		280 nm; 109,500 mJ/cm^2	
	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)
Honeycomb Type A (H1)	94.67	94.67	94.90	95.00	95.44	95.54

Table 22. Change in weight - Fiberglass

Material Type	Average Recorded Weight (g)					
	222 nm; 1,095 mJ/cm²		222 nm; 4,380 mJ/cm²		222 nm; 8,760 mJ/cm²	
	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)
Fiberglass G-10/FR4 (FG1)	6.27	6.25	6.24	6.23	6.24	6.22

Material Type	Average Recorded Weight (g)					
	253.4 nm; 14,600 mJ/cm²		253.4 nm; 58,400 mJ/cm²		253.4 nm; 116,800 mJ/cm²	
	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)
Fiberglass G-10/FR4 (FG1)	6.27	6.26	6.27	6.22	6.26	6.25

Material Type	Average Recorded Weight (g)					
	280 nm; 13,687.5 mJ/cm²		280 nm; 54,750 mJ/cm²		280 nm; 109,500 mJ/cm²	
	Pre (g)	Post (g)	Pre (g)	Post (g)	Pre (g)	Post (g)
Fiberglass G-10/FR4 (FG1)	6.25	6.23	6.25	6.25	6.26	6.24

6.2 Change in color

This section presents the effects of UV-C on the appearance of the plastics, honeycomb, and fiberglass materials tested. Post UV-C exposure, test specimens were qualitatively assessed for any color change when compared to pristine specimens. Table 23 and Table 24 summarize the qualitative color change observed in the six plastic material types and honeycomb and fiberglass materials, respectively.

Table 23. Qualitative color change summary – Plastics

Change in Color Compared to Pristine Specimens							
Wavelength Configuration	**Dosage (mJ/cm²)**	**Kydex 6565**	**Boltaron 9815E**	**Lexan XHR**	**Boltaron 9815N**	**ULTEM™ 9075**	**ULTEM™ 9085**
222 nm	**4,380**						
	8,760						
253.4 nm	**14,600**					N/A	N/A
	58,400						
	116,800						
280 nm	**54,750**						
	109,500						

No Color Change
Changes in Color

Table 24. Qualitative color change summary – Honeycomb and Fiberglass

Wavelength Configuration	Dosage (mJ/cm^2)	Honeycomb	Fiberglass G-10/FR4 (FG1)
222 nm	1,095		
	4,380		
	8,760		
253.4 nm	14,600		
	58,400		
	116,800		
280 nm	13,687.5		
	54,750		
	109,500		

No Color Change

Changes in Color

The qualitative assessment results showed that the accelerated UV-C aging tests cause discoloration in most materials considered in this study. The degree of discoloration varied based on the material type and the UV-C cumulative dosage. For Kydex 6565 at 222 nm - 4,380 mJ/cm^2 configuration, the color of the specimens turned to a slight yellowish hue from its original appearance and changed to darker yellow with the 8,760 mJ/cm^2 configuration. With the 253.4 nm wavelength configuration, Kydex 6565 specimens showed no change in color with the first dosage, and the discoloration effects were observed with the second and third dosage configurations. With the 280 nm dosage configuration, Kydex 6565 showed no change in color. Figure 28 to Figure 36 compare discoloration between pristine and UV-C aged specimens under various wavelength and dosage configurations.

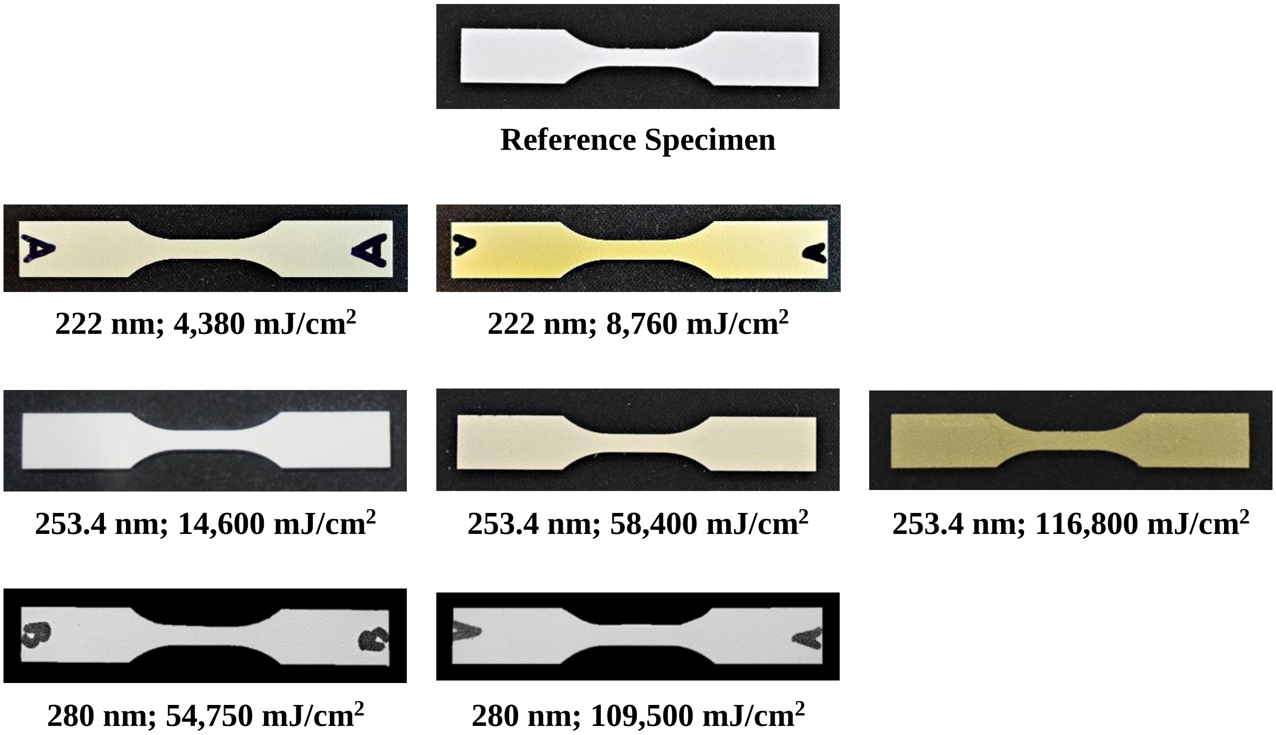

Figure 28 Qualitative comparison of the change in color – Kydex 6565

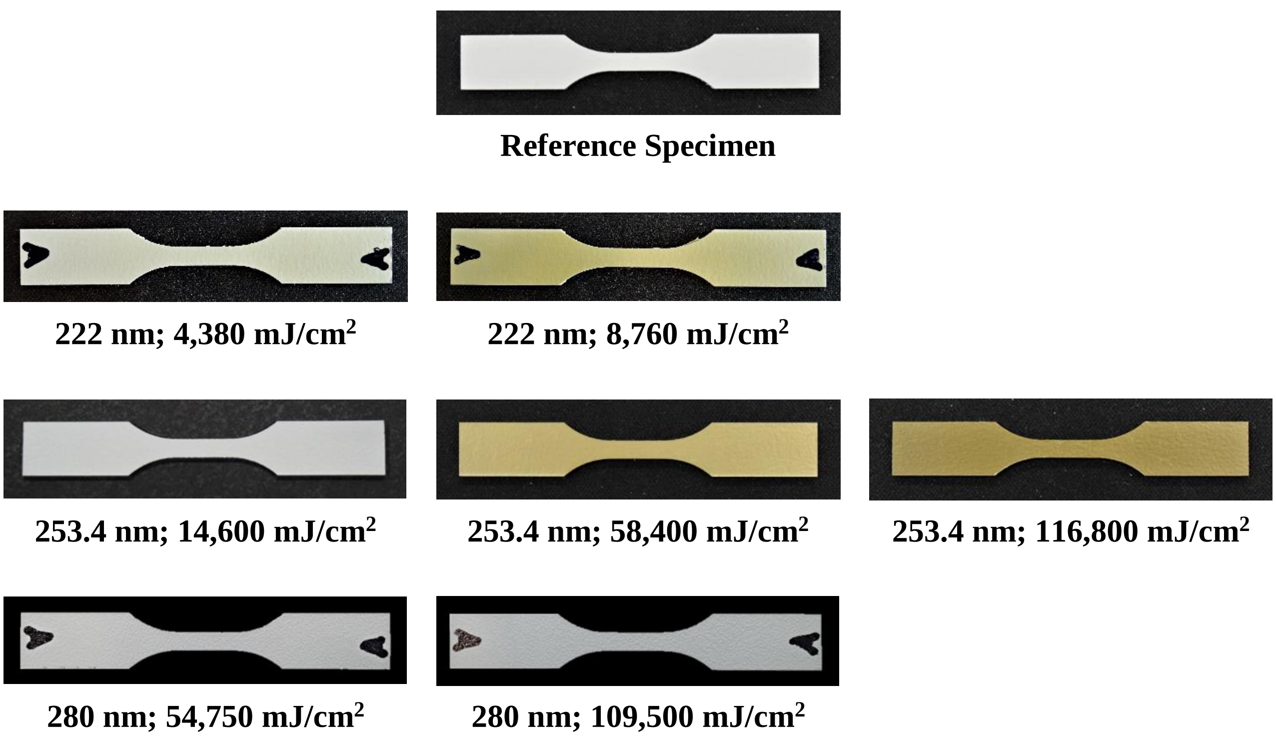

Figure 29. Qualitative comparison of the change in color – Boltaron 9815E

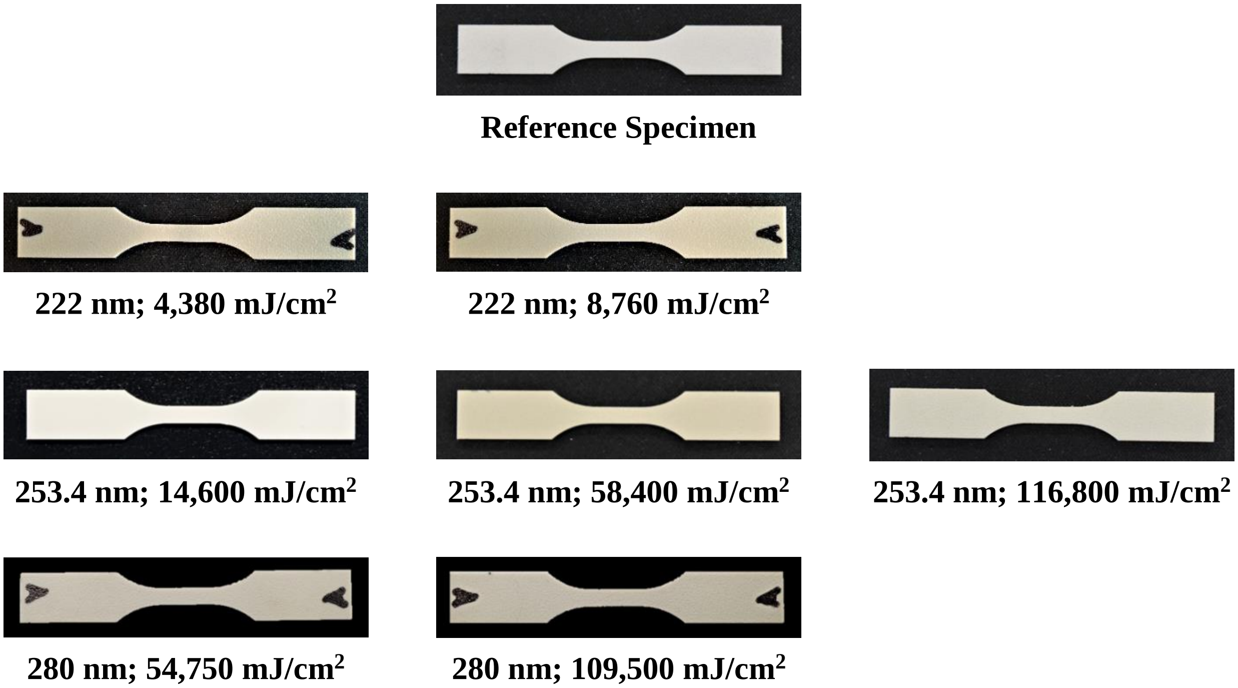

Figure 30. Qualitative comparison of the change in color – Lexan XHR shade 1

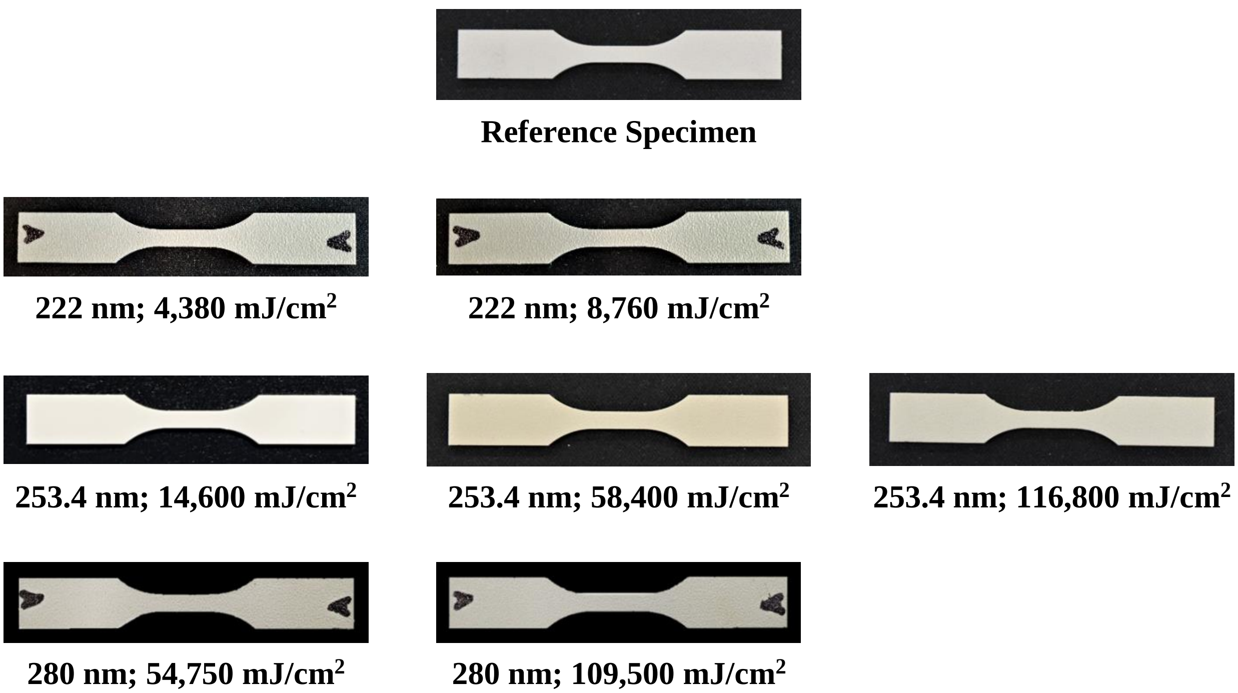

Figure 31. Qualitative comparison of the change in color – Lexan XHR shade 2

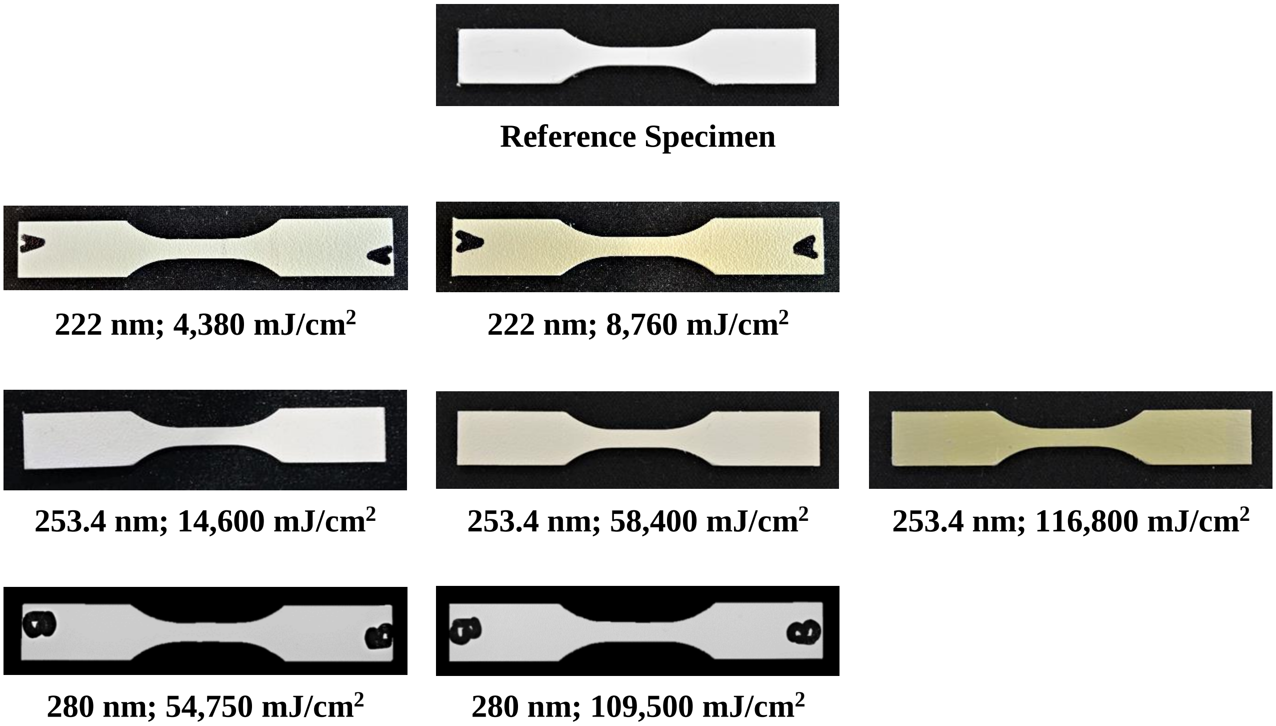

Figure 32. Qualitative comparison of the change in color – Boltaron 9815N

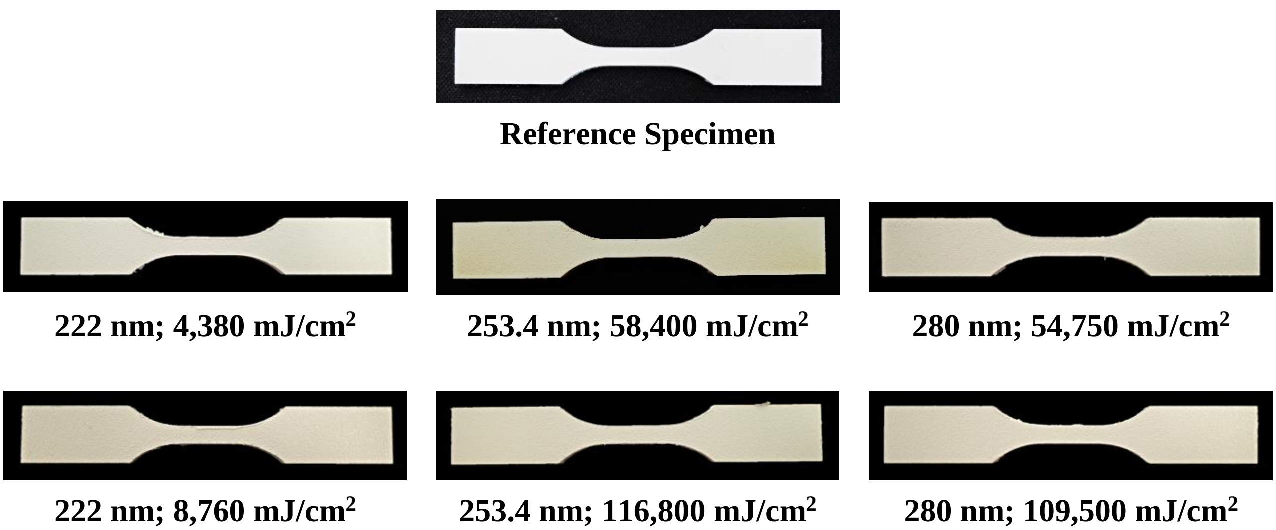

Figure 33. Qualitative comparison of the change in color – ULTEM™ 9075

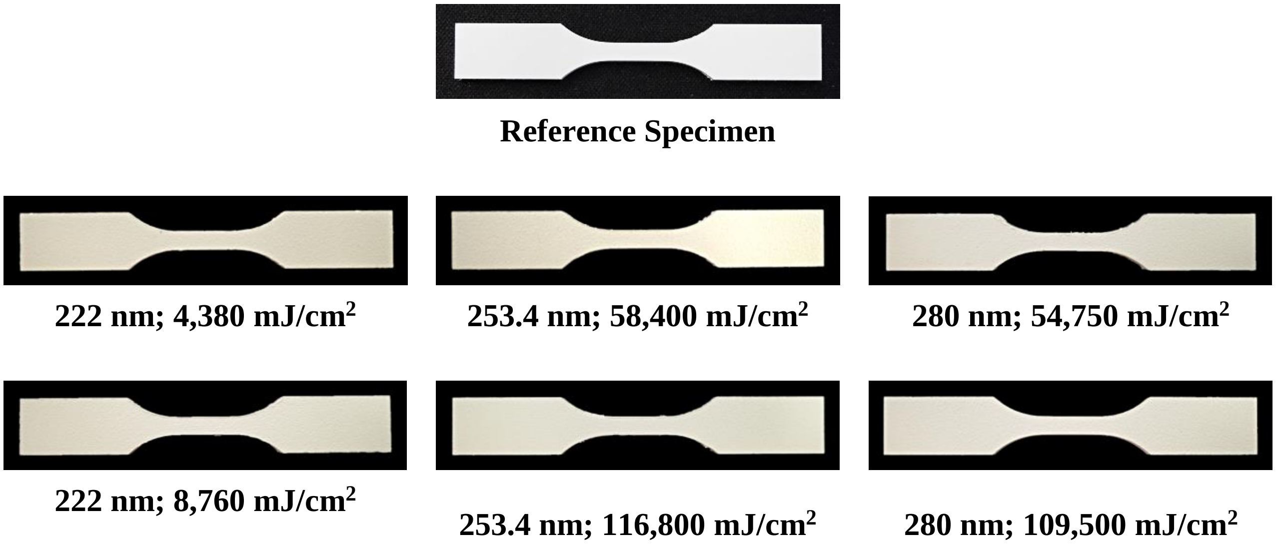

Figure 34. Qualitative comparison of the change in color – ULTEM™ 9085

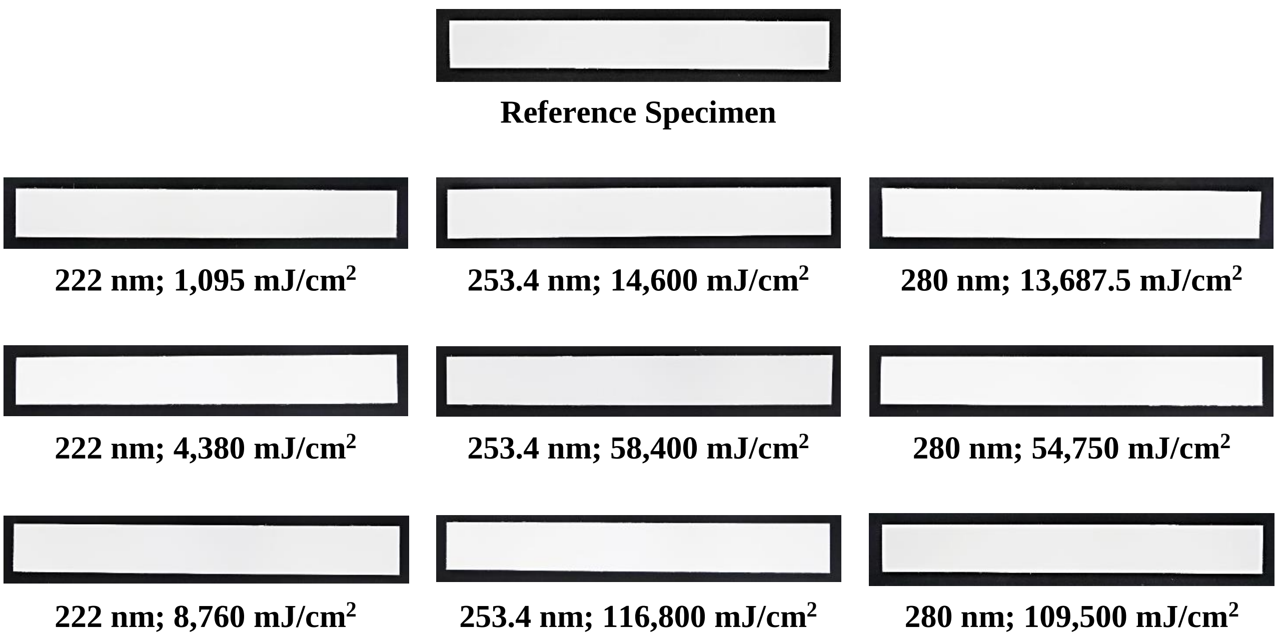

Figure 35. Qualitative comparison of the change in color – Honeycomb type A

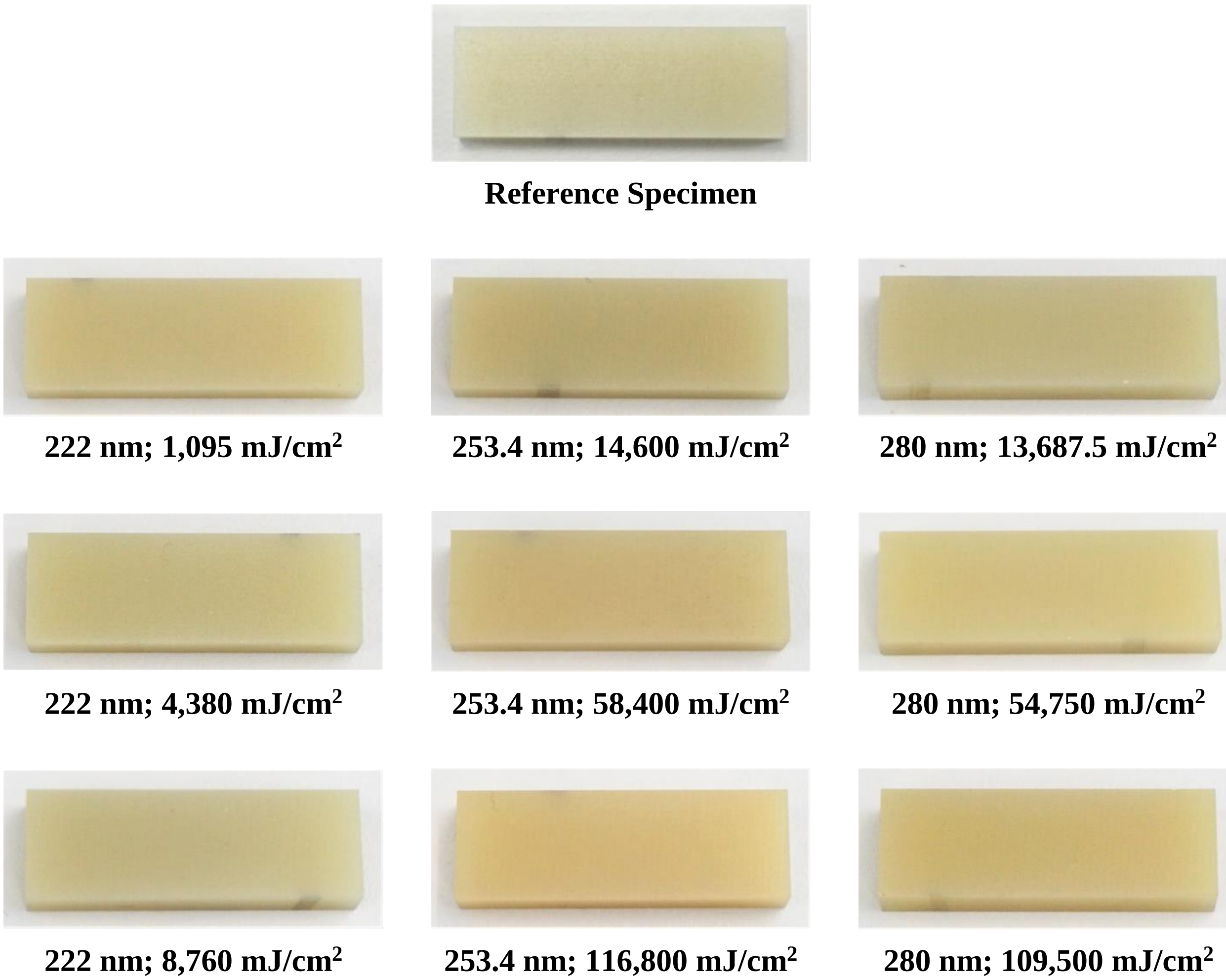

Figure 36. Qualitative comparison of the change in color – Fiberglass G-10/FR4

7 Conclusions

This study evaluated the long-term effects of UV-C irradiation on typical aircraft interior materials. The selected aircraft interior materials include six different plastics, one honeycomb, and one fiberglass material. Three different UV-C wavelength configurations were chosen with multiple cumulative dosages per wavelength configuration. The wavelength configurations selected for this study were 222 nm, 253.4 nm, and 280 nm. The virus inactivation treatment dose for each wavelength configuration was determined based on the literature review. Using the single treatment dose as the baseline, cumulative dosages were computed for accelerated UV-C aging tests equal to exposures of one time per day for one, four, and eight years. Test specimens were subjected to accelerated UV-C exposure and were evaluated for physical and mechanical properties. Plastic specimens were tested for tensile properties, the honeycomb was tested for flexure properties, and the fiberglass for short-beam strength properties.

Six different plastic materials, pristine and UV-C aged, were tested under uniaxial tensile loading conditions following the ASTM D638 test standard. Table 25 presents the percentage difference in average yield stress of UV-C aged specimens compared to pristine specimens. Kydex 6565 at 222 nm wavelength and a cumulative dose of 8,760 mJ/cm^2 showed a 10.39% reduction in average yield stress compared to its pristine counterparts.

Table 25. Results summary – Plastics (yield stress)

Percentage Difference Compared to Pristine Specimens – Yield Stress (Avg.)									
Wavelength Configuration	**Cumulative Time (years) - One dose/day**	**Cumulative Dosage (mJ/cm^2)**	**Kydex 6565**	**Boltaron 9815E**	**Lexan XHR**	**Boltaron 9815N**	**Ultem 9075**	**Ultem 9085**
Avg. Pristine (psi)	**N/A**	**N/A**	7548.1	5521.3	10328.4	6636.3	11776.0	10496.1
222 nm	**Four**	**4,380**	-4.12	2.16	-4.24	-8.39	4.59	3.69
	Eight	**8,760**	-10.39	1.88	1.25	-9.61	3.87	3.62
253.4 nm	**One**	**14,600**	-2.61	2.45	2.10	-3.97	N/A	N/A
	Four	**58,400**	-5.53	4.06	0.80	3.46	4.65	3.29
	Eight	**116,800**	-5.04	5.54	1.52	-2.15	4.27	6.01
280 nm	**Four**	**54,750**	-3.90	2.63	1.72	-1.71	4.12	4.39
	Eight	**109,500**	-4.51	3.26	-1.09	-1.90	4.05	4.37

Percentage difference compared to pristine specimens

- < 5%
- < between 5% to 10%
- > 10%

Table 26 presents the percentage difference in average ultimate tensile strength of UV-C aged specimens compared to pristine specimens.

Table 26. Results summary – Plastics (ultimate tensile strength)

Percentage Difference Compared to Pristine Specimens – Ultimate Tensile Strength (Avg.)									
Wavelength Configuration	**Cumulative Time (years) - One dose/day**	**Cumulative Dosage (mJ/cm²)**	**Kydex 6565**	**Boltaron 9815E**	**Lexan XHR**	**Boltaron 9815N**	**Ultem 9075**	**Ultem 9085**
Avg. Pristine (psi)	**N/A**	**N/A**	6680.5	5180.4	10147.8	5263.5	9722.5	8748.4
222 nm	**Four**	**4,380**	-16.49	-9.25	-10.47	-9.66	9.27	4.59
	Eight	**8,760**	-16.55	-6.24	0.04	-12.33	12.22	9.79
253.4 nm	**One**	**14,600**	-4.36	-3.14	-3.72	-2.49	N/A	N/A
	Four	**58,400**	-13.28	-6.79	0.70	-2.07	-1.65	5.42
	Eight	**116,800**	-19.20	-6.67	-2.18	-7.16	11.11	8.74
280 nm	**Four**	**54,750**	-9.12	0.26	-5.21	-6.42	7.78	4.26
	Eight	**109,500**	-9.40	-0.37	-7.09	-6.18	12.89	8.62

Percentage difference compared to pristine specimens

< 5%

< between 5% to 10%

> 10%

Table 27 presents the percentage difference in mechanical properties between pristine and UV-C aged specimens for honeycomb and fiberglass materials. For honeycomb material, specimens subjected to 253.4 nm - 14,600 mJ/cm^2 dosage presented a 9.66% reduction in maximum load compared to pristine specimens. However, the 4-year and 8-year configurations resulted in less than 5% reduction when compared to pristine specimens. Due to the limited sample count, further conclusions could not be made on this variation. Additional research should be performed to better understand this behavior. For fiberglass material, all three wavelength and cumulative dosage configurations showed less than a 5% reduction in short-beam strength compared to pristine specimens.

Table 27. Results summary – Honeycomb & Fiberglass

Percentage Difference Compared to Pristine Specimens				
Wavelength Configuration	**Cumulative Time (years) - One dose/day**	**Cumulative Dosage (mJ/cm^2)**	**Honeycomb – Maximum Load (lbs.)**	**Fiberglass – Short Beam Strength (psi)**
Avg. Pristine	**N/A**	**N/A**	152.4	9250.1
222 nm	**One**	**1,095**	-2.45	-0.91
	Four	**4,380**	-2.75	-0.16
	Eight	**8,760**	-0.22	-0.75
253.4 nm	**One**	**14,600**	-9.66	-0.56
	Four	**58,400**	-1.28	-0.80
	Eight	**116,800**	-0.24	-0.23
280 nm	**One**	**13,687.5**	5.52	-2.21
	Four	**54,750**	-3.47	-0.91
	Eight	**109,500**	-0.74	-0.26

Percentage difference compared to pristine specimens

< 5%

< between 5% to 10%

> 10%

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A Specimen dimensions - Plastics

Table A- 1. Specimen dimensions for Kydex 6565

Specimen	LO	WO	W1	W2	W3	Wavg	T1	T2	T3	Tavg
FAA-T-P1-D6-01	2.5045	0.3750	0.1255	0.1255	0.1260	0.1257	0.0465	0.0465	0.0470	0.0467
FAA-T-P1-D6-02	2.5060	0.3745	0.1260	0.1255	0.1250	0.1255	0.0465	0.0470	0.0470	0.0468
FAA-T-P1-D6-03	2.5045	0.3760	0.1260	0.1255	0.1255	0.1257	0.0470	0.0475	0.0475	0.0473
FAA-T-P1-D7-01	2.5040	0.3750	0.1265	0.1260	0.1255	0.1260	0.0510	0.0500	0.0500	0.0503
FAA-T-P1-D7-02	2.5040	0.3750	0.1255	0.1250	0.1255	0.1253	0.0475	0.0470	0.0470	0.0472
FAA-T-P1-D7-03	2.5035	0.3755	0.1260	0.1260	0.1260	0.1260	0.0480	0.0480	0.0480	0.0480
FAA-T-P1-D8-01	2.5040	0.3775	0.1255	0.1255	0.1255	0.1255	0.0475	0.0470	0.0470	0.0472
FAA-T-P1-D8-02	2.5035	0.3750	0.1260	0.1260	0.1265	0.1262	0.0490	0.0480	0.0480	0.0483
FAA-T-P1-D8-03	2.5020	0.3765	0.1240	0.1240	0.1240	0.1240	0.0485	0.0480	0.0480	0.0482
FAA-T-P1-D9-01	2.5035	0.3750	0.1270	0.1260	0.1260	0.1263	0.0475	0.0480	0.0485	0.0480
FAA-T-P1-D9-02	2.5030	0.3740	0.1260	0.1260	0.1255	0.1258	0.0475	0.0475	0.0475	0.0475
FAA-T-P1-D9-03	2.5035	0.3755	0.1260	0.1255	0.1255	0.1257	0.0470	0.0475	0.0475	0.0473
FAA-T-P1-D10-01	2.5030	0.3760	0.1265	0.1260	0.1265	0.1263	0.0475	0.0475	0.0475	0.0475
FAA-T-P1-D10-02	2.5050	0.3770	0.1255	0.1260	0.1270	0.1262	0.0475	0.0470	0.0475	0.0473
FAA-T-P1-D10-03	2.5030	0.3745	0.1270	0.1265	0.1265	0.1267	0.0475	0.0480	0.0475	0.0477
FAA-T-P1-D11-01	2.5035	0.3755	0.1260	0.1260	0.1260	0.1260	0.0475	0.0475	0.0475	0.0475
FAA-T-P1-D11-02	2.5020	0.3750	0.1270	0.1265	0.1265	0.1267	0.0485	0.0490	0.0480	0.0485
FAA-T-P1-D11-03	2.5040	0.3750	0.1265	0.1260	0.1260	0.1262	0.0470	0.0480	0.0480	0.0477
FAA-T-P1-D12-01	2.5025	0.3750	0.1260	0.1260	0.1260	0.1260	0.0470	0.0475	0.0470	0.0472
FAA-T-P1-D12-02	2.5035	0.3750	0.1260	0.1265	0.1260	0.1262	0.0475	0.0485	0.0475	0.0478
FAA-T-P1-D12-03	2.5020	0.3750	0.1265	0.1265	0.1260	0.1263	0.0480	0.0485	0.0485	0.0483

Table A- 2. Specimen dimensions for Boltaron 9815E

Specimen	LO	WO	W1	W2	W3	Wavg	T1	T2	T3	Tavg
FAA-T-P2-D6-01	2.5035	0.3760	0.1255	0.1255	0.1250	0.1253	0.0500	0.0510	0.0500	0.0503
FAA-T-P2-D6-02	2.5030	0.3750	0.1260	0.1250	0.1250	0.1253	0.0510	0.0510	0.0515	0.0512
FAA-T-P2-D6-03	2.5045	0.3755	0.1255	0.1250	0.1255	0.1253	0.0510	0.0505	0.0510	0.0508
FAA-T-P2-D7-01	2.5030	0.3750	0.1260	0.1255	0.1260	0.1258	0.0500	0.0500	0.0500	0.0500
FAA-T-P2-D7-02	2.5040	0.3765	0.1255	0.1260	0.1250	0.1255	0.0500	0.0505	0.0505	0.0503
FAA-T-P2-D7-03	2.5075	0.3755	0.1250	0.1260	0.1260	0.1257	0.0500	0.0500	0.0505	0.0502
FAA-T-P2-D8-01	2.5000	0.3770	0.1235	0.1230	0.1235	0.1233	0.0550	0.0545	0.0540	0.0545
FAA-T-P2-D8-02	2.5025	0.3755	0.1255	0.1255	0.1260	0.1257	0.0500	0.0505	0.0505	0.0503
FAA-T-P2-D8-03	2.5040	0.3760	0.1250	0.1250	0.1255	0.1252	0.0500	0.0505	0.0500	0.0502
FAA-T-P2-D9-01	2.5040	0.3750	0.1260	0.1260	0.1260	0.1260	0.0505	0.0505	0.0500	0.0503
FAA-T-P2-D9-02	2.5030	0.3750	0.1265	0.1260	0.1260	0.1262	0.0510	0.0510	0.0510	0.0510
FAA-T-P2-D9-03	2.5035	0.3750	0.1260	0.1255	0.1260	0.1258	0.0505	0.0505	0.0500	0.0503
FAA-T-P2-D10-01	2.5035	0.3755	0.1260	0.1250	0.1250	0.1253	0.0500	0.0505	0.0500	0.0502
FAA-T-P2-D10-02	2.5035	0.3750	0.1255	0.1255	0.1255	0.1255	0.0500	0.0505	0.0500	0.0502
FAA-T-P2-D10-03	2.5030	0.3755	0.1260	0.1255	0.1260	0.1258	0.0520	0.0515	0.0505	0.0513
FAA-T-P2-D11-01	2.5065	0.3750	0.1250	0.1260	0.1255	0.1255	0.0505	0.0515	0.0510	0.0510
FAA-T-P2-D11-02	2.5030	0.3750	0.1260	0.1255	0.1255	0.1257	0.0510	0.0500	0.0500	0.0503
FAA-T-P2-D11-03	2.5030	0.3755	0.1260	0.1255	0.1260	0.1258	0.0510	0.0510	0.0510	0.0510
FAA-T-P2-D12-01	2.5025	0.3750	0.1260	0.1255	0.1260	0.1258	0.0510	0.0520	0.0510	0.0513
FAA-T-P2-D12-02	2.5025	0.3750	0.1255	0.1250	0.1255	0.1253	0.0505	0.0505	0.0500	0.0503
FAA-T-P2-D12-03	2.5025	0.3750	0.1260	0.1260	0.1260	0.1260	0.0500	0.0500	0.0505	0.0502

Table A- 3. Specimen dimensions for Lexan XHR

Specimen	LO	WO	W1	W2	W3	Wavg	T1	T2	T3	Tavg
FAA-T-P3-D6-01	2.5035	0.3775	0.1280	0.1280	0.1280	0.1280	0.0630	0.0630	0.0625	0.0628
FAA-T-P3-D6-02	2.5025	0.3755	0.1260	0.1260	0.1270	0.1263	0.0620	0.0625	0.0620	0.0622
FAA-T-P3-D6-03	2.5020	0.3750	0.1260	0.1265	0.1270	0.1265	0.0620	0.0625	0.0625	0.0623
FAA-T-P3-D7-01	2.5035	0.3750	0.1270	0.1260	0.1260	0.1263	0.0640	0.0640	0.0635	0.0638
FAA-T-P3-D7-02	2.5025	0.3750	0.1270	0.1270	0.1280	0.1273	0.0635	0.0635	0.0630	0.0633
FAA-T-P3-D7-03	2.5020	0.3750	0.1280	0.1280	0.1280	0.1280	0.0625	0.0630	0.0625	0.0627
FAA-T-P3-D8-01	2.5030	0.3750	0.1280	0.1280	0.1275	0.1278	0.0635	0.0630	0.0630	0.0632
FAA-T-P3-D8-02	2.5020	0.3750	0.1280	0.1280	0.1280	0.1280	0.0635	0.0635	0.0635	0.0635
FAA-T-P3-D8-03	2.5035	0.3755	0.1270	0.1270	0.1270	0.1270	0.0625	0.0630	0.0625	0.0627
FAA-T-P3-D9-01	2.5035	0.3750	0.1270	0.1270	0.1270	0.1270	0.0635	0.0635	0.0635	0.0635
FAA-T-P3-D9-02	2.5030	0.3745	0.1280	0.1280	0.1280	0.1280	0.0640	0.0635	0.0635	0.0637
FAA-T-P3-D9-03	2.5025	0.3750	0.1270	0.1265	0.1265	0.1267	0.0630	0.0630	0.0630	0.0630
FAA-T-P3-D10-01	2.5025	0.3755	0.1285	0.1280	0.1280	0.1282	0.0640	0.0640	0.0635	0.0638
FAA-T-P3-D10-02	2.5030	0.3750	0.1270	0.1265	0.1280	0.1272	0.0640	0.0640	0.0640	0.0640
FAA-T-P3-D10-03	2.5030	0.3755	0.1280	0.1280	0.1285	0.1282	0.0625	0.0630	0.0630	0.0628
FAA-T-P3-D11-01	2.5030	0.3755	0.1285	0.1280	0.1285	0.1283	0.0635	0.0630	0.0640	0.0635
FAA-T-P3-D11-02	2.5035	0.3755	0.1285	0.1280	0.1285	0.1283	0.0630	0.0630	0.0630	0.0630
FAA-T-P3-D11-03	2.5025	0.3750	0.1285	0.1285	0.1290	0.1287	0.0640	0.0650	0.0650	0.0647
FAA-T-P3-D12-01	2.5015	0.3750	0.1280	0.1280	0.1280	0.1280	0.0630	0.0630	0.0630	0.0630
FAA-T-P3-D12-02	2.5025	0.3755	0.1275	0.1270	0.1270	0.1272	0.0630	0.0625	0.0625	0.0627
FAA-T-P3-D12-03	2.5050	0.3765	0.1265	0.1270	0.1265	0.1267	0.0615	0.0615	0.0615	0.0615

Table A- 4. Specimen dimensions for Boltaron 9815N

Specimen	LO	WO	W1	W2	W3	Wavg	T1	T2	T3	Tavg
FAA-T-P4-D6-01	2.4795	0.3755	0.1220	0.1225	0.1220	0.1222	0.0485	0.0480	0.0480	0.0482
FAA-T-P4-D6-02	2.4840	0.3740	0.1240	0.1235	0.1230	0.1235	0.0485	0.0480	0.0480	0.0482
FAA-T-P4-D6-03	2.5205	0.3750	0.1255	0.1250	0.1255	0.1253	0.0490	0.0485	0.0485	0.0487
FAA-T-P4-D7-01	2.5335	0.3730	0.1240	0.1235	0.1230	0.1235	0.0490	0.0485	0.0480	0.0485
FAA-T-P4-D7-02	2.4755	0.3780	0.1230	0.1235	0.1240	0.1235	0.0480	0.0485	0.0480	0.0482
FAA-T-P4-D7-03	2.4790	0.3760	0.1215	0.1210	0.1215	0.1213	0.0485	0.0485	0.0485	0.0485
FAA-T-P4-D8-01	2.4770	0.3745	0.1230	0.1230	0.1230	0.1230	0.0480	0.0485	0.0485	0.0483
FAA-T-P4-D8-02	2.4805	0.3740	0.1245	0.1240	0.1235	0.1240	0.0485	0.0480	0.0480	0.0482
FAA-T-P4-D8-03	2.4770	0.3760	0.1220	0.1230	0.1235	0.1228	0.0490	0.0490	0.0490	0.0490
FAA-T-P4-D9-01	2.5030	0.3775	0.1285	0.1280	0.1280	0.1282	0.0500	0.0505	0.0500	0.0502
FAA-T-P4-D9-02	2.5020	0.3775	0.1280	0.1270	0.1280	0.1277	0.0510	0.0505	0.0505	0.0507
FAA-T-P4-D9-03	2.5215	0.3760	0.1235	0.1240	0.1245	0.1240	0.0490	0.0490	0.0490	0.0490
FAA-T-P4-D10-01	2.4790	0.3760	0.1245	0.1245	0.1250	0.1247	0.0485	0.0485	0.0490	0.0487
FAA-T-P4-D10-02	2.5030	0.3780	0.1300	0.1295	0.1305	0.1300	0.0495	0.0495	0.0490	0.0493
FAA-T-P4-D10-03	2.5020	0.3775	0.1280	0.1270	0.1275	0.1275	0.0505	0.0505	0.0500	0.0503
FAA-T-P4-D11-01	2.5035	0.3780	0.1305	0.1300	0.1310	0.1305	0.0505	0.0500	0.0505	0.0503
FAA-T-P4-D11-02	2.4765	0.3745	0.1230	0.1220	0.1220	0.1223	0.0490	0.0485	0.0490	0.0488
FAA-T-P4-D11-03	2.5280	0.3760	0.1195	0.1200	0.1205	0.1200	0.0490	0.0490	0.0490	0.0490
FAA-T-P4-D12-01	2.4780	0.3735	0.1280	0.1280	0.1280	0.1280	0.0490	0.0490	0.0485	0.0488
FAA-T-P4-D12-02	2.4815	0.3760	0.1230	0.1230	0.1235	0.1232	0.0485	0.0485	0.0480	0.0483
FAA-T-P4-D12-03	2.5020	0.3780	0.1295	0.1295	0.1295	0.1295	0.0500	0.0500	0.0495	0.0498

Table A- 5. Specimen dimensions for ULTEM^{TM} 9075

Specimen	LO	WO	W1	W2	W3	Wavg	T1	T2	T3	Tavg
FAA-T-P5-D7-01	2.5085	0.3825	0.1220	0.1195	0.1220	0.1212	0.1195	0.1205	0.1200	0.1200
FAA-T-P5-D7-02	2.5095	0.3820	0.1240	0.1195	0.1205	0.1213	0.1175	0.1200	0.1195	0.1190
FAA-T-P5-D7-03	2.5095	0.3820	0.1230	0.1195	0.1210	0.1212	0.1205	0.1205	0.1200	0.1203
FAA-T-P5-D8-01	2.5090	0.3835	0.1215	0.1215	0.1220	0.1217	0.1180	0.1185	0.1190	0.1185
FAA-T-P5-D8-02	2.5085	0.3835	0.1260	0.1205	0.1205	0.1223	0.1205	0.1200	0.1205	0.1203
FAA-T-P5-D8-03	2.5085	0.3825	0.1230	0.1215	0.1230	0.1225	0.1195	0.1190	0.1190	0.1192
FAA-T-P5-D9-01	2.5095	0.3835	0.1245	0.1220	0.1230	0.1232	0.1185	0.1185	0.1185	0.1185
FAA-T-P5-D9-02	2.5095	0.3825	0.1205	0.1195	0.1210	0.1203	0.1170	0.1170	0.1170	0.1170
FAA-T-P5-D9-03	2.5075	0.3820	0.1250	0.1205	0.1200	0.1218	0.1165	0.1165	0.1180	0.1170
FAA-T-P5-D10-01	2.5115	0.3835	0.1220	0.1210	0.1210	0.1213	0.1175	0.1180	0.1170	0.1175
FAA-T-P5-D10-02	2.5075	0.3825	0.1245	0.1220	0.1240	0.1235	0.1175	0.1175	0.1180	0.1177
FAA-T-P5-D10-03	2.5105	0.3835	0.1250	0.1225	0.1240	0.1238	0.1195	0.1190	0.1190	0.1192
FAA-T-P5-D11-01	2.5095	0.3835	0.1250	0.1205	0.1210	0.1222	0.1165	0.1170	0.1165	0.1167
FAA-T-P5-D11-02	2.5090	0.3830	0.1255	0.1205	0.1230	0.1230	0.1205	0.1210	0.1195	0.1203
FAA-T-P5-D11-03	2.5105	0.3805	0.1250	0.1220	0.1220	0.1230	0.1180	0.1180	0.1180	0.1180
FAA-T-P5-D12-01	2.5100	0.3805	0.1255	0.1220	0.1230	0.1235	0.1185	0.1185	0.1185	0.1185
FAA-T-P5-D12-02	2.5085	0.3795	0.1200	0.1195	0.1220	0.1205	0.1175	0.1185	0.1175	0.1178
FAA-T-P5-D12-03	2.5100	0.3805	0.1295	0.1215	0.1205	0.1238	0.1215	0.1205	0.1205	0.1208

Table A- 6. Specimen dimensions for ULTEM^{TM} 9085

Specimen	LO	WO	W1	W2	W3	Wavg	T1	T2	T3	Tavg
FAA-T-P6-D7-01	2.5100	0.3835	0.1225	0.1215	0.1220	0.1220	0.1205	0.1210	0.1205	0.1207
FAA-T-P6-D7-02	2.5090	0.3825	0.1240	0.1205	0.1215	0.1220	0.1165	0.1160	0.1155	0.1160
FAA-T-P6-D7-03	2.5080	0.3820	0.1230	0.1205	0.1215	0.1217	0.1180	0.1180	0.1175	0.1178
FAA-T-P6-D8-01	2.5095	0.3825	0.1210	0.1205	0.1215	0.1210	0.1150	0.1170	0.1160	0.1160
FAA-T-P6-D8-02	2.5095	0.3825	0.1215	0.1205	0.1220	0.1213	0.1165	0.1165	0.1165	0.1165
FAA-T-P6-D8-03	2.5090	0.3825	0.1235	0.1210	0.1220	0.1222	0.1145	0.1165	0.1160	0.1157
FAA-T-P6-D9-01	2.5095	0.3815	0.1230	0.1225	0.1255	0.1237	0.1200	0.1185	0.1180	0.1188
FAA-T-P6-D9-02	2.5085	0.3830	0.1240	0.1215	0.1240	0.1232	0.1170	0.1185	0.1165	0.1173
FAA-T-P6-D9-03	2.5095	0.3815	0.1225	0.1210	0.1225	0.1220	0.1150	0.1165	0.1160	0.1158
FAA-T-P6-D10-01	2.5090	0.3835	0.1225	0.1200	0.1220	0.1215	0.1160	0.1165	0.1165	0.1163
FAA-T-P6-D10-02	2.5100	0.3835	0.1225	0.1205	0.1220	0.1217	0.1145	0.1150	0.1150	0.1148
FAA-T-P6-D10-03	2.5110	0.3835	0.1240	0.1205	0.1220	0.1222	0.1215	0.1215	0.1205	0.1212
FAA-T-P6-D11-01	2.5120	0.3835	0.1230	0.1215	0.1230	0.1225	0.1200	0.1205	0.1210	0.1205
FAA-T-P6-D11-02	2.5085	0.3825	0.1220	0.1200	0.1220	0.1213	0.1170	0.1175	0.1165	0.1170
FAA-T-P6-D11-03	2.5095	0.3835	0.1240	0.1215	0.1245	0.1233	0.1170	0.1175	0.1175	0.1173
FAA-T-P6-D12-01	2.5110	0.3835	0.1235	0.1230	0.1245	0.1237	0.1175	0.1165	0.1175	0.1172
FAA-T-P6-D12-02	2.5100	0.3835	0.1220	0.1200	0.1230	0.1217	0.1165	0.1165	0.1165	0.1165
FAA-T-P6-D12-03	2.5090	0.3805	0.1235	0.1210	0.1235	0.1227	0.1165	0.1165	0.1165	0.1165

B Specimen dimensions - Honeycomb

Table B- 1. Specimen dimensions for Honeycomb type A

Specimen	LO	W1	W2	W3	Wavg	T1	T2	T3	Tavg
FAA-F-H1-D6-01	24.0000	3.0170	3.0175	3.0170	3.0172	0.4035	0.4045	0.4065	0.4048
FAA-F-H1-D6-02	24.0000	3.0195	3.0190	3.0260	3.0215	0.4150	0.4100	0.4120	0.4123
FAA-F-H1-D6-03	24.0000	3.0220	3.2250	3.0215	3.0895	0.4100	0.4155	0.4100	0.4118
FAA-F-H1-D6-04	24.0000	3.0120	3.0160	3.0220	3.0167	0.4075	0.4060	0.4100	0.4078
FAA-F-H1-D6-05	24.0000	3.0205	3.0205	3.0205	3.0205	0.4230	0.4150	0.4145	0.4175
FAA-F-H1-D7-01	24.0000	3.0190	3.0190	3.0180	3.0187	0.4120	0.4160	0.4145	0.4142
FAA-F-H1-D7-02	24.0000	3.0190	3.0190	3.0190	3.0190	0.4110	0.4200	0.4235	0.4182
FAA-F-H1-D7-03	24.0000	3.0120	3.0180	3.0150	3.0150	0.4085	0.4095	0.4065	0.4082
FAA-F-H1-D7-04	24.0000	3.0155	3.0160	3.0180	3.0165	0.4095	0.4120	0.4090	0.4102
FAA-F-H1-D7-05	24.0000	3.0200	3.0300	3.0300	3.0267	0.4070	0.4080	0.4045	0.4065
FAA-F-H1-D8-01	24.0000	3.0220	3.0205	3.0190	3.0205	0.4070	0.4065	0.4255	0.4130
FAA-F-H1-D8-02	24.0000	3.0200	3.0200	3.0215	3.0205	0.4035	0.4035	0.4110	0.4060
FAA-F-H1-D8-03	24.0000	3.0205	3.0205	3.0230	3.0213	0.4100	0.4205	0.4270	0.4192
FAA-F-H1-D8-04	24.0000	3.0220	3.0280	3.0205	3.0235	0.4085	0.4340	0.4075	0.4167
FAA-F-H1-D8-05	24.0000	3.0250	3.0210	3.0205	3.0222	0.4110	0.4145	0.4140	0.4132
FAA-F-H1-D9-01	24.0000	3.0225	3.0180	3.0180	3.0195	0.4150	0.4170	0.4145	0.4155
FAA-F-H1-D9-02	24.0000	3.0210	3.0230	3.0235	3.0225	0.4090	0.4105	0.4200	0.4132
FAA-F-H1-D9-03	24.0000	3.0295	3.0220	3.0230	3.0248	0.4045	0.4300	0.4285	0.4210
FAA-F-H1-D9-04	24.0000	3.0195	3.0190	3.0190	3.0192	0.4115	0.4335	0.4165	0.4205
FAA-F-H1-D9-05	24.0000	3.0180	3.0185	3.0195	3.0187	0.4090	0.4275	0.4245	0.4203
FAA-F-H1-D10-01	24.0000	3.0205	3.0210	3.0205	3.0207	0.4065	0.4045	0.4045	0.4052
FAA-F-H1-D10-02	24.0000	3.0235	3.0225	3.0220	3.0227	0.4105	0.4115	0.4100	0.4107
FAA-F-H1-D10-03	24.0000	3.0230	3.0215	3.0205	3.0217	0.4130	0.4050	0.4070	0.4083
FAA-F-H1-D10-04	24.0000	3.0185	3.0190	3.0200	3.0192	0.4070	0.4120	0.4120	0.4103
FAA-F-H1-D10-05	24.0000	3.0145	3.0155	3.0165	3.0155	0.4080	0.4100	0.4220	0.4133
FAA-F-H1-D11-01	24.0000	3.0150	3.0160	3.0165	3.0158	0.4075	0.4085	0.4065	0.4075
FAA-F-H1-D11-02	24.0000	3.0180	3.0185	3.0195	3.0187	0.4055	0.4065	0.4035	0.4052
FAA-F-H1-D11-03	24.0000	3.0215	3.0200	3.0230	3.0215	0.4070	0.4070	0.4050	0.4063
FAA-F-H1-D11-04	24.0000	3.0195	3.0215	3.0185	3.0198	0.4095	0.4120	0.4110	0.4108
FAA-F-H1-D11-05	24.0000	3.0065	3.0065	3.0060	3.0063	0.4035	0.4030	0.4030	0.4032
FAA-F-H1-D12-01	24.0000	3.0215	3.0225	3.0215	3.0218	0.4055	0.4080	0.4060	0.4065
FAA-F-H1-D12-02	24.0000	3.0205	3.0205	3.0250	3.0220	0.4110	0.4325	0.4415	0.4283
FAA-F-H1-D12-03	24.0000	3.0235	3.0230	3.0190	3.0218	0.4045	0.4150	0.4040	0.4078
FAA-F-H1-D12-04	24.0000	3.0240	3.0240	3.0175	3.0218	0.4075	0.4045	0.4175	0.4098
FAA-F-H1-D12-05	24.0000	3.0260	3.0200	3.0205	3.0222	0.4080	0.4130	0.4110	0.4107
FAA-F-H1-D13-01	24.0000	3.0190	3.0190	3.0195	3.0192	0.4090	0.4100	0.4085	0.4092
FAA-F-H1-D13-02	24.0000	3.0245	3.0190	3.0190	3.0208	0.4075	0.4090	0.4075	0.4080
FAA-F-H1-D13-03	24.0000	3.0190	3.0185	3.0195	3.0190	0.4095	0.4040	0.4070	0.4068
FAA-F-H1-D13-04	24.0000	3.0205	3.0280	3.0405	3.0297	0.4030	0.4040	0.4260	0.4110
FAA-F-H1-D13-05	24.0000	3.0190	3.0220	3.0225	3.0212	0.4030	0.4030	0.4025	0.4028
FAA-F-H1-D14-01	24.0000	3.0225	3.0230	3.0195	3.0217	0.4110	0.4110	0.4115	0.4112
FAA-F-H1-D14-02	24.0000	3.0220	3.0290	3.0165	3.0225	0.4120	0.4110	0.4110	0.4113
FAA-F-H1-D14-03	24.0000	3.0270	3.0295	3.0240	3.0268	0.4150	0.4120	0.4130	0.4133
FAA-F-H1-D14-04	24.0000	3.0185	3.0205	3.0235	3.0208	0.4075	0.4050	0.4040	0.4055
FAA-F-H1-D14-05	24.0000	3.0220	3.0220	3.0205	3.0215	0.4055	0.4070	0.4080	0.4068

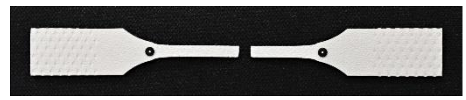
C Specimen dimensions - Fiberglass

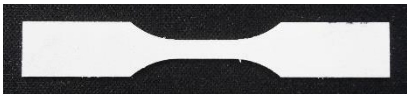
Table C- 1. Specimen dimensions for Fiberglass G-10/FR4

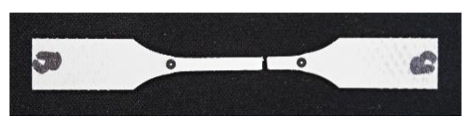
Specimen	LO	W1	W2	W3	Wavg	T1	T2	T3	Tavg
FAA-S-FG1-D6-01	1.5070	0.5020	0.5020	0.5020	0.5020	0.2550	0.2550	0.2550	0.2550
FAA-S-FG1-D6-02	1.5075	0.5020	0.5015	0.5015	0.5017	0.2565	0.2560	0.2560	0.2562
FAA-S-FG1-D6-03	1.5070	0.5015	0.5015	0.5015	0.5015	0.2565	0.2565	0.2560	0.2563
FAA-S-FG1-D6-04	1.5090	0.5010	0.5010	0.5020	0.5013	0.2575	0.2575	0.2565	0.2572
FAA-S-FG1-D6-05	1.5075	0.5015	0.5010	0.5005	0.5010	0.2565	0.2565	0.2570	0.2567
FAA-S-FG1-D7-01	1.5105	0.5015	0.5015	0.5015	0.5015	0.2565	0.2565	0.2560	0.2563
FAA-S-FG1-D7-02	1.5080	0.5020	0.5015	0.5015	0.5017	0.2535	0.2535	0.2535	0.2535
FAA-S-FG1-D7-03	1.5075	0.5010	0.5015	0.5020	0.5015	0.2565	0.2565	0.2565	0.2565
FAA-S-FG1-D7-04	1.5075	0.5015	0.5020	0.5020	0.5018	0.2530	0.2540	0.2560	0.2543
FAA-S-FG1-D7-05	1.5070	0.5020	0.5020	0.5015	0.5018	0.2565	0.2565	0.2565	0.2565
FAA-S-FG1-D8-01	1.5075	0.5015	0.5010	0.5010	0.5012	0.2560	0.2560	0.2565	0.2562
FAA-S-FG1-D8-02	1.5075	0.5020	0.5020	0.5015	0.5018	0.2545	0.2545	0.2540	0.2543
FAA-S-FG1-D8-03	1.5070	0.5015	0.5010	0.5020	0.5015	0.2545	0.2545	0.2545	0.2545
FAA-S-FG1-D8-04	1.5075	0.5015	0.5020	0.5020	0.5018	0.2530	0.2535	0.2560	0.2542
FAA-S-FG1-D8-05	1.5075	0.5020	0.5010	0.5005	0.5012	0.2565	0.2565	0.2565	0.2565
FAA-S-FG1-D9-01	1.5075	0.5015	0.5015	0.5015	0.5015	0.2545	0.2545	0.2540	0.2543
FAA-S-FG1-D9-02	1.5075	0.5010	0.5010	0.5020	0.5013	0.2565	0.2565	0.2565	0.2565
FAA-S-FG1-D9-03	1.5065	0.5015	0.5020	0.5020	0.5018	0.2550	0.2525	0.2530	0.2535
FAA-S-FG1-D9-04	1.5075	0.5015	0.5015	0.5015	0.5015	0.2555	0.2550	0.2550	0.2552
FAA-S-FG1-D9-05	1.5075	0.5010	0.5010	0.5015	0.5012	0.2550	0.2530	0.2525	0.2535
FAA-S-FG1-D10-01	1.5075	0.5020	0.5015	0.5015	0.5017	0.2530	0.2540	0.2555	0.2542
FAA-S-FG1-D10-02	1.5070	0.5015	0.5020	0.5020	0.5018	0.2530	0.2535	0.2560	0.2542
FAA-S-FG1-D10-03	1.5075	0.4995	0.5005	0.5010	0.5003	0.2550	0.2550	0.2550	0.2550
FAA-S-FG1-D10-04	1.5070	0.5020	0.5015	0.5015	0.5017	0.2565	0.2565	0.2565	0.2565
FAA-S-FG1-D10-05	1.5085	0.5015	0.5020	0.5020	0.5018	0.2560	0.2555	0.2555	0.2557
FAA-S-FG1-D11-01	1.5080	0.5020	0.5020	0.5020	0.5020	0.2515	0.2525	0.2535	0.2525
FAA-S-FG1-D11-02	1.5075	0.5015	0.5015	0.5020	0.5017	0.2560	0.2565	0.2565	0.2563
FAA-S-FG1-D11-03	1.5075	0.5015	0.5020	0.5020	0.5018	0.2530	0.2535	0.2555	0.2540
FAA-S-FG1-D11-04	1.5070	0.5015	0.5020	0.5015	0.5017	0.2550	0.2550	0.2545	0.2548
FAA-S-FG1-D11-05	1.5070	0.5010	0.5015	0.5020	0.5015	0.2555	0.2555	0.2555	0.2555
FAA-S-FG1-D12-01	1.5100	0.5005	0.5010	0.5020	0.5012	0.2565	0.2565	0.2565	0.2565
FAA-S-FG1-D12-02	1.5070	0.5020	0.5015	0.5010	0.5015	0.2565	0.2570	0.2570	0.2568
FAA-S-FG1-D12-03	1.5075	0.5020	0.5020	0.5015	0.5018	0.2545	0.2540	0.2540	0.2542
FAA-S-FG1-D12-04	1.5075	0.5010	0.5015	0.5020	0.5015	0.2565	0.2565	0.2565	0.2565
FAA-S-FG1-D12-05	1.5075	0.5020	0.5015	0.5020	0.5018	0.2525	0.2535	0.2555	0.2538
FAA-S-FG1-D13-01	1.5075	0.5005	0.5010	0.5020	0.5012	0.2550	0.2545	0.2545	0.2547
FAA-S-FG1-D13-02	1.5075	0.5020	0.5015	0.5015	0.5017	0.2565	0.2575	0.2570	0.2570
FAA-S-FG1-D13-03	1.5070	0.5015	0.5010	0.5015	0.5013	0.2570	0.2575	0.2575	0.2573
FAA-S-FG1-D13-04	1.5070	0.5015	0.5015	0.5010	0.5013	0.2545	0.2530	0.2525	0.2533
FAA-S-FG1-D13-05	1.5075	0.5015	0.5015	0.5020	0.5017	0.2565	0.2565	0.2565	0.2565
FAA-S-FG1-D14-01	1.5105	0.5015	0.5020	0.5020	0.5018	0.2565	0.2565	0.2565	0.2565
FAA-S-FG1-D14-02	1.5070	0.5015	0.5020	0.5020	0.5018	0.2550	0.2530	0.2530	0.2537
FAA-S-FG1-D14-03	1.5070	0.5010	0.5015	0.5020	0.5015	0.2530	0.2535	0.2555	0.2540
FAA-S-FG1-D14-04	1.5095	0.5015	0.5020	0.5020	0.5018	0.2545	0.2545	0.2540	0.2543
FAA-S-FG1-D14-05	1.5100	0.5015	0.5015	0.5020	0.5017	0.2560	0.2565	0.2565	0.2563

D Specimen pictures - Plastics

Table D- 1. Test photographs for FAA-T-P1-DX-0X (Kydex 6565)

	Pre-Aging	**Post-Aging/ Pre-Test**	**Post-Test**
FAA-T-P1-D6-01			
FAA-T-P1-D6-02			
FAA-T-P1-D6-03			
FAA-T-P1-D7-01			
FAA-T-P1-D7-02			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P1-D7-03			
FAA-T-P1-D8-01			
FAA-T-P1-D8-02			
FAA-T-P1-D8-03			
FAA-T-P1-D9-01			
FAA-T-P1-D9-02			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P1-D9-03			
FAA-T-P1-D10-01			
FAA-T-P1-D10-02			
FAA-T-P1-D10-03			
FAA-T-P1-D11-01			

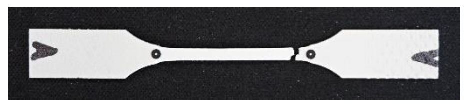
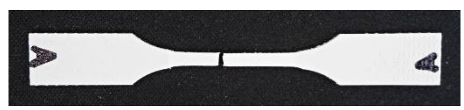
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P1-D11-02			
FAA-T-P1-D11-03			
FAA-T-P1-D12-01			
FAA-T-P1-D12-02			
FAA-T-P1-D12-03			

Table D- 2. Test photographs for FAA-T-P2-DX-0X (Boltaron 9815E)

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P2-D6-01			
FAA-T-P2-D6-02			
FAA-T-P2-D6-03			
FAA-T-P2-D7-01			
FAA-T-P2-D7-02			
FAA-T-P2-D7-03			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P2-D6-01			
FAA-T-P2-D8-01			
FAA-T-P2-D8-02			
FAA-T-P2-D8-03			
FAA-T-P2-D9-01			
FAA-T-P2-D9-02			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P2-D6-01			
FAA-T-P2-D9-03			
FAA-T-P2-D10-01			
FAA-T-P2-D10-02			
FAA-T-P2-D10-03			
FAA-T-P2-D11-01			

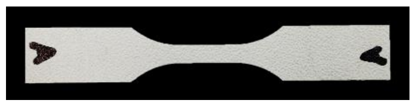
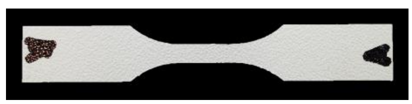
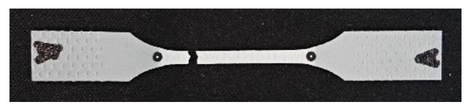
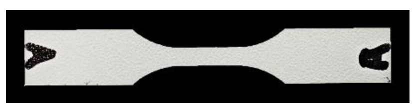
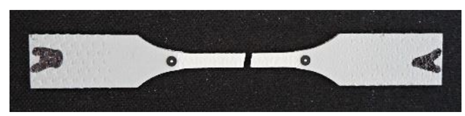
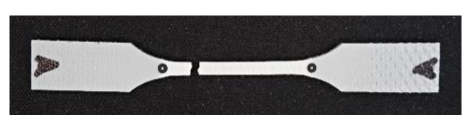
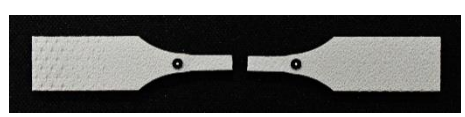
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P2-D6-01			
FAA-T-P2-D11-02			
FAA-T-P2-D11-03			
FAA-T-P2-D12-01			
FAA-T-P2-D12-02			
FAA-T-P2-D12-03			

Table D- 3. Test photographs for FAA-T-P3-DX-0X (Lexan XHR)

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P3-D6-01		Image is unavailable.	
FAA-T-P3-D6-02			
FAA-T-P3-D6-03			
FAA-T-P3-D7-01			
FAA-T-P3-D7-02			
FAA-T-P3-D7-03			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P3-D8-01			
FAA-T-P3-D8-02			
FAA-T-P3-D8-03			
FAA-T-P3-D9-01			
FAA-T-P3-D9-02			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P3-D9-03			
FAA-T-P3-D10-01			
FAA-T-P3-D10-02			
FAA-T-P3-D10-03			
FAA-T-P3-D11-01			

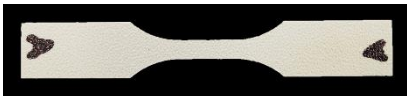
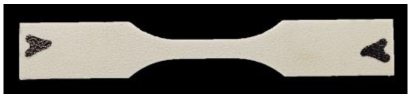
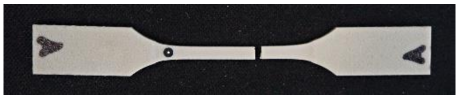
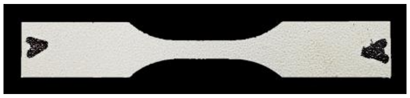
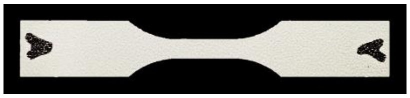
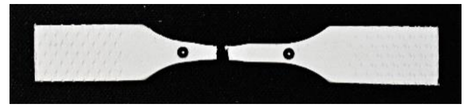
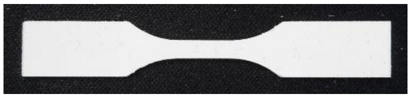
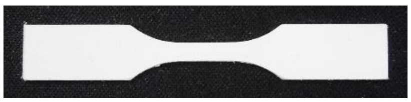
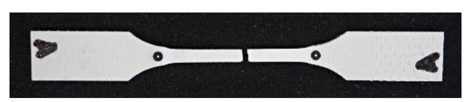
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P3-D11-02			
FAA-T-P3-D11-03			
FAA-T-P3-D12-01			
FAA-T-P3-D12-02			
FAA-T-P3-D12-03			

Table D- 4. Test photographs for FAA-T-P4-DX-0X (Boltaron 9815N)

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P4-D6-01			
FAA-T-P4-D6-02			
FAA-T-P4-D6-03			
FAA-T-P4-D7-01			
FAA-T-P4-D7-02			
FAA-T-P4-D7-03			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P4-D8-01			
FAA-T-P4-D8-02			
FAA-T-P4-D8-03			
FAA-T-P4-D9-01			
FAA-T-P4-D9-02			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P4-D9-03			
FAA-T-P4-D10-01			
FAA-T-P4-D10-02			
FAA-T-P4-D10-03			
FAA-T-P4-D11-01			

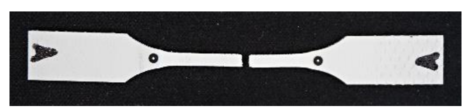
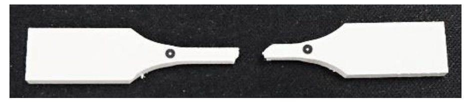
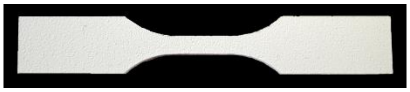
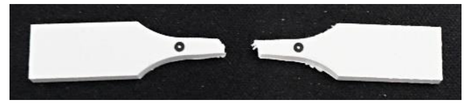
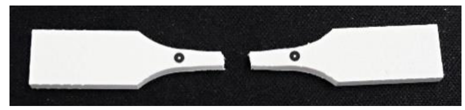
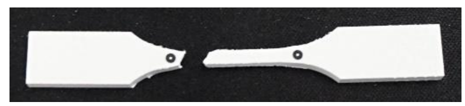
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P4-D11-02			
FAA-T-P4-D11-03			
FAA-T-P4-D12-01			
FAA-T-P4-D12-02			
FAA-T-P4-D12-03			

Table D- 5. Test photographs for FAA-T-P5-DX-0X (ULTEM™ 9075)

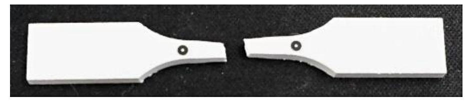
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P5-D7-01			
FAA-T-P5-D7-02			
FAA-T-P5-D7-03			
FAA-T-P5-D8-01			
FAA-T-P5-D8-02			
FAA-T-P5-D8-03			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P5-D9-01			
FAA-T-P5-D9-02			
FAA-T-P5-D9-03			
FAA-T-P5-D10-01			
FAA-T-P5-D10-02			

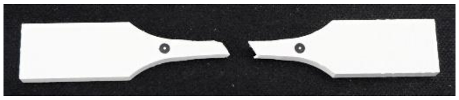
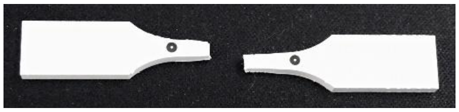
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P5-D10-03			
FAA-T-P5-D11-01			
FAA-T-P5-D11-02			
FAA-T-P5-D11-03			
FAA-T-P5-D12-01			

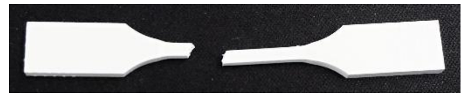
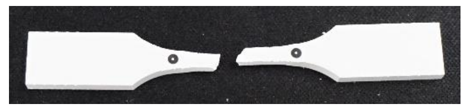
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-T-P5-D12-02			
FAA-T-P5-D12-03			

Table D- 6. Test photographs for FAA-T-P6-DX-0X (ULTEM™ 9085)

Pre-Aging	Post-Aging/ Pre-Test	Post-Test
		
		
		
		
		
		

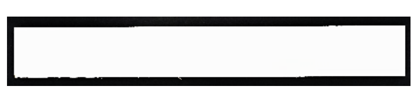
Pre-Aging	Post-Aging/ Pre-Test	Post-Test
		
		
		
		
		

Pre-Aging	Post-Aging/ Pre-Test	Post-Test
		
		
		
		
		

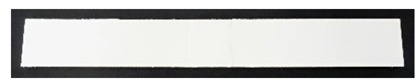
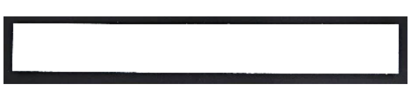
Pre-Aging	Post-Aging/ Pre-Test	Post-Test
		
		

E Specimen Pictures - Honeycomb

Table E- 1. Test photographs for FAA-F-H1-DX-0X (Honeycomb type A)

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-F-H1-D6-01			
FAA-F-H1-D6-02			
FAA-F-H1-D6-03			
FAA-F-H1-D6-04			
FAA-F-H1-D6-05			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-F-H1-D7-01			
FAA-F-H1-D7-02			
FAA-F-H1-D7-03			
FAA-F-H1-D7-04			
FAA-F-H1-D7-05			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-F-H1-D8-01			
FAA-F-H1-D8-02			
FAA-F-H1-D8-03			
FAA-F-H1-D8-04			
FAA-F-H1-D8-05			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-F-H1-D9-01			
FAA-F-H1-D9-02			
FAA-F-H1-D9-03			
FAA-F-H1-D9-04		Image is unavailable.	
FAA-F-H1-D9-05			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-F-H1-D10-01			
FAA-F-H1-D10-02			
FAA-F-H1-D10-03			
FAA-F-H1-D10-04			
FAA-F-H1-D10-05			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-F-H1-D11-01			
FAA-F-H1-D11-02			
FAA-F-H1-D11-03			
FAA-F-H1-D11-04			
FAA-F-H1-D11-05			

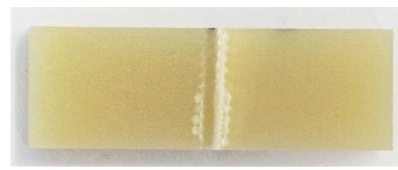
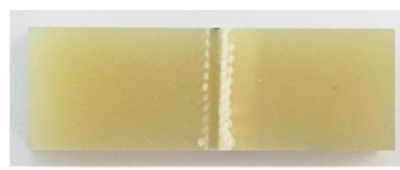
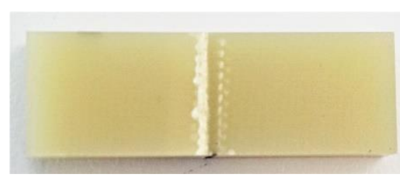
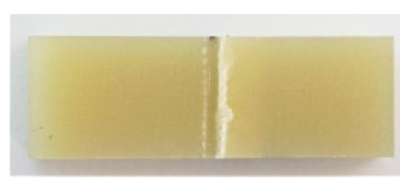
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-F-H1-D12-01			
FAA-F-H1-D12-02			
FAA-F-H1-D12-03			
FAA-F-H1-D12-04			
FAA-F-H1-D12-05			

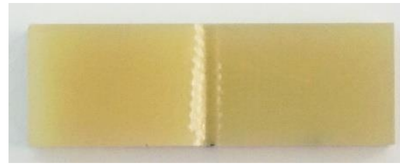
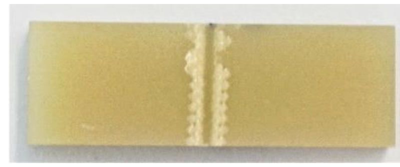
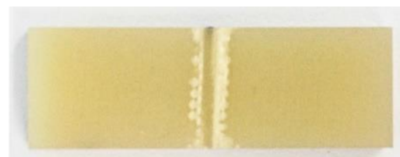
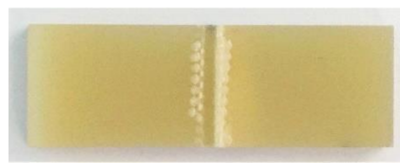
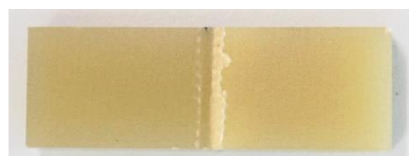
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-F-H1-D13-01			
FAA-F-H1-D13-02			
FAA-F-H1-D13-03			
FAA-F-H1-D13-04			
FAA-F-H1-D13-05			

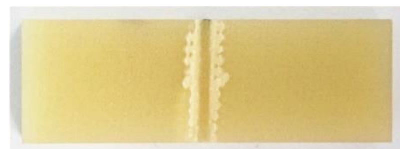
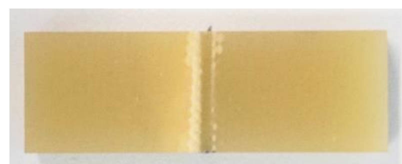
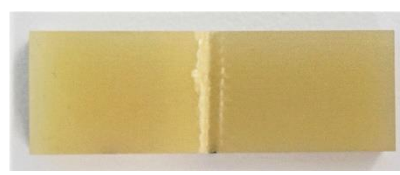
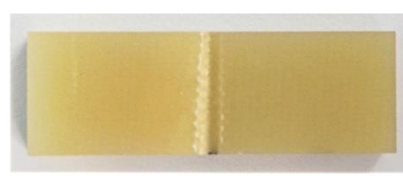
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-F-H1-D14-01			
FAA-F-H1-D14-02			
FAA-F-H1-D14-03			
FAA-F-H1-D14-04			
FAA-F-H1-D14-05			

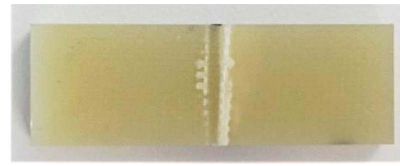
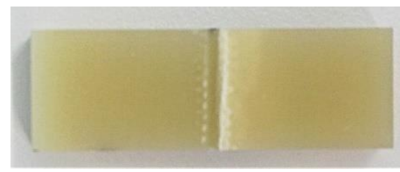
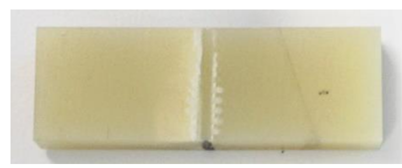
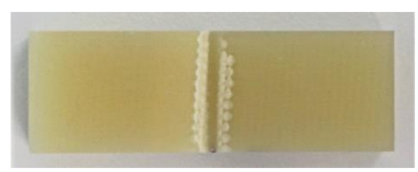
F Specimen Pictures - Fiberglass

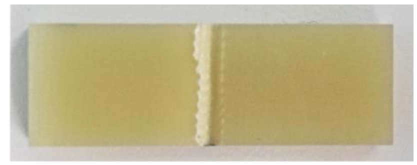
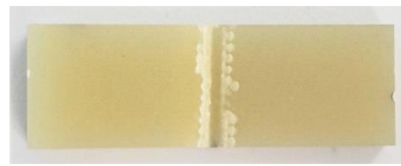
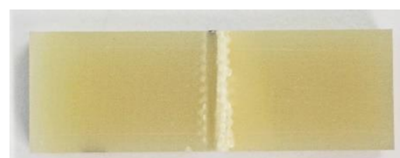
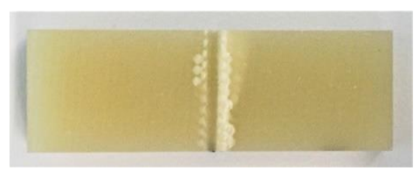
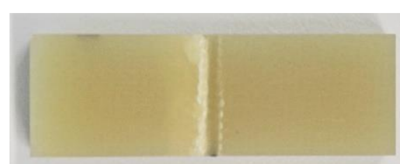
Table F- 1. Test photographs for FAA-S-FG1-DX-0X (Fiberglass G-10/FR4)

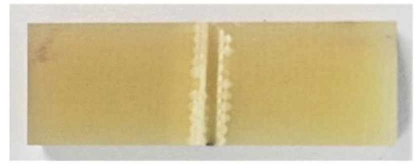
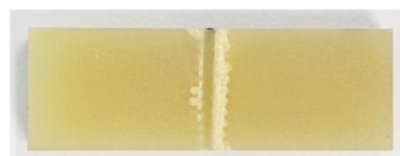
	Pre-Aging	**Post-Aging/ Pre-Test**	**Post-Test**
FAA-S-FG1-D6-01			
FAA-S-FG1-D6-02			
FAA-S-FG1-D6-03			
FAA-S-FG1-D6-04			
FAA-S-FG1-D6-05			

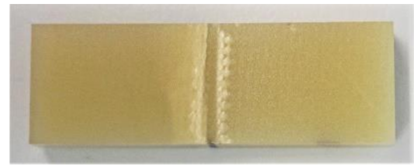
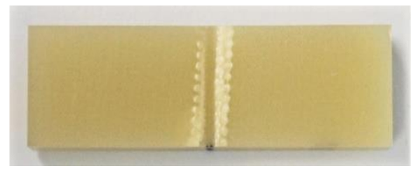
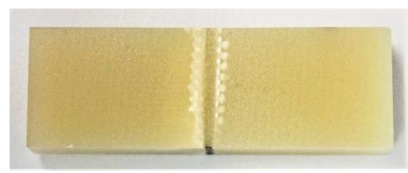
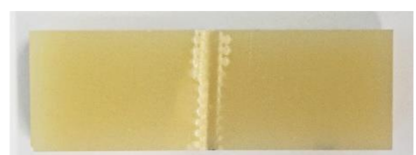
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-S-FG1-D7-01			
FAA-S-FG1-D7-02			
FAA-S-FG1-D7-03			
FAA-S-FG1-D7-04			
FAA-S-FG1-D7-05			

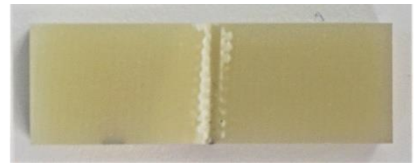
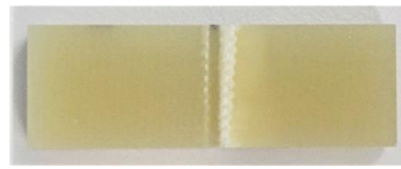
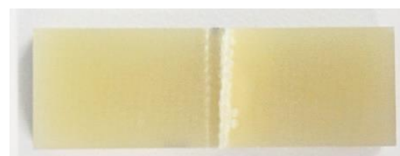
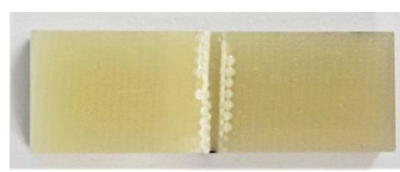
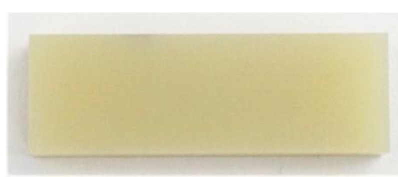
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-S-FG1-D8-01			
FAA-S-FG1-D8-02			
FAA-S-FG1-D8-03			
FAA-S-FG1-D8-04			
FAA-S-FG1-D8-05			

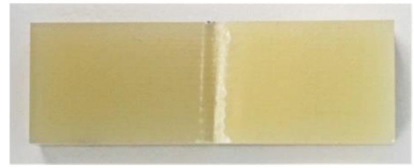
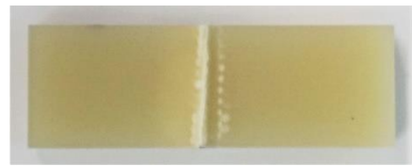
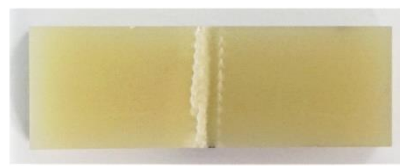
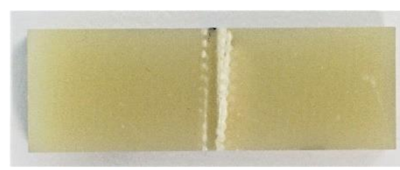
	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-S-FG1-D9-01			
FAA-S-FG1-D9-02			
FAA-S-FG1-D9-03			
FAA-S-FG1-D9-04			
FAA-S-FG1-D9-05			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-S-FG1-D10-01			
FAA-S-FG1-D10-02			
FAA-S-FG1-D10-03			
FAA-S-FG1-D10-04			
FAA-S-FG1-D10-05			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-S-FG1-D11-01			
FAA-S-FG1-D11-02			
FAA-S-FG1-D11-03			
FAA-S-FG1-D11-04			
FAA-S-FG1-D11-05			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-S-FG1-D12-01			
FAA-S-FG1-D12-02			
FAA-S-FG1-D12-03			
FAA-S-FG1-D12-04		Image is unavailable.	
FAA-S-FG1-D12-05			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-S-FG1-D13-01			
FAA-S-FG1-D13-02			
FAA-S-FG1-D13-03			
FAA-S-FG1-D13-04			
FAA-S-FG1-D13-05			

	Pre-Aging	Post-Aging/ Pre-Test	Post-Test
FAA-S-FG1-D14-01			
FAA-S-FG1-D14-02			
FAA-S-FG1-D14-03			
FAA-S-FG1-D14-04			
FAA-S-FG1-D14-05