

# Materials Testing for Durability to UVC Light Exposure

## UVC曝晒下材料的耐久性

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# Topics

- Ultraviolet Germicidal Irradiance (UVGI)  
紫外线杀菌
- Durability of materials exposed to UVC light  
UVC照射下的材料耐久性
- UVC exposure test results  
UVC曝晒测试结果
- Standard test protocols for UVC testing  
UVC测试的标准测试方案



*Disclaimer: We aren't supporting use of our products for UVGI applications, just material testing.*  
*免责声明: 我们不支持将我们的产品用于UVGI应用, 只支持材料测试。*

# Ultraviolet Germicidal Irradiation (UVGI)

- The use of ultraviolet (UV) wavelengths of light in the germicidal range (200–320) for the disinfection of air and surfaces.

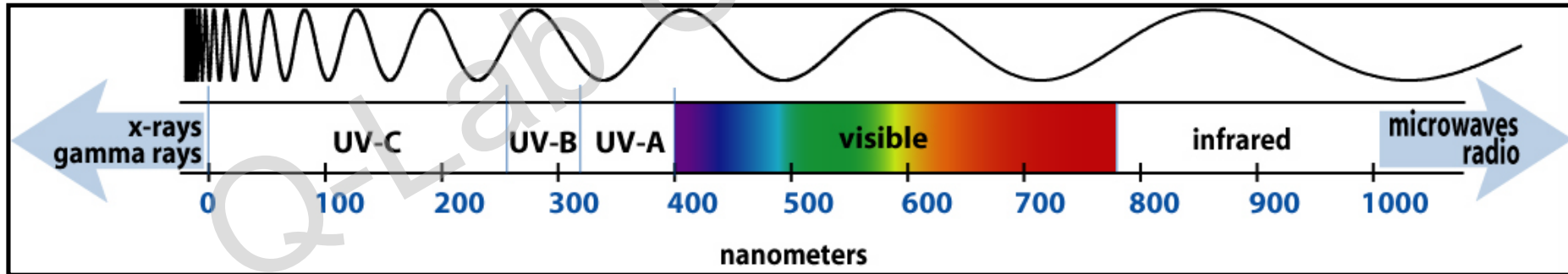
利用200-320nm紫外杀菌波段对空气和物体表面进行消毒

*Ultraviolet Germicidal Irradiation Handbook*

- Method for disinfection of air, water and surfaces that uses radiation with wavelength in the range 240 to 280 nm to kill or inactivate micro-organisms.

使用240-280nm波段对空气、水和物体表面进行消毒、杀灭微生物

*ISO 29464*



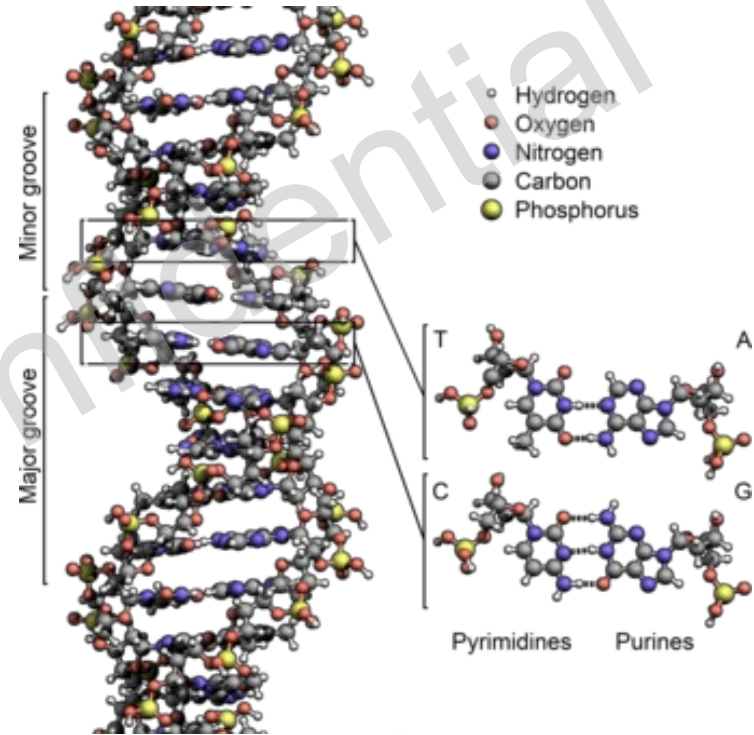
# How UVGI Works

- Ultraviolet light causes crosslinking of DNA or RNA strands

紫外光引起DNA或RNA链的交联

- Inactivates a cell's ability to replicate

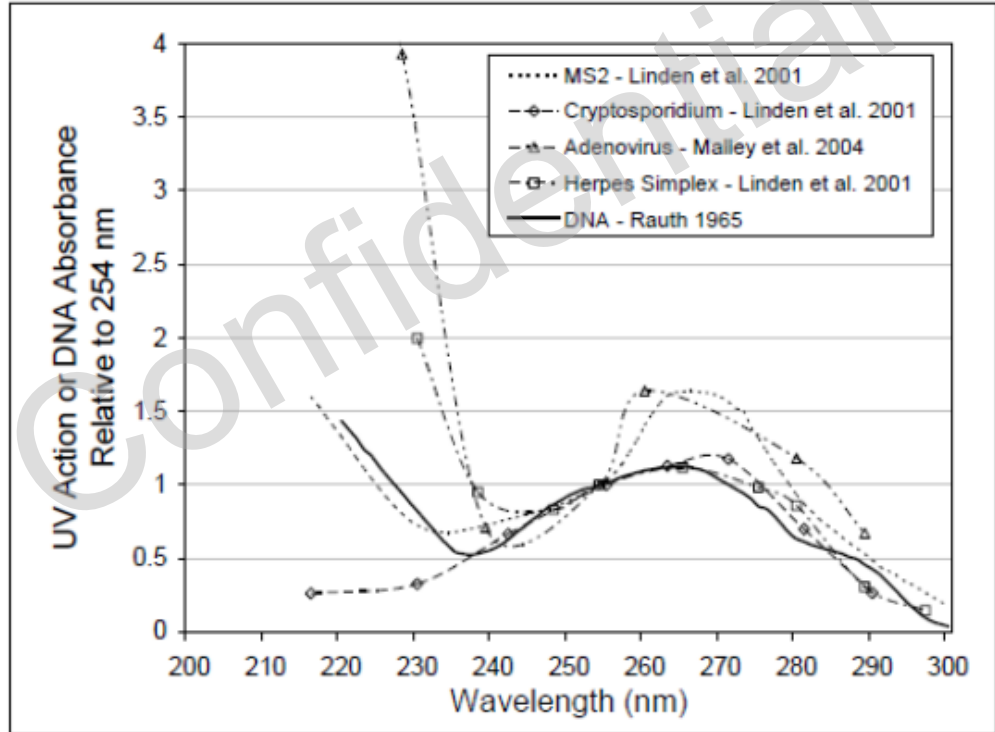
抑制细胞再生的能力



# Action Spectra of DNA & Select Microorganisms

## DNA和微生物的作用光谱

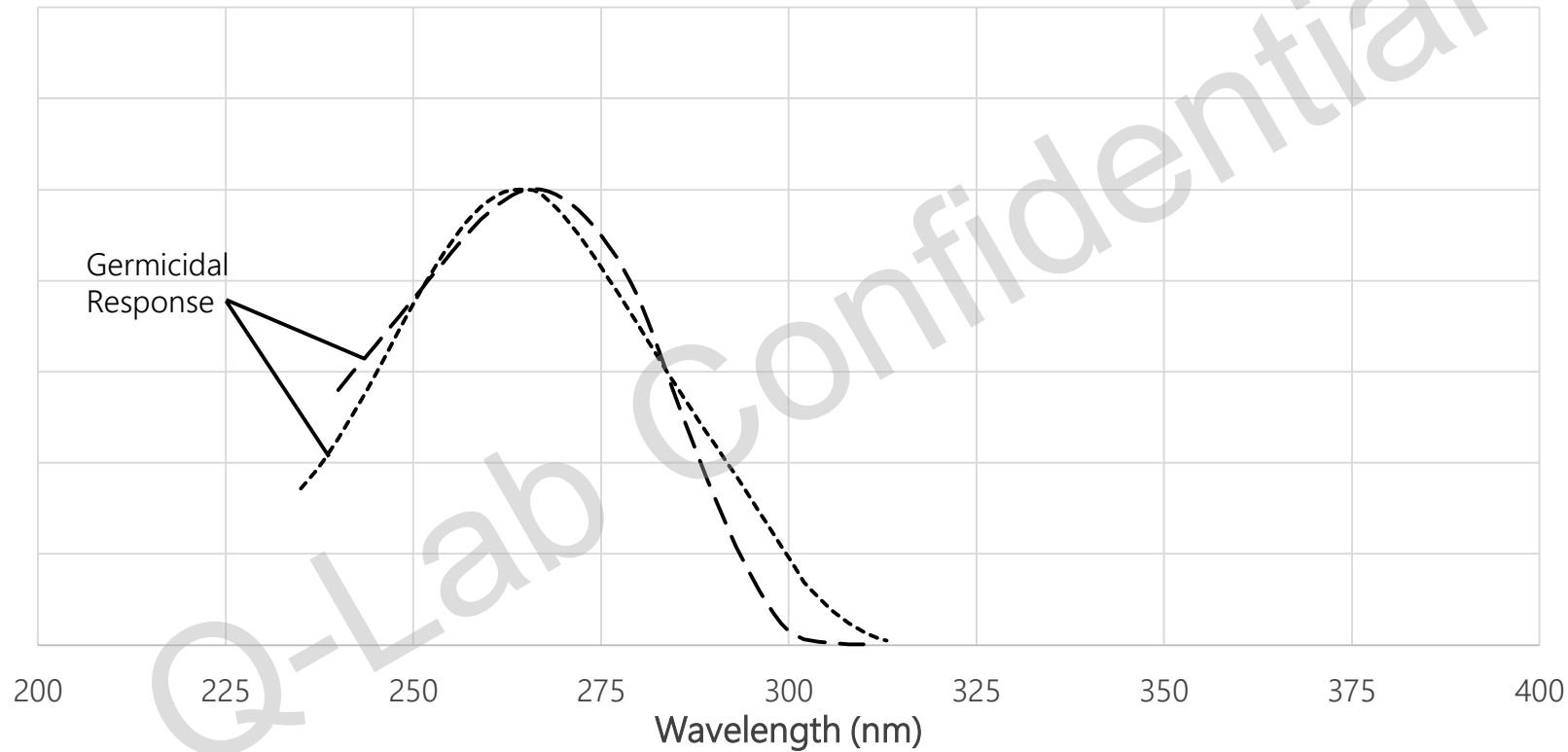
*USEPA UV Disinfection  
guidance manual, 2006*



Source: Adapted from Rauth (1965), Linden et al. (2001), and Malley et al. (2004)

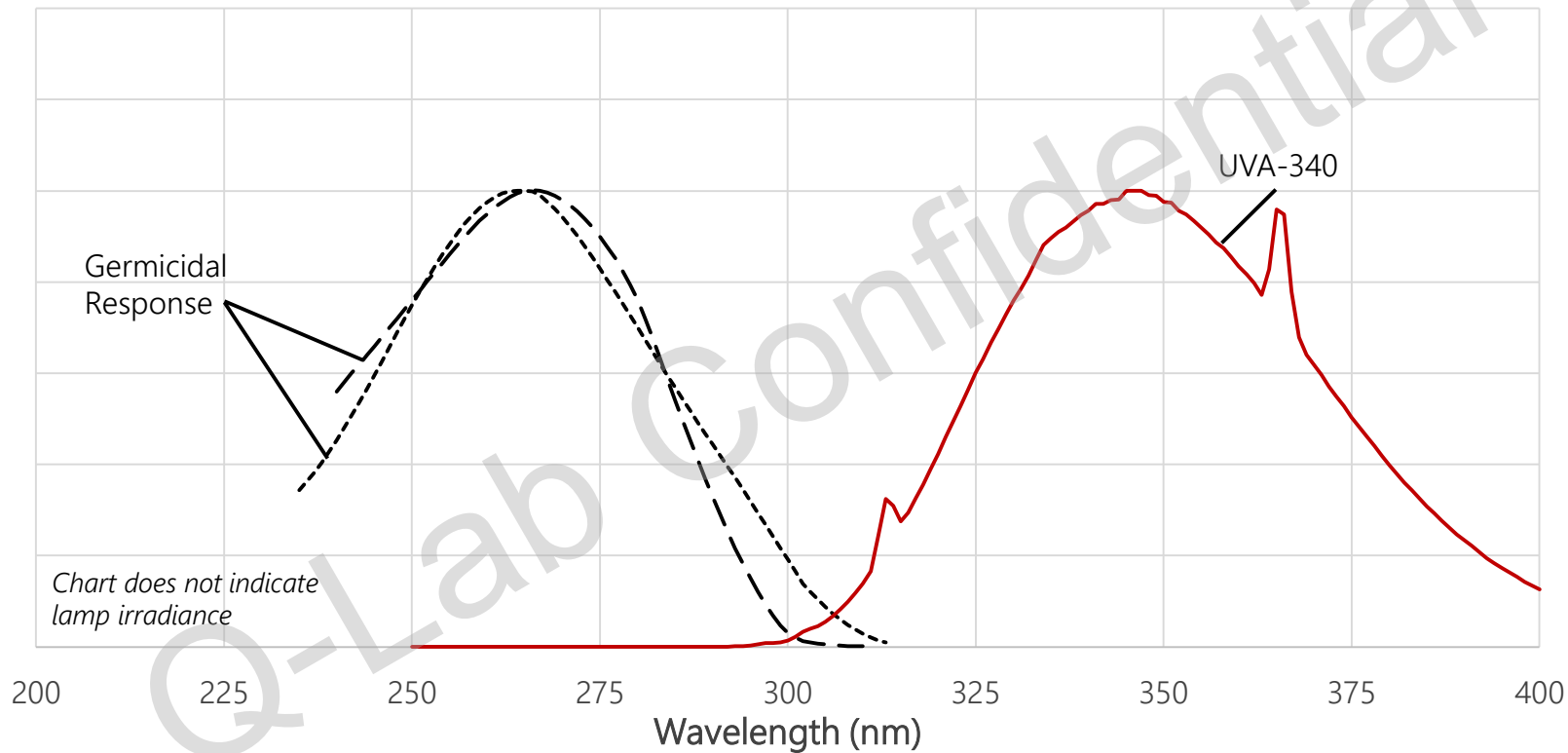
## Relative Spectral Irradiance and Germicidal Response

### 相对辐照度和杀菌响应曲线



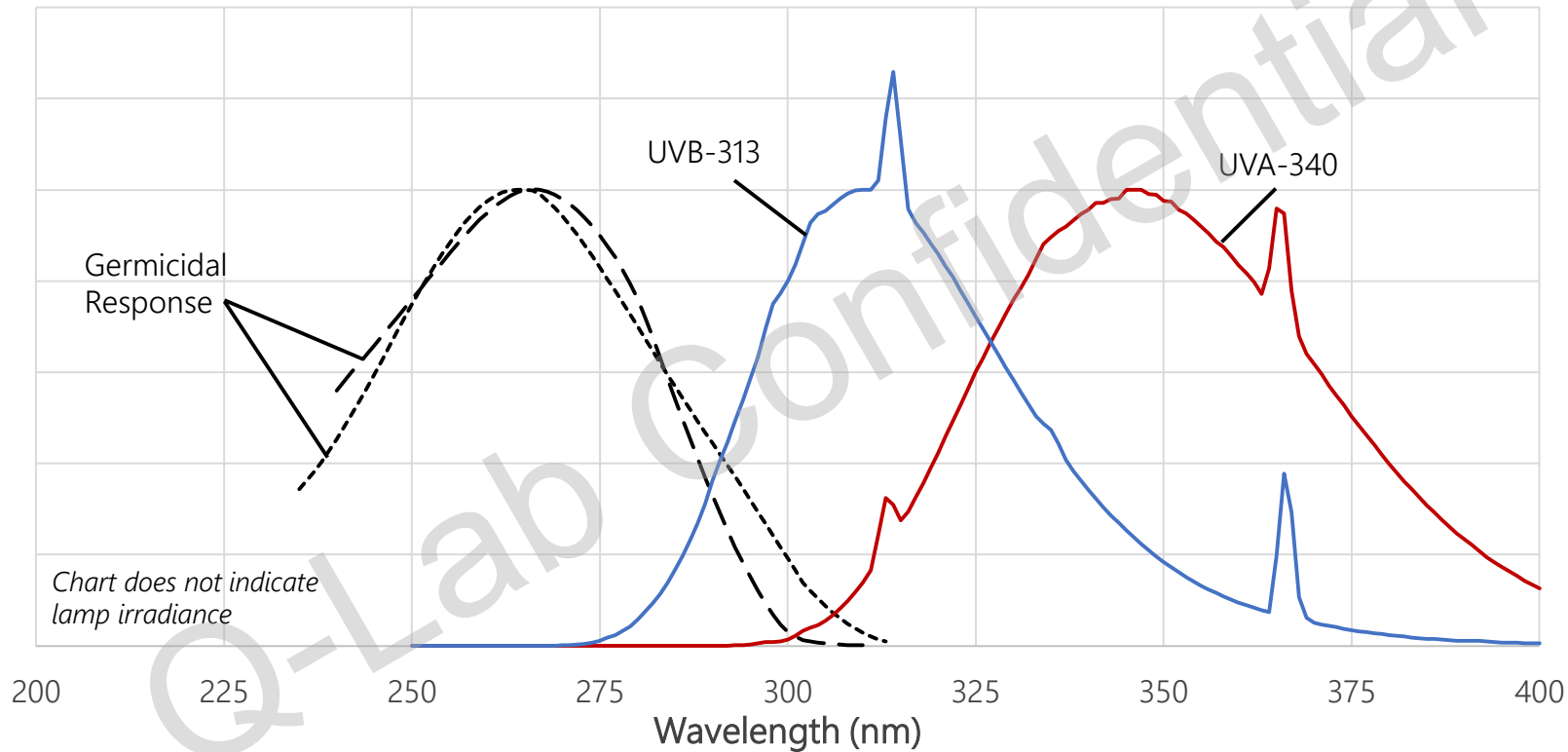
## Relative Spectral Irradiance and Germicidal Response

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# Relative Spectral Irradiance and Germicidal Response

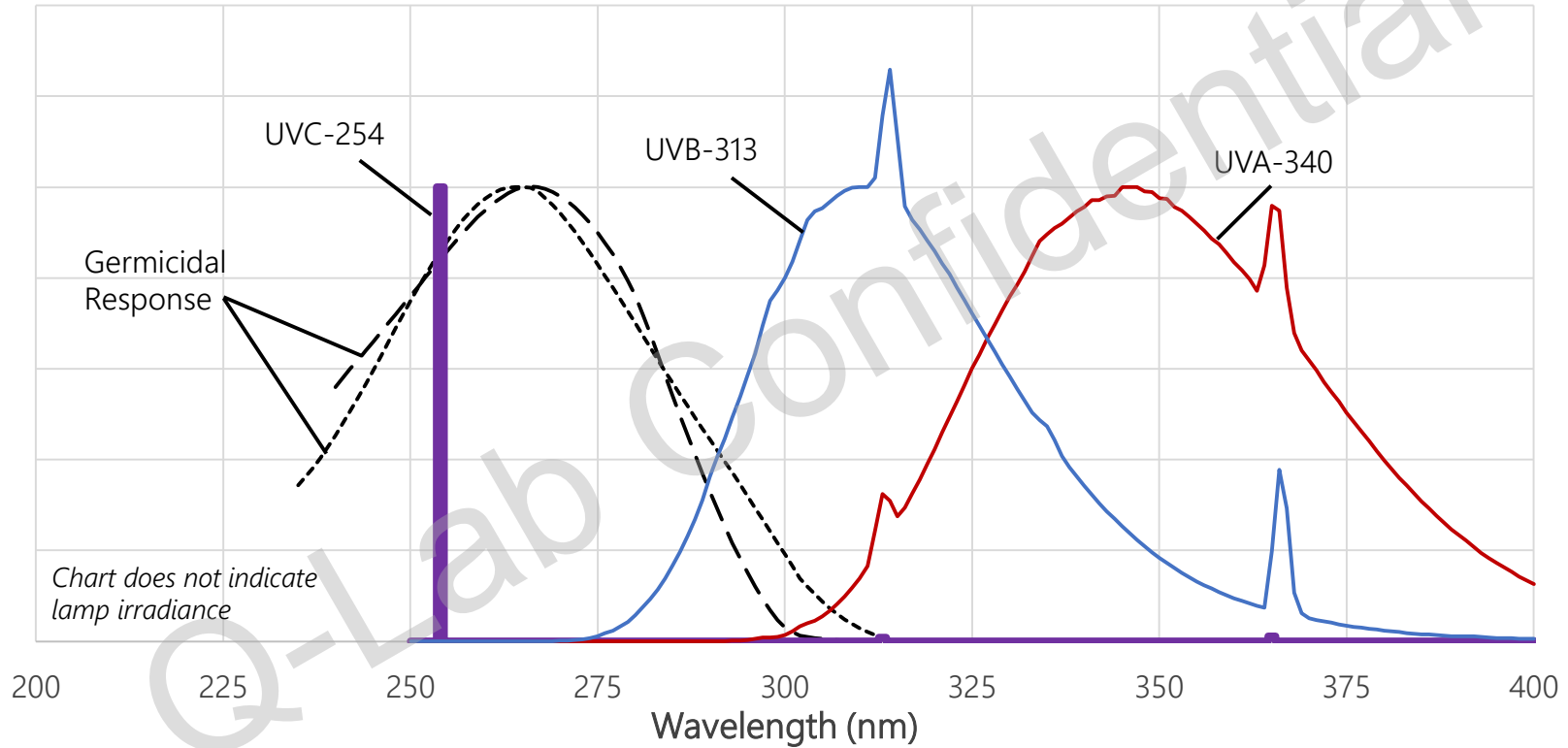
## 相对辐照度和杀菌响应曲线





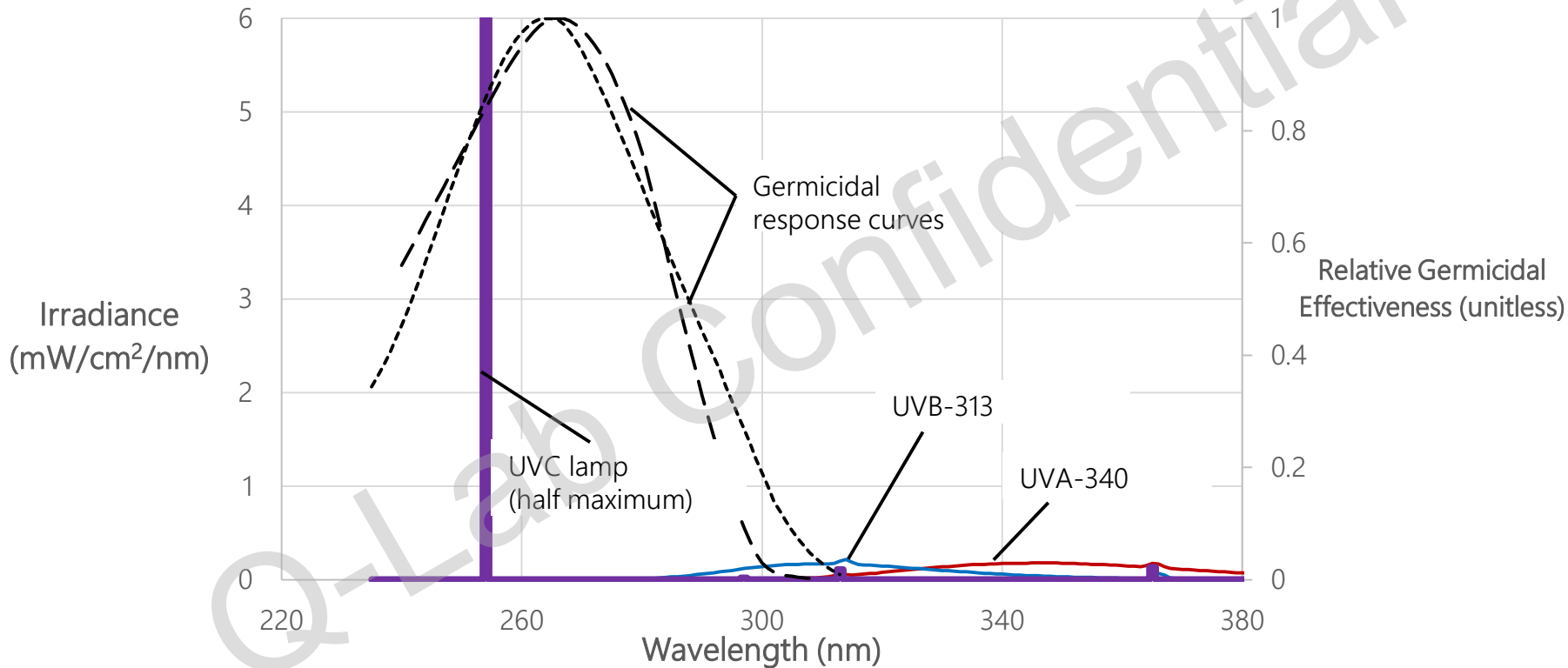
# Relative Spectral Irradiance and Germicidal Response

## 相对辐照度和杀菌响应曲线

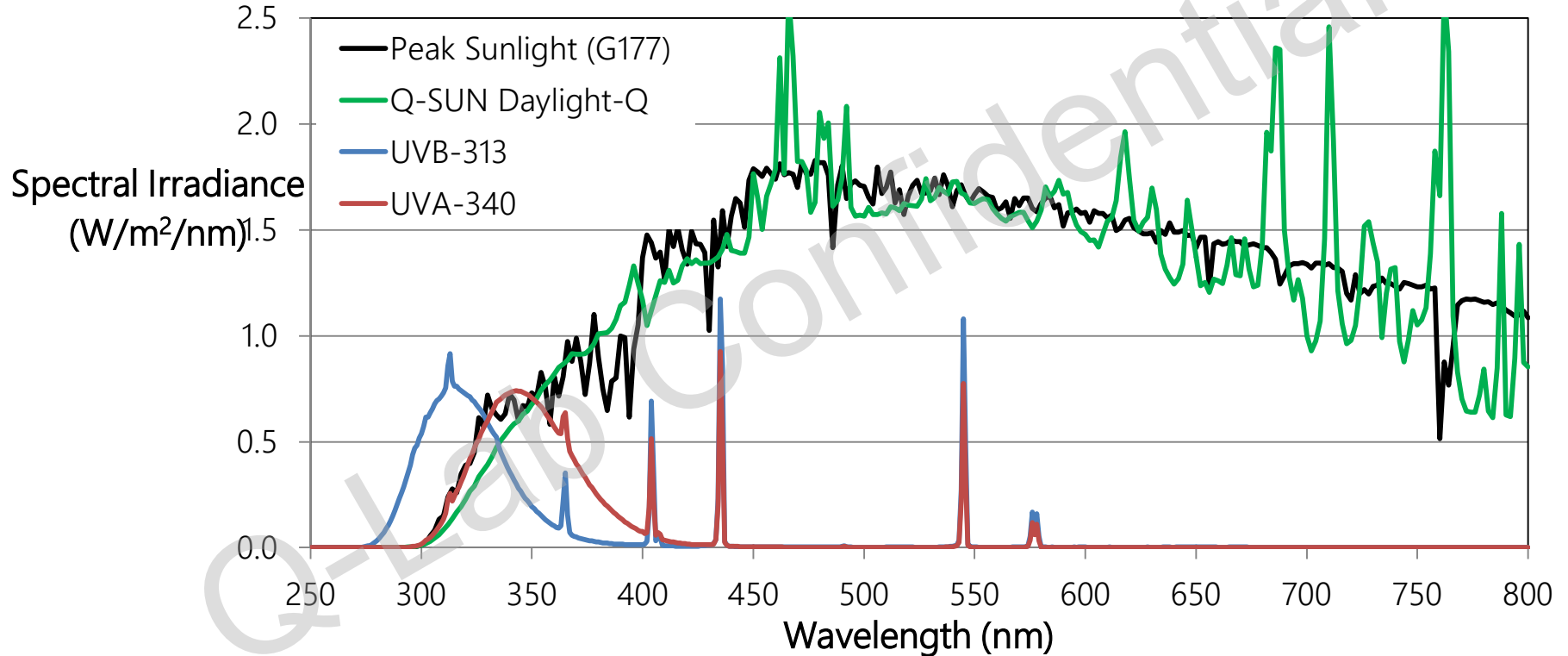


# Actual Spectral Irradiance and Germicidal Response

## 实际的辐照度和杀菌响应曲线



# Fluorescent UV, Xenon Arc, and Sunlight



# UVGI Applications



Medical facilities



HVAC



Emergency Vehicles

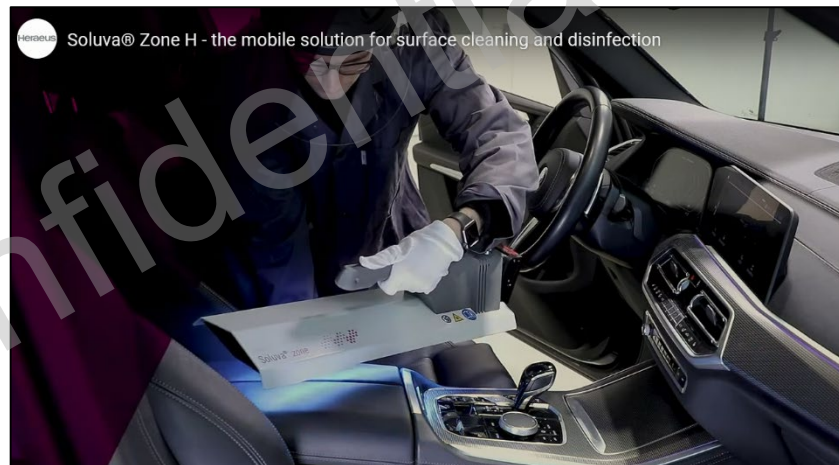


Airports



Schools

# UVGI Applications



Interior materials are not typically designed to withstand UV exposure, so UVC exposures are not often considered during material development

室内材料通常不能抵抗紫外照射，在材料开发时候UVC照射也不常被考虑

# UVC Light for UVGI Applications

- UVC light is effective at inactivating viruses and other microorganisms

UVC能有效灭活病毒和其他微生物

- As a result, indoor materials are now being subjected to highly destructive UVC energy

因此，室内材料正受到UVC紫外线的破坏

- The actual UVC dose experienced is unpredictable in most applications

在大多数应用中，实际紫外线剂量是不可预测的

- Because UVC light is very damaging, UVC exposures will often be much faster than standard weathering tests for outdoor materials

由于UVC具有很强的破坏性，UVC暴露通常比室外材料的标准光老化测试要快得多

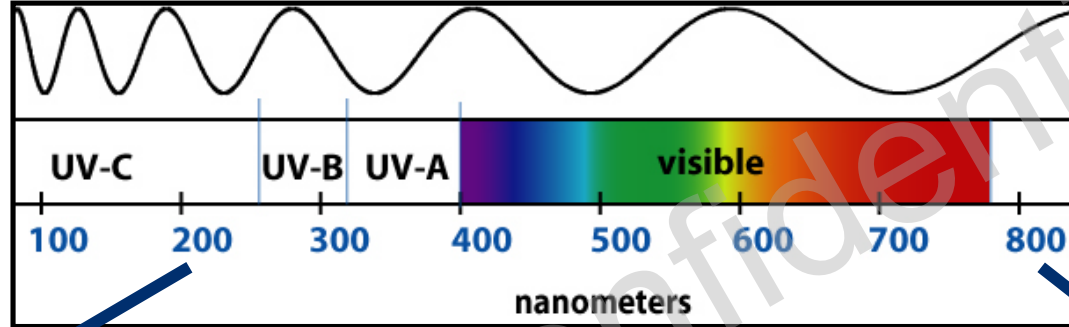
*Let's look at some UVC exposures of plastics and other materials*

*諷慘龔痢痢在擊貞促黠材料暴露在UVC下的案例*

# Units in UVC Exposure Testing

- Energy  $1 \text{ Joule} = 1 \text{ W}\cdot\text{s}$
- Irradiance (Power)  $1 \text{ mW/cm}^2 = 10 \text{ W/m}^2$
- Radiant Dosage (Energy) (Irradiance  $\times$  Time)  
 $1 \text{ mJ/cm}^2 = 10 \text{ J/m}^2$
- The energy of a photon is inversely proportional to its wavelength  
光子的能量与其波长成反比
- Short-wavelength light has more energy per photon and is more damaging than long-wavelength light  
短波紫外线的能量大于长波紫外线

# Electromagnetic Spectrum

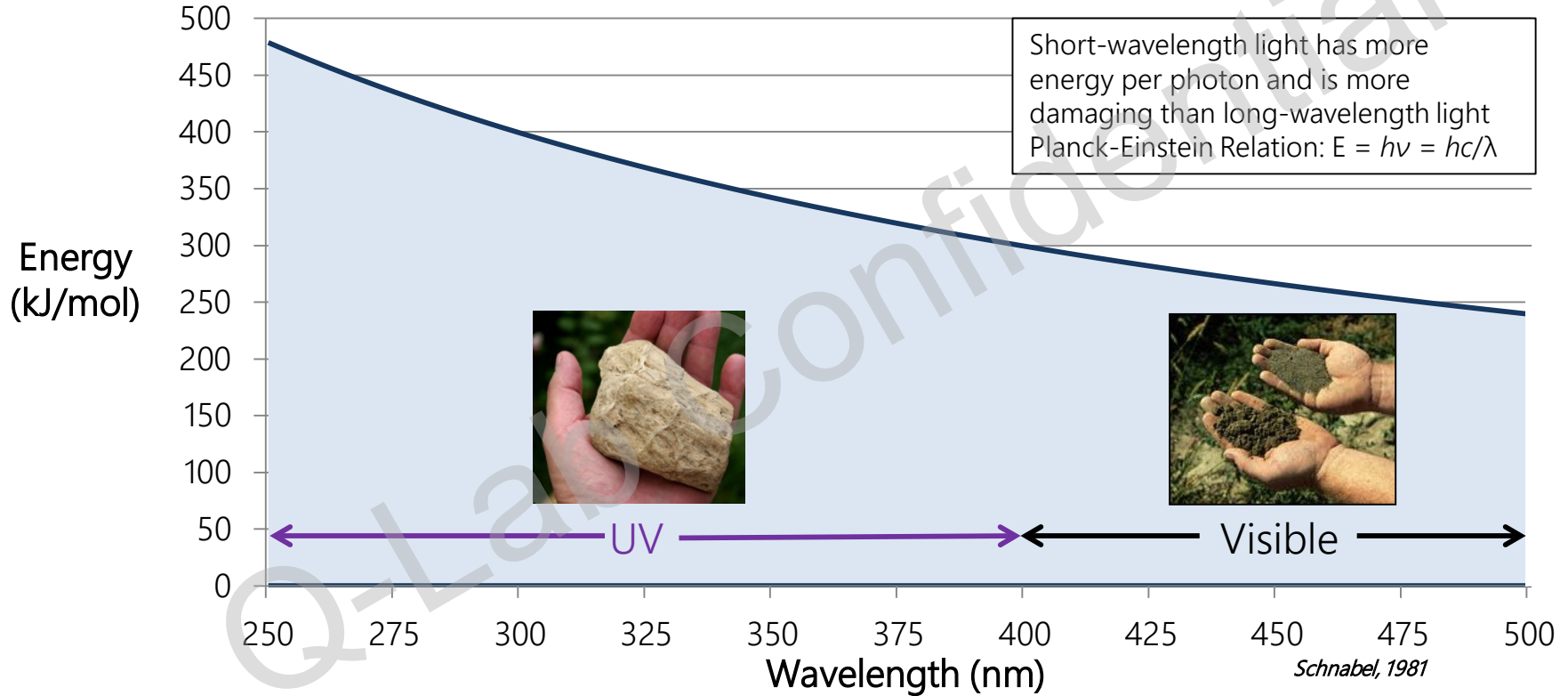


The energy of a photon is inversely proportional to its wavelength





# Energy per Photon (Quantum)



# UVC Light and Chemical Bond Breaking

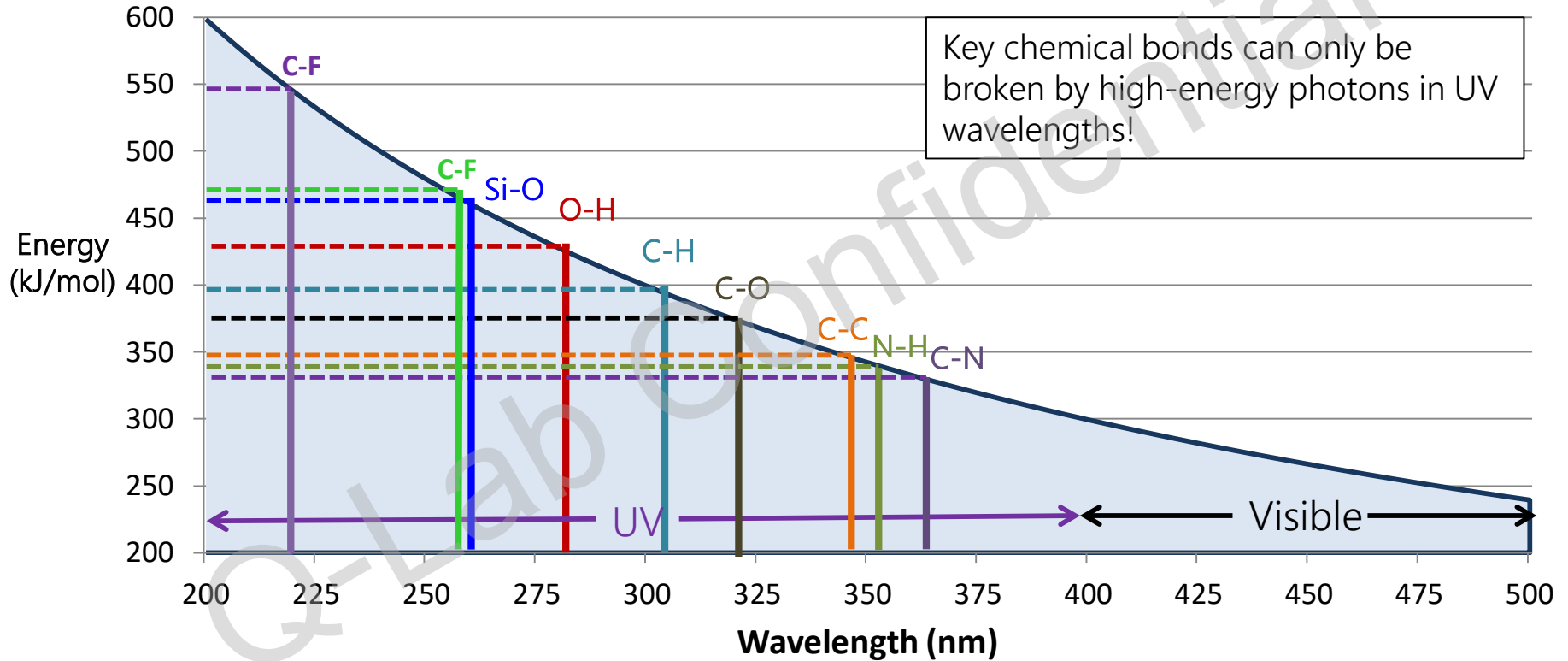
## 化学键断裂和光子能量

Chemical Bond	Energy to break bond (kJ/mol)	Wavelength of photon with equivalent energy (nm)
C-N	330	363
N-H	339	353
C-C	348	344
C-O	372	321
C-H	393	304
O-H	426	281
Si-O	452	265
C-F (CH <sub>3</sub> F)	460	260
C-F (CF <sub>4</sub> )	544	220

Schnabel, 1981

Bonds can only be broken by photons with a wavelength **shorter than** the threshold value shown  
UVC photons have the potential to be **very** damaging. *Are they, though?*  
键只能被小于该阈值波长的光子打断

# Chemical Bond Energy & Photon Wavelength



# UVC Durability Testing

## UVC耐候测试

- Test instrument and cycle  
测试设备和程序
- UVC-254 vs fluorescent UV lamps  
UVC-254 vs 荧光紫外灯管

# Laboratory UVC Testing

- Tests conducted in the QUV/uvc tester - a new model of the QUV tester

新型号QUV/uvc测试机

- Onboard UV sensor precisely controls irradiance at 254 nm

校准控制254nm处的辐照度

- Features light baffles and automatic safety shut-off features

具有光挡板和自动安全关闭功能

- Water functions (condensation, spray) removed for simplicity

移除了冷凝和水喷淋功能



# UVC Exposure

- **Irradiance:** 3 mW/cm<sup>2</sup> (30 W/m<sup>2</sup>)  
(low- to mid-range of achievable set points)
- **Temperature:** 30°C black panel
- **Duration:** 200 hours (2.16 kJ/cm<sup>2</sup>)  
(evaluate color at 24, 100, 200 hours)



# UVC-254 Lamp



# UVC Test Results

- Painted Panels 涂层板
- Vinyl Flooring 乙烯基地板
- Fabrics 织物
- Leathers 皮革
- Surface Materials 表面材料

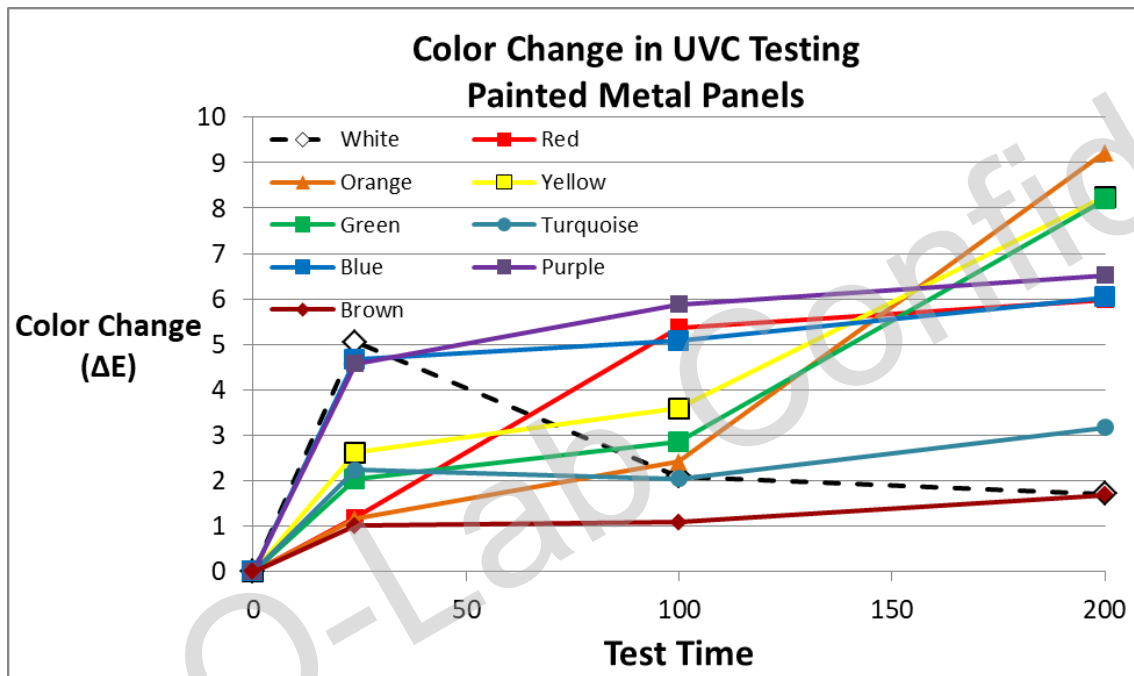


# Painted Panels: Visual Evaluation



*Significant changes in gloss and color*

# Painted Panels: Color Change



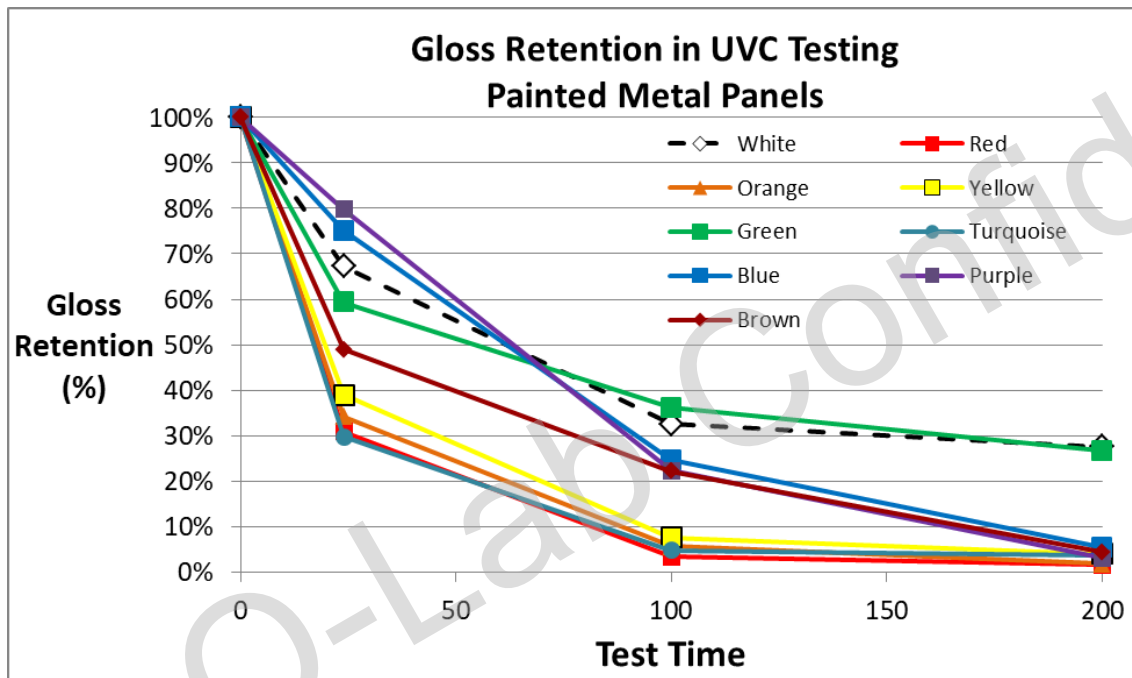
- General-purpose acrylic modified alkyd spray paint

通用丙烯酸改性醇酸喷涂

- Noticeable color change in only 100-200 hours

100-200小时颜色就发生明显变化

# Painted Panels: Gloss Retention



- General-purpose acrylic modified alkyd spray paint

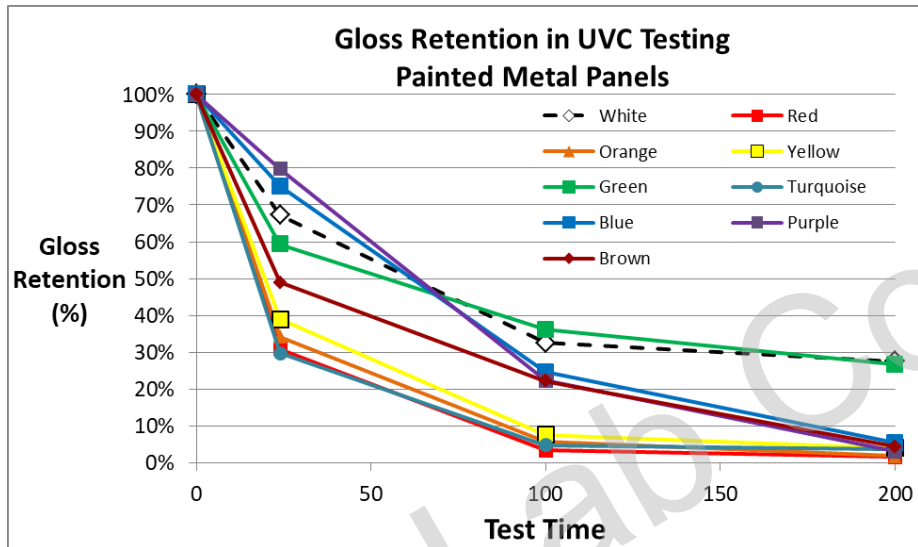
通用丙烯酸改性醇酸喷涂

- Major loss of gloss in only 100 hours

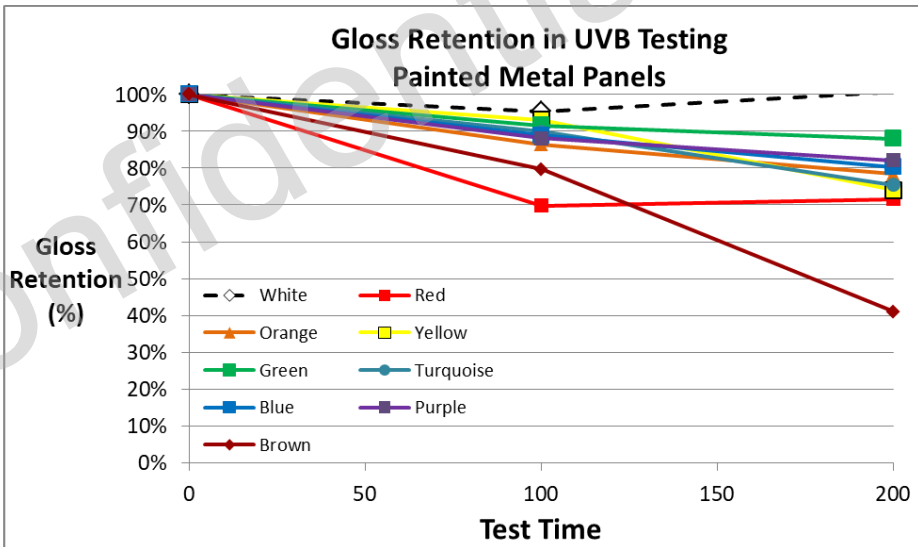
100小时光泽就发生很大变化

# Painted Panels: UVC and UVB Exposures

## UVC



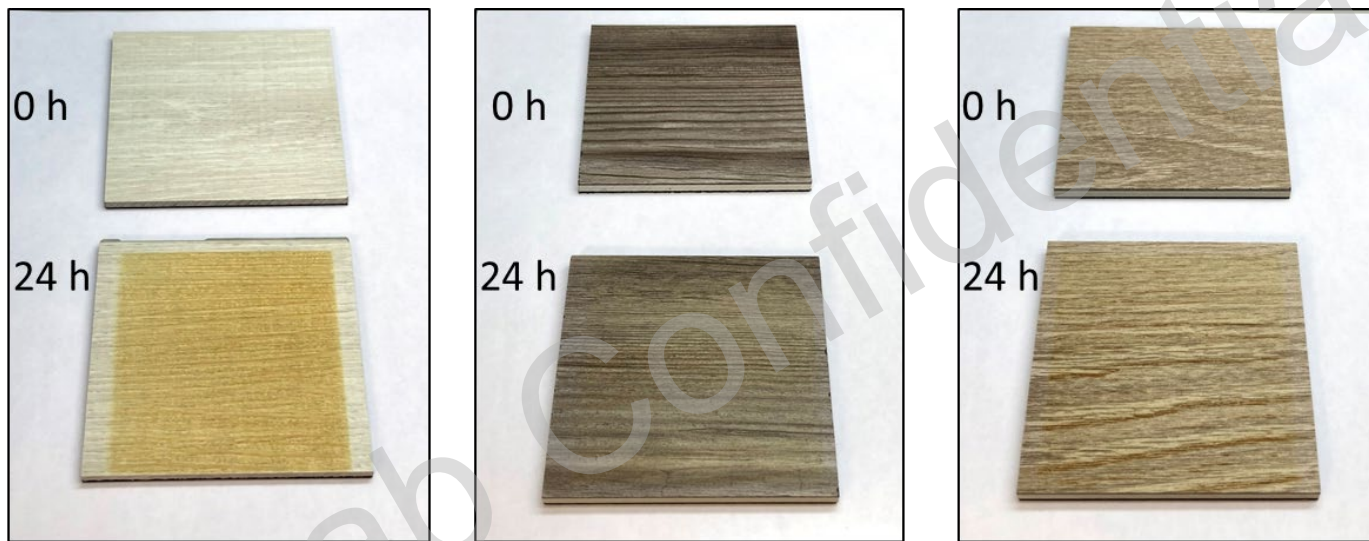
## UVB



UVC testing is very harsh even compared to UVB testing – which is also known to degrade materials quickly

UVC比UVB测试还要严苛很多！

# Vinyl Flooring: Visual Evaluation



- Commercially-available vinyl flooring material  
市面上采购的乙烯基地板
- Major discoloration in just a day of testing!  
一天的测试颜色显著变化

# Plastics: Visual Evaluation



- Significant degradation in clear and yellow plastics

透明和黄色塑料显著老化

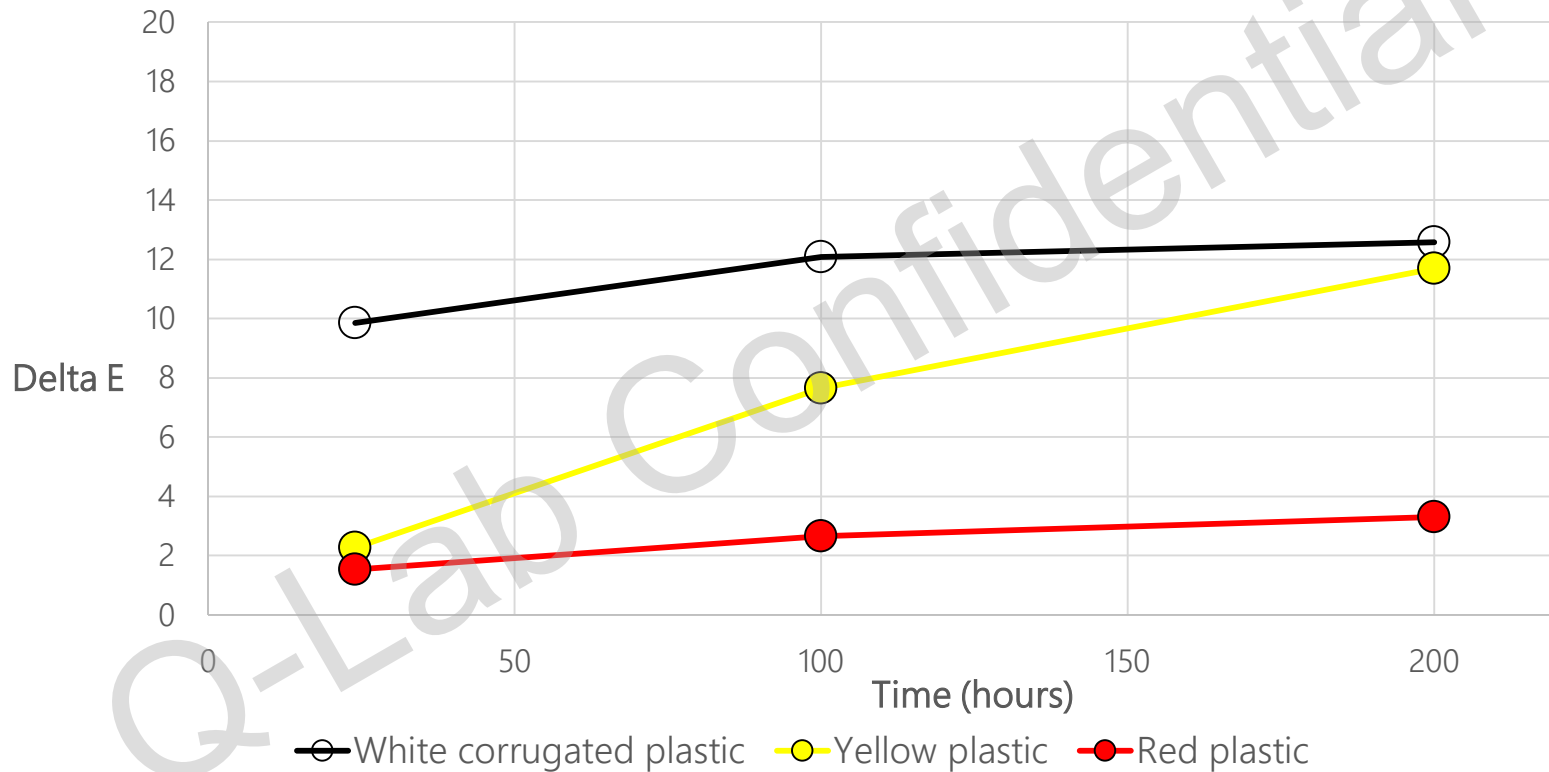
- Degradation is yellowing/darkening, likely of base polymer

老化是变黄/变暗，可能是基材的降解

- Red plastic showed less color change and retained more gloss

红色塑料显示出较少的颜色变化，并保留了更多光泽

# Plastics: Color Change



# Fabrics: Visual Evaluation



- Cheap synthetic fabrics are surprisingly UVC-resistant!

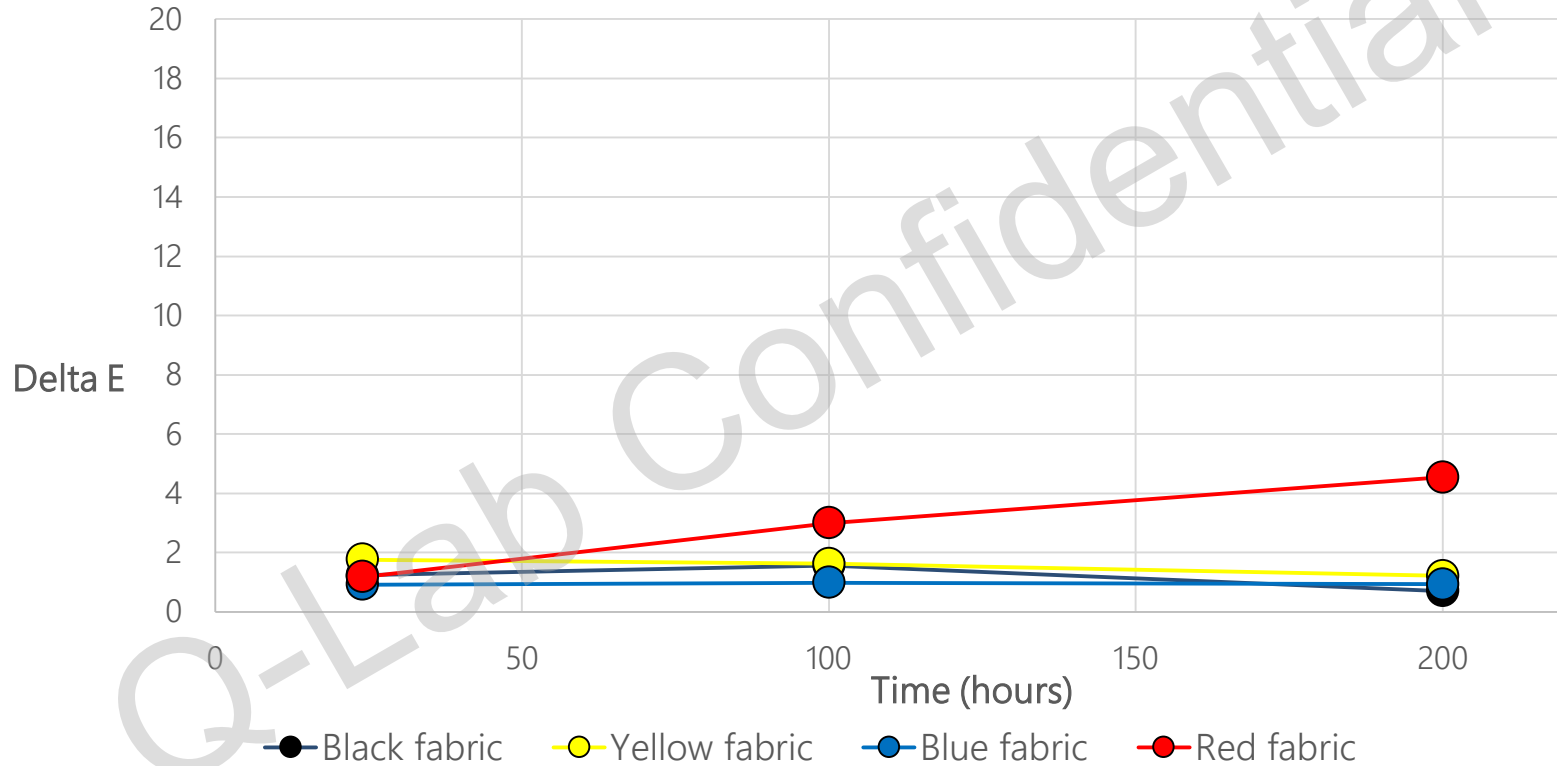
廉价的合成纤维具有惊人的抗紫外线能力！

- The floral print at righties an exception

右边的印花是个例外



# Fabrics: Color Change



# Leathers: Visual Evaluation



- Wide variety in performance of synthetic leathers

合成革性能多样

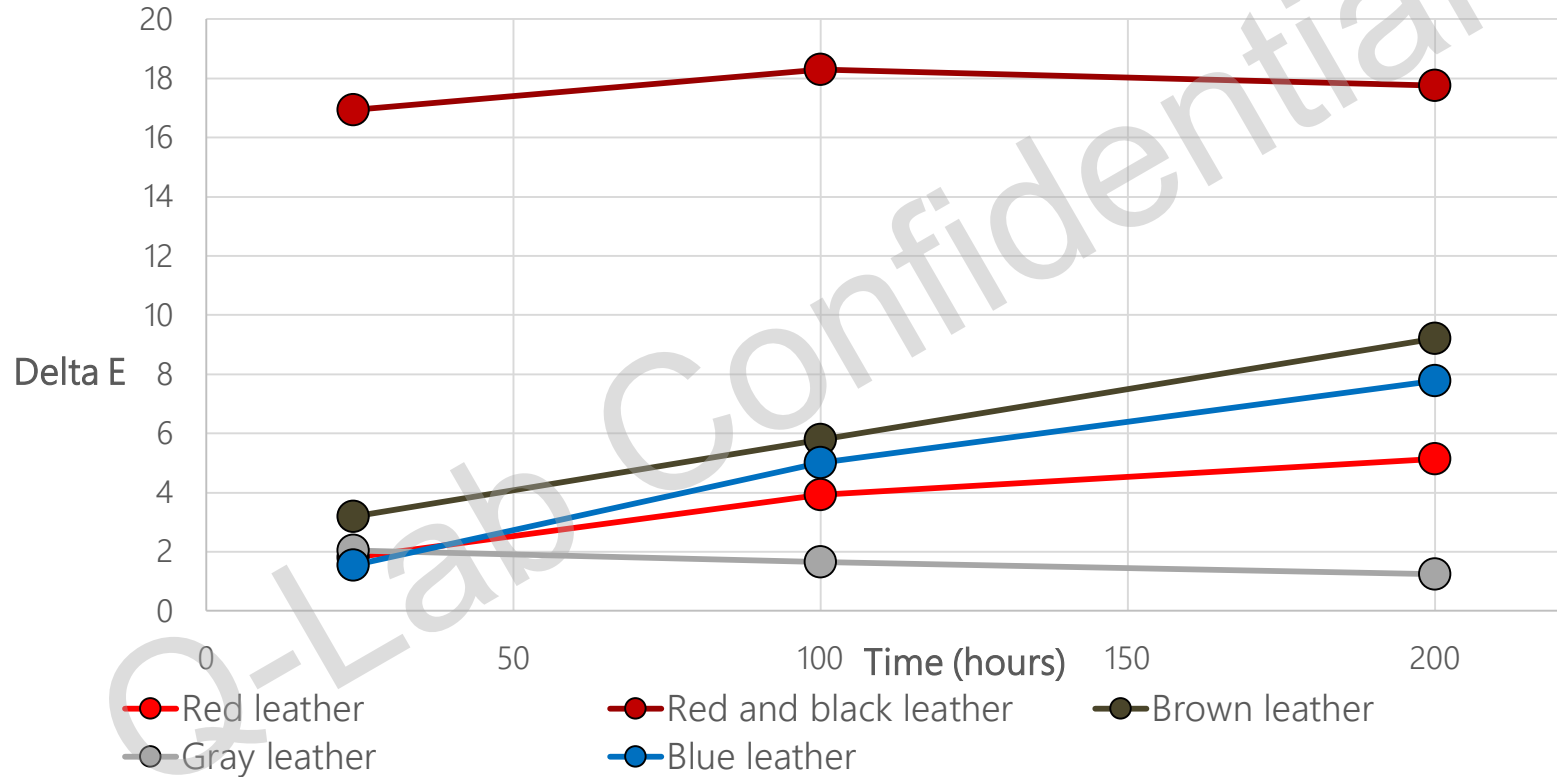
- Red, blue, and gray very little change

红色、蓝色和灰色变化很小

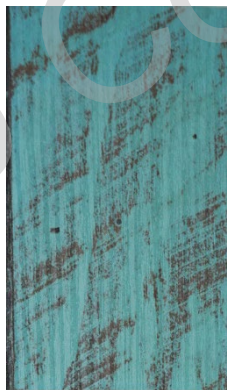
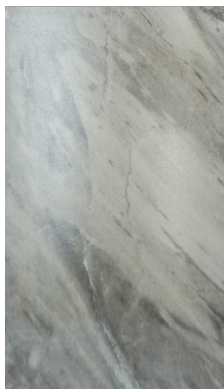
- Brown and red/black degraded very quickly – color fade observed

棕色和红色/黑色降解很快-观察到褪色

# Leathers: Color Change



# Surface Materials: Visual Evaluation



- Surface / tiling materials are fairly UVC resistant

表面/瓷砖材料相当耐紫外线

- Some yellowing observed in lighter-colored specimens

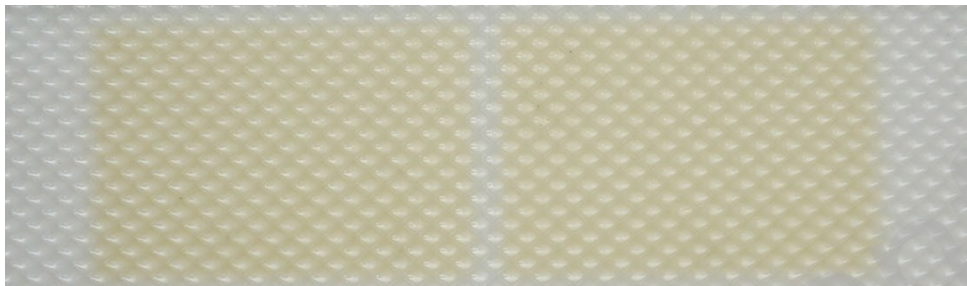
在浅色样品中观察到一些黄变

# Laboratory and Real-World UVC Exposures

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## Lab and Real-World UVGI Exposures

### 实验室和真实情况下的紫外杀菌测试



- Even short UVC exposures caused significant damage to some materials

即使短时间的UVC紫外线照射也会对某些材料造成严重损坏

- *What do these tests correlate to in terms of real-world UVGI exposure?*

这些测试与真实世界的UVGI暴露有什么关联？

# Material Exposure to UVGI



*Many surfaces will be significantly over-exposed in an effort to ensure all areas receive sufficient dose; possibly 10 × the target dose*  
*为确保所有区域获得足够的剂量，许多表面将明显过度暴露；可能是目标剂量的10倍*

# Disinfection Levels

Term	Kill/Deactivation Ratio	Comments
1-Log	90%	Also called D90 Disinfection; commonly-used benchmark
2-Log	99%	
3-Log	99.9%	
4-Log	99.99%	
5-Log	99.999%	Lowest level of "sterilization"
6-Log	99.9999%	Typically the lowest level measureable

*Dose vs kill ratio varies by microorganism and follows a logarithmic decay rate*  
*剂量与灭菌有效率因微生物而异, 并遵循对数衰减*



## What are typical UVGI exposure doses?

### 什么是常规的紫外杀菌曝晒剂量？

- 2 mJ/cm<sup>2</sup> to 1500 mJ/cm<sup>2</sup> have been cited for various microorganisms and disinfection levels (1-log to 6-log)  
2 mJ/cm<sup>2</sup> to 1500 mJ/cm<sup>2</sup> 被用来杀菌和消毒 ( 1-log to 6-log )
- 1 J/cm<sup>2</sup> has been suggested as a standard UVGI cycle  
1 J/cm<sup>2</sup> 是建议的一个标准的UVGI的cycle

# UVC Radiant Dosage

Assume 1 "cycle" of UVGI is a dose of 1 J/cm<sup>2</sup> (estimates for this value vary significantly!)

假定1个UVGI的剂量是1J/cm<sup>2</sup>

At irradiance of 3 mW/cm<sup>2</sup>, a single dose is achieved in 334 seconds

使用3 mW/cm<sup>2</sup>的辐照度，测试334秒达到1J/cm<sup>2</sup>，也就是一个UVGI

(334 s × 3 mW/cm<sup>2</sup> = 334 s × 3 mJ/s·cm<sup>2</sup> = 1000 mJ/cm<sup>2</sup>)

UVGI Cycle Frequency	Time to achieve one year of UVC dosage at 254 nm irradiance of 3 mW/cm <sup>2</sup> (hours) 一年累计的UVC辐射量·需要用QUV做多少小时?	100 hour test represents how many years of UVGI? 100小时的UVC测试·相当于多少年UVGI
Daily	34	3.0
Weekly	4.8	20.8
Monthly	1.2	83.3

# Potential Standard Test Parameters

- Irradiance: 1-6 mW/cm<sup>2</sup> (10-60 W/m<sup>2</sup>)  
*Will reciprocity be valid for UVC testing? 倒易率对UVC测试有效吗?*
- Temperature: 30-63 °C BPT (Black Panel Temperature)  
*Are room temp values more practical? Does high temp accelerate? 室温更实际?*
- Cycle: Continuous or Light/Dark cycling  
*Will dark periods affect results? 黑暗循环对测试有影响?*
- Duration: 200-1000 hours  
*Usually not specified in standard operating practice  
Short exposures acceptable, or longer tests required? 测试时间多少合适?*

# UVC Dose Reciprocity

- Will these exposures deliver the same result?

这些曝晒会达到同样的测试结果吗？

100 hours @ 1.5 mW/cm<sup>2</sup>

50 hours @ 3.0 mW/cm<sup>2</sup>

25 hours @ 6.0 mW/cm<sup>2</sup>

12.5 hours @ 12.0 mW/cm<sup>2</sup>

*All achieve 540 J/cm<sup>2</sup>*

- In the QUV/uvc tester you can run all of these tests to verify reciprocity (LIGHT/DARK cycling also possible)

使用QUV/uvc你可以运行以上所有测试来验证线性关系  
(光照/黑暗 循环也可以)

# Conclusions

- Ultraviolet Germicidal Irradiation (UVGI) is growing quickly; any commercial space is a candidate

UVGI的市场发展很快（很多商业环境可以使用）

- Your materials may be exposed to more UVC energy than anyone can predict  
你的产品可能会接收到比预期更多的UVC照射
- UVC laboratory testing shows significant degradation in a short timeframe to a variety of products

UVC测试在短时间内就对很多材料产生显著老化

- Test protocols are in the process of being standardized  
相关UVC测试标准正在制定中

# Question?



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