Ushio Application Note

Reflectance of materials at 222nm

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Introduction

There is growing interest in the application of far ultraviolet (UV) radiation, particularly UVC (100 nm to 280 nm), for use in the disinfection of occupied spaces. The filtered krypton-chloride (KrCl) excimer lamps used in Care222, which emit at 222 nm have been shown to provide similar, or improved pathogen reduction rates, while being safe for human eye and skin exposure at levels magnitudes higher than from the typical 254 nm lamps or UVC light emitting diodes (LED). This opens new opportunities to provide disinfection of air and surfaces in the presence of people.

Existing lighting design software can be modified to plan the placement of 222 nm light fixtures for disinfection and calculating irradiance distribution across a room. However, the reflectance of materials within an occupied space, such as walls, furniture, ceilings, and floors, should be considered to achieve reasonably accurate distribution models and predict the applied UV dose levels. Wengraitis (1) provided extensive reflection data for various ceiling tiles between 200 nm and 400 nm, which are very important for upper air, germicidal UV (GUV) applications. Since Care222 lamps are mainly used to irradiate occupied, lower room areas, ceiling reflectance is usually unimportant for these use cases. Unfortunately, there is no reflectance data at 222nm available in the literature for other interior building materials like wall paint, floors, furniture surfaces, or other interesting materials.

To remedy this situation, Ushio America developed a setup to measure reflectance of materials with a Care222 lamp. Some of these measurements have been verified in collaboration with NIST and have been reported recently (2). Although the measurement methods differed significantly, it was found that the results obtained by Ushio America agreed with a reasonable accuracy with the results obtained by NIST.

Measurement setup and materials

The measurement setup and related calculations have been described in (2). The materials reported here were obtained in collaboration with Acuity Brands and Boeing. Other materials were available at Ushio America.

Some of the reported measurements have been obtained over the course of several months, with different samples (of the same name) and different reference materials. It is therefore expected that measured values for the “same” material will vary. It should be noted that the uncertainty of the absolute measurements has been estimated to be 7%. It should also be noted that the applied measurement method cannot differentiate between specular (aka mirror) and diffuse (lambertian) reflectance.

Nonetheless, it is believed that the provided results are still of great value, providing reference data for a variety of materials that have not been available so far. It should also be mentioned, that reflectance data in the 222nm range are strongly influenced by (invisible) surface contaminants that may change over time, but also by irradiation with 222nm.

Measured reflectance values for various materials

Building materials

CEILING TILES			Reflectance
CEILING TILE - WHITE - MEDIUM TEXTURE	ARMSTRONG, CERAMAGUARD UNDERPERFORATED, WHITE	VARIES BY SIZE	33.0%
CEILING TILE - WHITE - FINE TEXTURE	ARMSTRONG, ULTIMA, WHITE	VARIES BY SIZE	6.9%
FLOORING			
BIOBASED TILE - OFFWHITE	ARMSTRONG, BIOFLOORING, STRIATIONS BBT, BISQUE	T3614	8.2%
LVT - LUXURY VINYL TILE - OFFWHITE	ARMSTRONG, LVT BIOME BOREAL STOCKHOLM	ST280	9.4%
WALL TREATMENT - VERTICAL SURFACES			
ACOUSTICAL PANEL - WHITE	ARMSTRONG, INVISACOUSTICS, WHITE WALL TILE	1212WH	13.4%
ACOUSTICAL PANEL - BLACK	ARMSTRONG, INVISACOUSTICS, BLACK WALL TILE	1212BL	6.1%
CONRETE			

SEALED CONCRETE	TRUEFORM CONCRETE, WHITE LINEN, TOP SURFACE SEALER	2021-HB7 with MS-45 sealer	6.1%
RAW CONCRETE	TRUEFORM CONCRETE, WHITE LINEN, BOTTOM SURFACE UNSEALED	2021-HB7	8.6%
WOOD FINISHES			
LIGHT WOOD - OAK	STEELCASE, NATURAL VENEER, OPEN PORE, PLANKED OAK	3P61	8.6%
DARK WOOD - WALNUT	STEELCASE, NATURAL VENEER, OPEN PORE, CLEAR WALNUT-LOW GLOSS	V1BW	9.0%
COUNTERTOP FINISHES			
COUNTERTOP - SOLID SURFACE	CORIAN SOLID SURFACE, DESIGNER WHITE		8.6%
COUNTERTOP - STONE	CORIAN QUARTZ, SNOW WHITE		8.6%
COUNTERTOP - LAMINATE	STEELCASE, LAMINATE STANDARD SURFACES, ARCTIC WHITE	2L30	15.4%
PAINTED SURFACES			
PAINT ON GYPSUM - GREY	BEHR TOASTY GREY	N320-2	7.1%
PAINT ON GYPSUM - WHITE	BEHR WHITE	WHITE 52	7.8%
RAW METAL			
	STAINLESS STEEL POLISHED		28.9%
	POLISHED CHROME		32.6%

Other Building Materials

Ceiling tiles	
A pebble NRC (white)	6.8%
A Invisacoustics 1212white	12.1%
A Invisacoustics 1212Black	6.1%
A Optima Tegular white	6.8%
A Ultima white	6.7%
A Medinton H5331	8.7%
Fine fissued open plan white	19.6%
Cerama guard 605 (white)	28.7%
Cirrus (white)	21.3%
Cirrus (light gray)	16.1%
Mesa (white)	4.9%
Pebble NRC	6.5%
Fine fissued med taupe	7.3%
A ledges (white)	8.3%
Cleanroom VL (white)	8.2%
Cala White	6.1%

Flooring	
A Biome ST280	9.0%
A Medintech 84163	8.7%
A Bio-flooring T3676	9.4%
A Cornelius Creek J5220	8.0%
A Crown Texture 5C811	8.0%
Paint	
Behr white -52	6.7%
Behr Toasty N320-2	8.0%
Behr N340-1	7.5%
Behr YLW11	8.1%
Behr 710-E	7.5%

Notes:

Based on the measured samples, reflectance values at 222nm of <10% can be assumed for flooring materials and regular paints.

Ceiling and acoustic tiles seem to fall into distinct groups. One group having reflectance of <10% and another group having much higher values. Fortunately ceiling tiles will not significantly influence the irradiance distribution in a room with Care222, since the preferred orientation is pointing downward, with no light hitting the ceiling.

Metals and other materials

Metals	
Alu black anodized	7.8%
Alu black anodized sandblast	4.0%
Alu foil (w. adhesive on back)	58.5%
Alu tape	53.8%
Al5052- clear Anodized	12.5%
Aluminum polished	55.6%
Al polished with fingerprint	54.5%
Alu sandblasted	36.0%
Brass 260	24.2%
316 SS	36.0%
304 SS scratched	21.7%
304 SS dull side	25.3%
304 SS	22.4%
SS sandblasted	19.5%
SS polished	33.9%
Copper thin material (coated?)	7.4%
copper foil	27.6%
Copper 110 alloy	6.8%
Titanium Alloy 6AL4V	21.4%
Titanium Alloy 6AL4V dull backside	7.1%

Other materials	
2 sheets white printer paper	26.8%
brown cardboard	4.0%
glass	7.0%
Blue duct tape	8.1%
black velvet	0.7%
Kapton film (PI)	16.2%
Mylar	7.4%
Polyethylene sheet	17.0%
Acrylic sheet 3mm thick	11.2%
Polycarbonate 1/4" thick	8.2%
TYVEK	53.2%
Lexan Polycarbonate (white)	12.1%
Polyvinyl Floride (PVF) film	7.9%
Kydex (black, Polycarbonate)	9.3%
Fiberglass epoxy (dull)	5.4%
Fiberglass epoxy (shiny)	8.2%
Kevlar cloth	32.1%
Fiberglass cloth	32.1%
Teflon coated fiberglass	8.5%
Carbon fiber mesh (black)	3.0%
RTV rubber	7.8%
EPDM rubber	7.4%

Notes:

Many of these materials were random samples and the values should be used with caution. Some materials seem to have been coated(e.g. adhesive) on one side, for example the Titanium sample.

It is obvious that the surface roughness has an influence on the measured reflectance. There is also some indication that highly polished Aluminum can degrade rather quickly over time by a few percent, most likely due to surface oxidation and contamination.

Since stainless steel is often used as a base material for germicidal testing, it should be noted that the reflectance can vary widely, depending on material type and especially the surface finish. This can influence germicidal testing results significantly, and supports proposals to use glass instead. It should also be noted that the reflectance could be significantly different if the materials are wet (i.e. covered with water or saliva), but no measurements are currently available.

Highly reflective materials

High reflectance materials	
BaSo4 Spectrolux	72.1%
PTFE 1/16" thick	63.3%
PTFE 3/8" thick	83.8%
PTFE 0.08mm thick	50.9%
PTFE 0.37mm thick	80.4%
Teflon tape	27.6%
Porex PMR05	87.6%
Porex PMR15	88.4%
Anolux 1	63.7%
Anolux 3	60.0%
Anolux UVS	58.1%
Anolux Dezin Brilliant	58.7%

Notes: The measured values are generally significantly lower than published reflectance values at 254nm and certainly lower than visible reflectance. Even PTFE, considered one of the best reflective materials in the UVC range, barely reaches 90% reflectance. It was also found that the reflectance of PTFE can vary widely depending on manufacturer, processing, surface finish, and thickness. Aluminum based reflector materials, even those specifically optimized for 254nm, do not perform as well at 222nm.

References

1. *Ultraviolet Spectral Reflectance of Ceiling Tiles, and Implications for the Safe Use of Upper-Room Ultraviolet Germicidal Irradiation.* **Wengraitis, Stephen and Reed, Nicholas G.** s.l. : John Wiley & Sons, Ltd, November 2012, Photochemistry and Photobiology, Vol. 88, pp. 1480–1488. ISSN: 0031-8655.

2. *Reflectance measurements of building materials in the Far UVC (222nm) wavelength range.* **Holger Claus, Catherine Cooksey.** San Diego : SPIE, 2022. Preliminary - Proc. SPIE Optics + Photonics 2022.