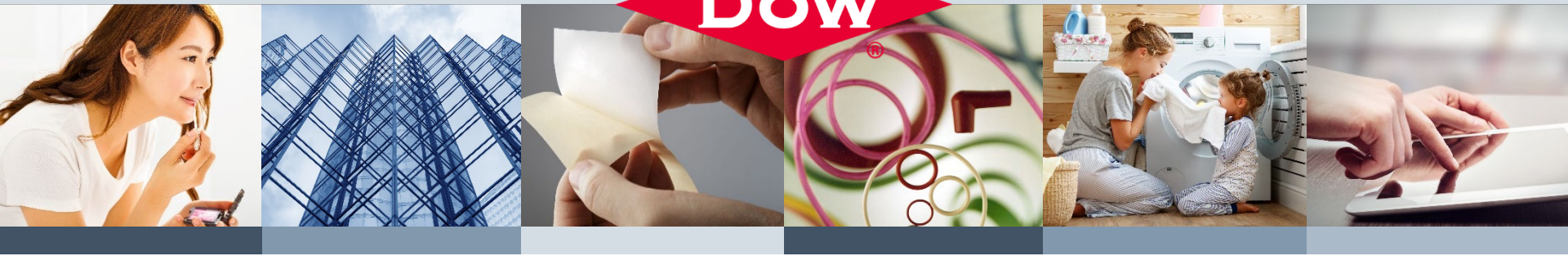

Consumer Solutions

Innovation in water purification systems with UV-C LEDs and silicone optics

François De Buyl, Dow, Belgium and Merlijn Janssen, Philips Lighting, Poland

7th International LED Professional Symposium and Expo

Sept. 26-28, 2017 | Bregenz, Austria

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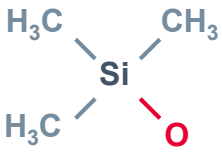
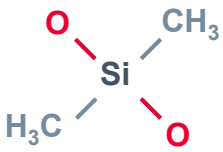
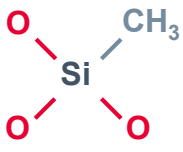
SILOXANE BUILDING BLOCKS



$R_3SiO_{1/2}$
M



$R_2SiO_{2/2}$
D

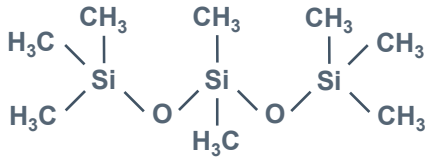


$RSiO_{3/2}$
T

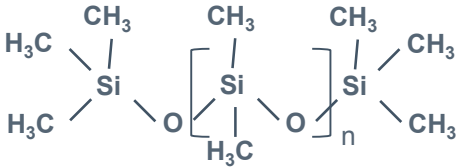
$SiO_{4/2}$
Q

Organic — **Inorganic**

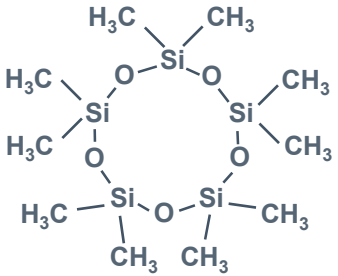
End capping | Linear polymers | Branching and networks



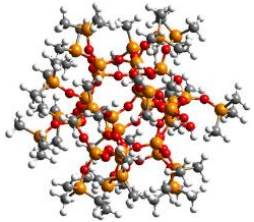
MDM
XIAMETER™ PMX 200 Fluid 1 cSt



MD_nM
XIAMETER™ PMX 200 Fluid x cSt

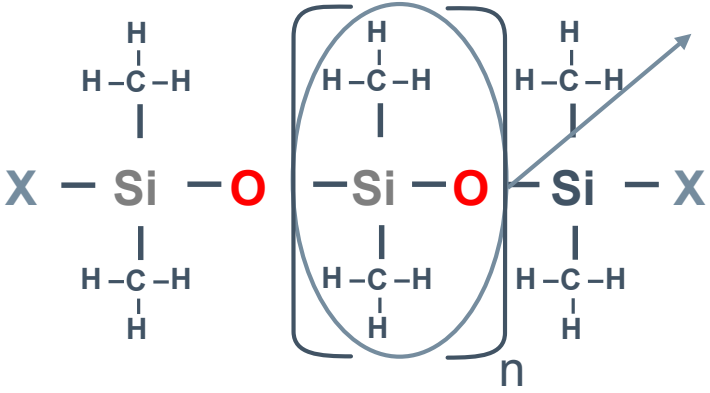


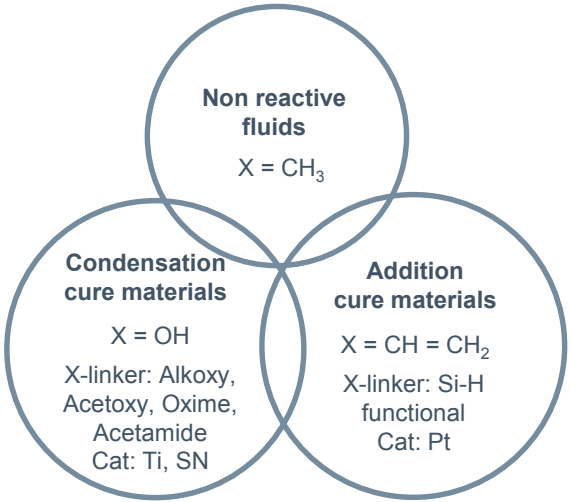
D5
XIAMETER™ PMX 245 Fluid



MQ resin

POLY-DI-METHYL-SILOXANE (PDMS)



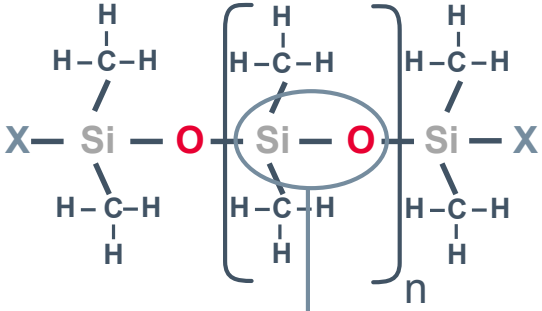


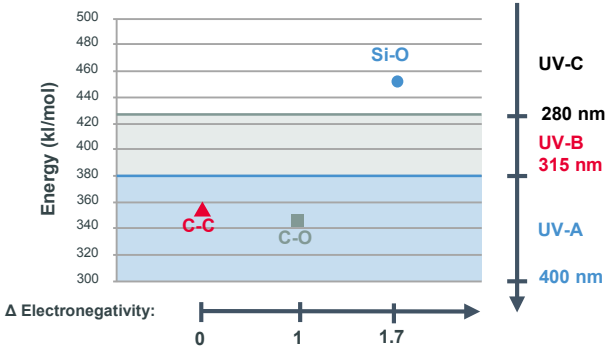
n	0	1	2	8	40	200	2,000
MW/Mn (g/mol)	162	236	311	705	3,200	14,800	150,000
Visc (cSt)	0.65	1.0	1.5	5	50	1,000	1,000,000

SILICONE VS. ORGANIC POLYMERS

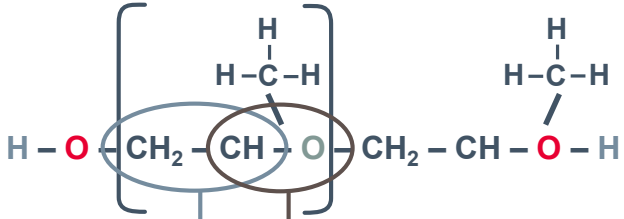
High photo-thermal stability

Silicone polymers



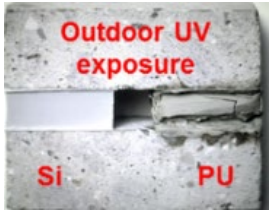


Organic polymers, e.g.,



Bonds	Energy (kJ/mol)	
Si-O	445	Ionic
Si-C	306	
C-C	346	Covalent
C-O	356	

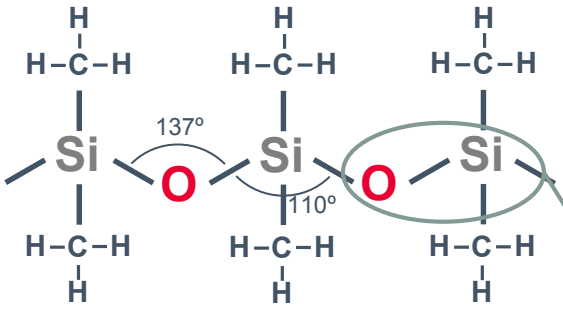
Polyurethane (PU)
Polysulfide
Polystyrene (PS)
Polyisobutylene (PIB)
Polyether (EO, PO)
Polyolefins (PE, PP)
Polyamides (PA)
Acrylics (PMMA)
Polycarbonate (PC)



SILICONE VS. ORGANIC POLYMERS

High photo-thermal stability

Silicone polymers



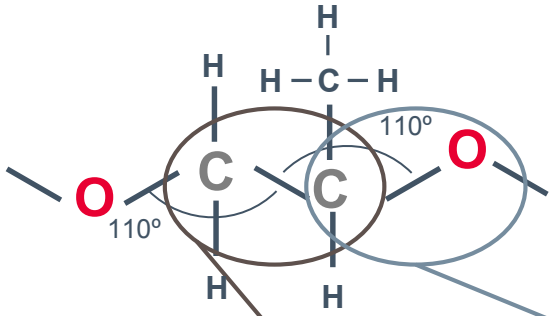
Barrier for rotation

Si-O-Si: free

CH_2-$CH(CH_3)$: ca 14 kJ/mol

Bond length = 1.63 Å

Organic polymers, e.g.,



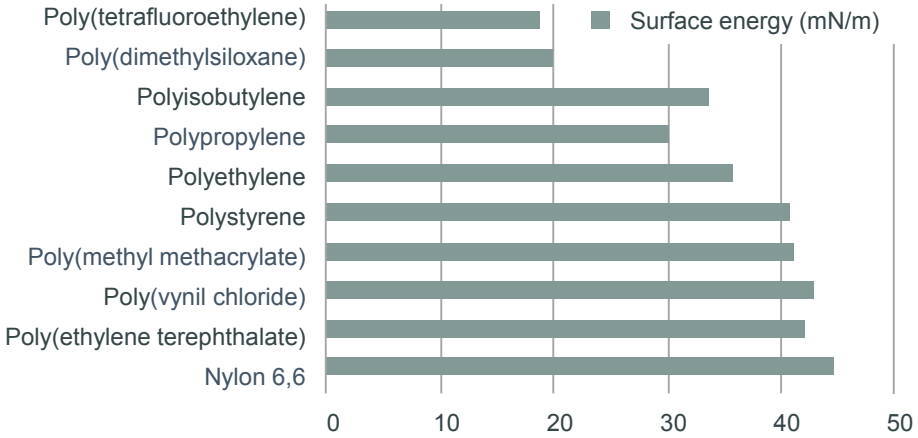
- Polyurethane (PU)
- Polysulfide
- Polystyrene (PS)
- Polyisobutylene (PIB)
- Polyether (EO, PO)
- Polyolefins (PE, PP)
- Polyamides (PA)
- Acrylics (PMMA)
- Polycarbonate (PC)

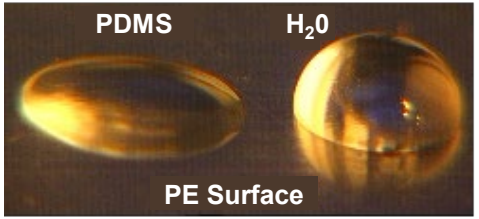
Bond length = 1.53 Å

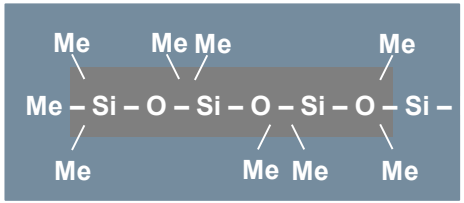
Bond length = 1.42 Å

SILICONE VS. ORGANIC POLYMERS

High flexibility + weak intermolecular forces = low surface energy

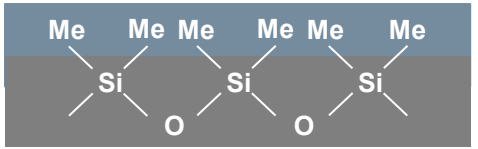






Non-polar (hydrophobic)

Polar (hydrophilic)



Polar substrate (glass)

Unusual surface and interface properties, e.g.,

- Low surface energy and low critical surface tension
- High spreading and wetting on polar and dispersive surfaces
- Hydrophobic characters and high water (vapor) permeability
- Adherence or non-adherence
- Pro-foamer or de-foamer

SILASTIC™ MOLDABLE OPTICAL SILICONES

What are they?

Injection moldable optical silicone materials are designed for unique applications such as TIR lenses, light guides, diffusers and reflectors.

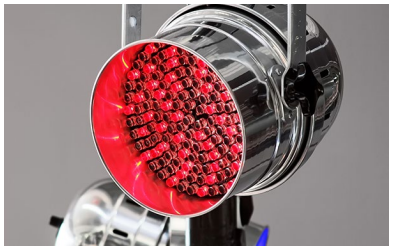



SILASTIC™ MOLDABLE OPTICAL SILICONES

What applications are they used for?

SILASTIC™ moldable optical silicones have proven performance in LED **lamps and luminaires applications** such as outdoor street lights, automotive and roadway lighting, stadium, entertainment and retail lighting, professional spot lights, flashlights and architectural lighting.

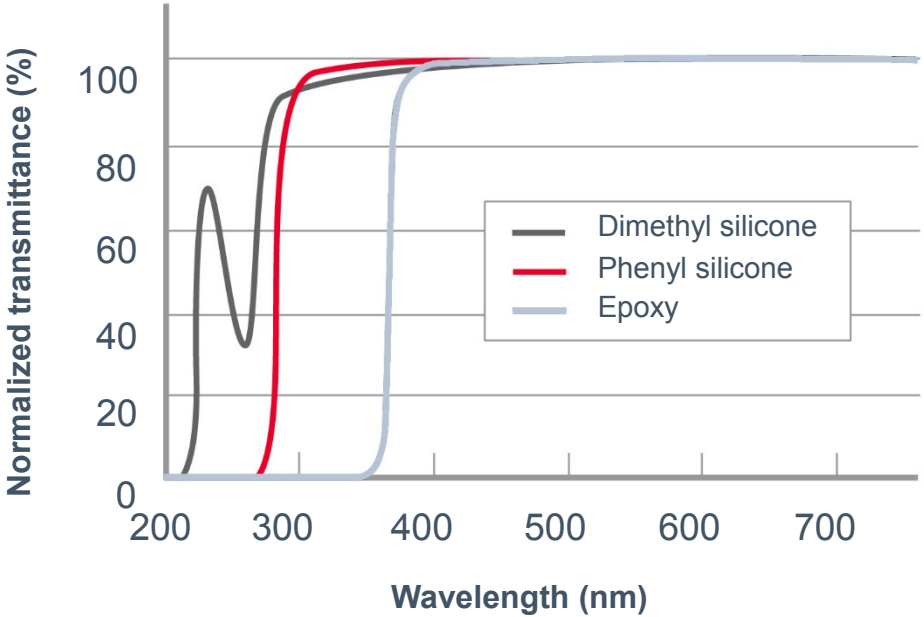


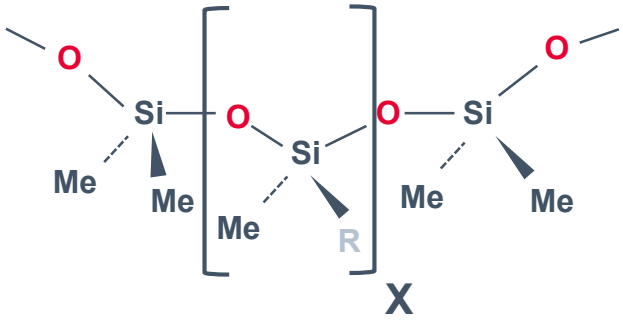



SILASTIC™ MOLDABLE OPTICAL SILICONE

Why silicone in this particular application?

1. High transmittance in UV wavelengths range, down to ca. 270 nm





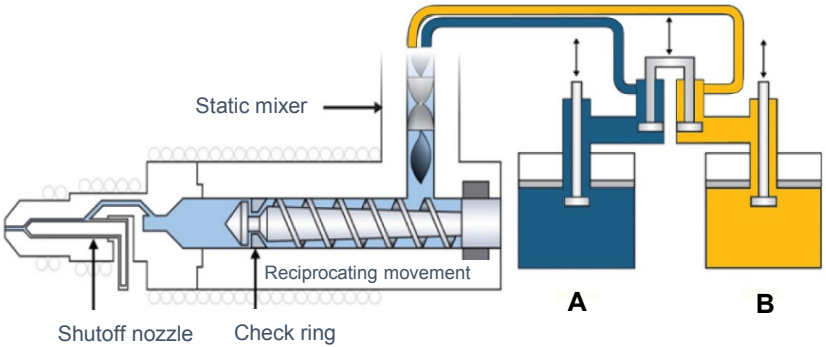
R = Methyl or phenyl

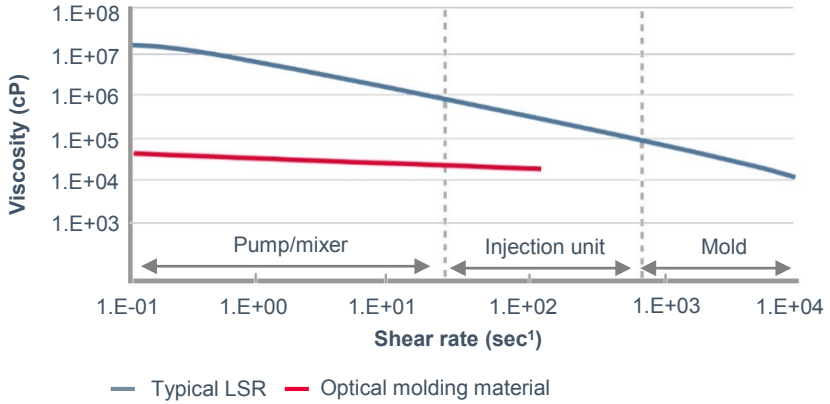
SILASTIC™ MOLDABLE OPTICAL SILICONE

Why silicone in this particular application?

2. Injection molding of optical part with complex shape and severe undercut (negative draft angle)
3. Ease of fabrication by liquid injection molding; low filling pressure
4. Good flow lengths in thin wall thickness, silicone will accurately replicate mold surface polish or optical design features
5. Direct gating; no secondary polishing

Gaggione LLC66x7 silicone collimator

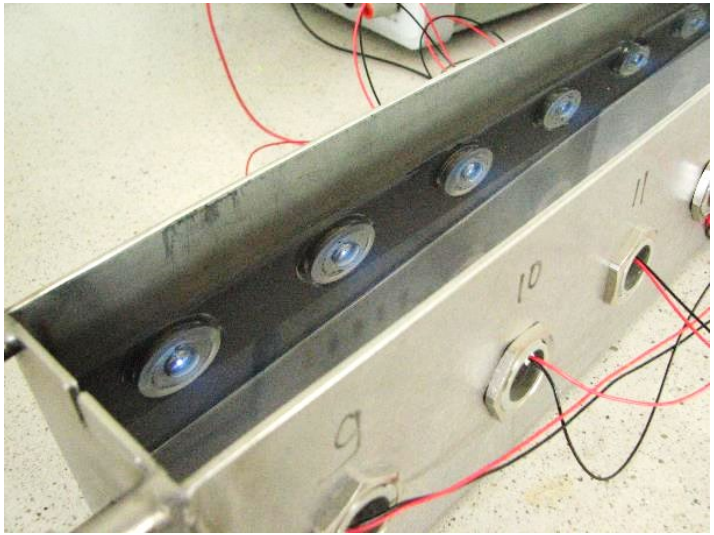




SILASTIC™ MOLDABLE OPTICAL SILICONE

Why silicone in this particular application?

6. Enables water tight LED module, up to IP-68
7. Enables high impact protection of LED module, up to IK-10



SILASTIC™ MOLDABLE OPTICAL SILICONE

Why silicone in this particular application?

8. Stable under UV radiation exposure: non-yellowing, non-hardening
   - **Certified UL-746C(f1),** i.e., stable mechanical and flame resistance performances after 1000 hours Xenon, 1 week 82ºC underwater

Dow

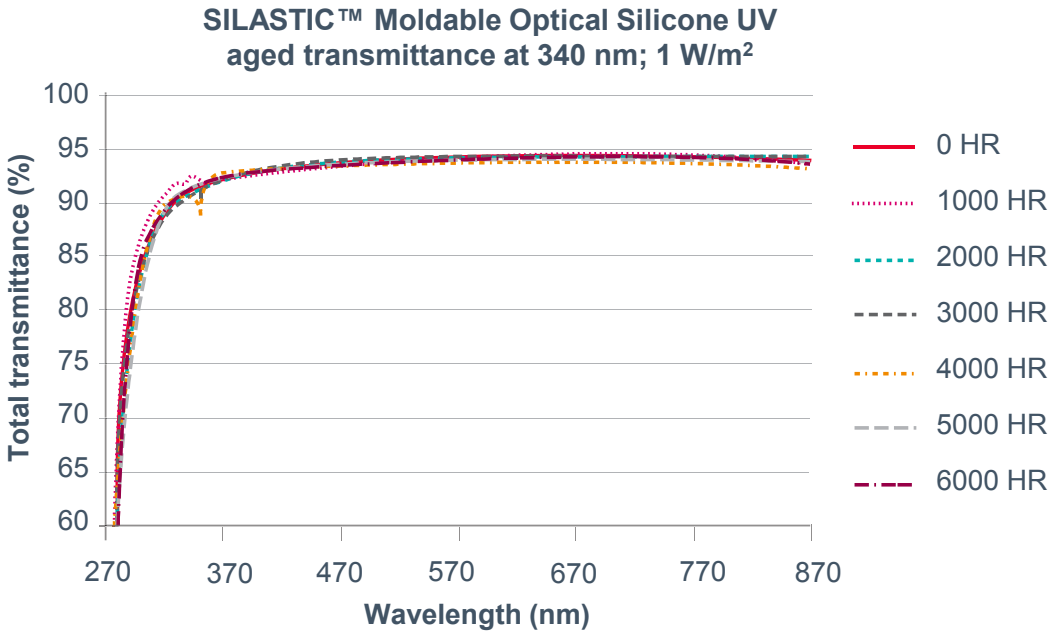
- Tested up to 6000 hours against UV-A, 340 nm, ca. 1 W/m²
- Tested up to 6000 hours against sunlight UV-A+B, ca. 14 W/m²
  OSRAM Ultra Vitalux 300 W; 13.6 W UV-A (315-400 nm),
  3.0 W UV-B (280-315 nm)

Philips lighting

- Tested against UV-C, 275 nm, ca. 8 mW

SILASTIC™ MOLDABLE OPTICAL SILICONE

Stability against UV-A accelerated aging

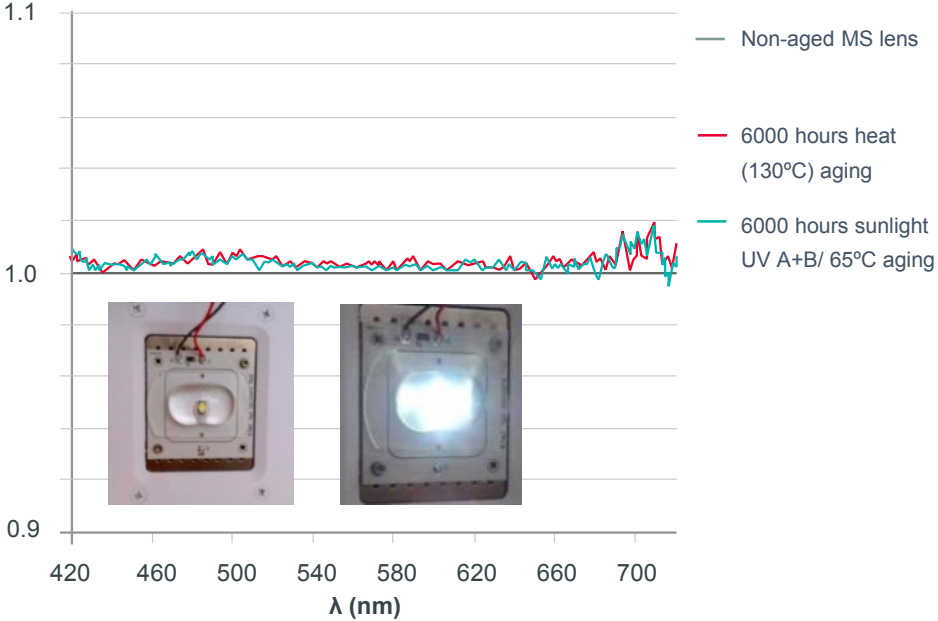


Measurements with a Varian Cary 5000 UV-VIS-NIR Spectrophotometer with a ~6” integrating sphere on SILASTIC™ MS-1002 Moldable Silicone and SILASTIC™ MS-1003 Moldable Silicone specimens of ca. 3 mm thickness.

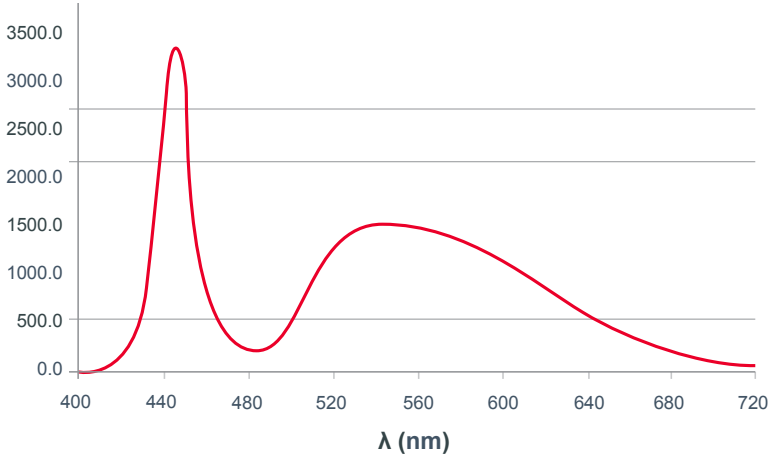
SILASTIC™ MOLDABLE OPTICAL SILICONE

Stability against sunlight UV-A+B accelerated aging

Relative luminous flux vs. initial: SILASTIC™ Moldable Optical Silicone



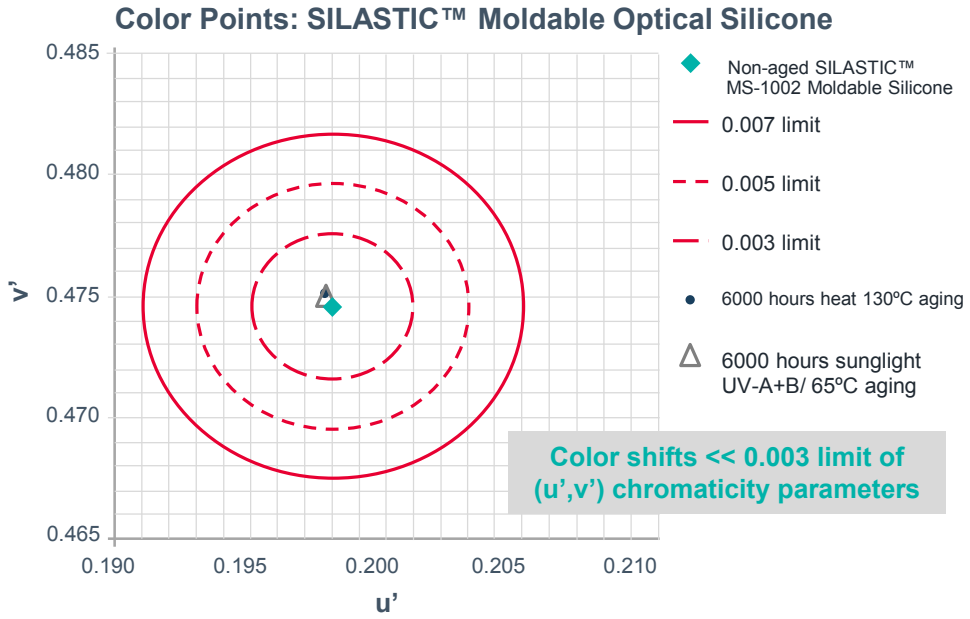
10-6 W Luminous flux

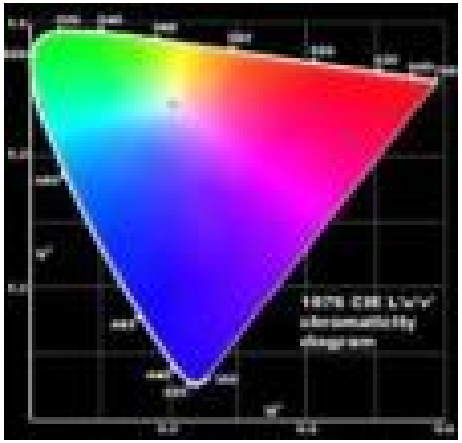


Measurements on molded optics of ca. 13 mm thickness, light flux density and chromaticity parameters determined with a 1 m diameter integrating sphere, Cree XML light engine (4V, 200 mA).

SILASTIC™ MOLDABLE OPTICAL SILICONE

Stability against sunlight UV-A+B accelerated aging

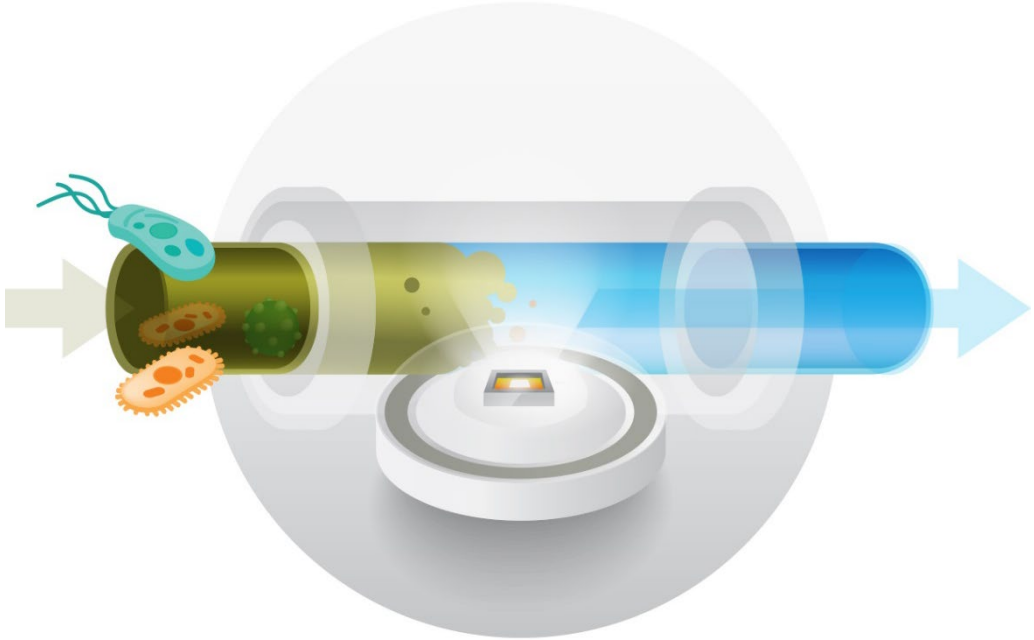




Measurements on molded optics of ca. 13 mm thickness, light flux density and chromaticity parameters determined with a 1 m diameter integrating sphere, Cree XML light engine (4V, 200 mA).

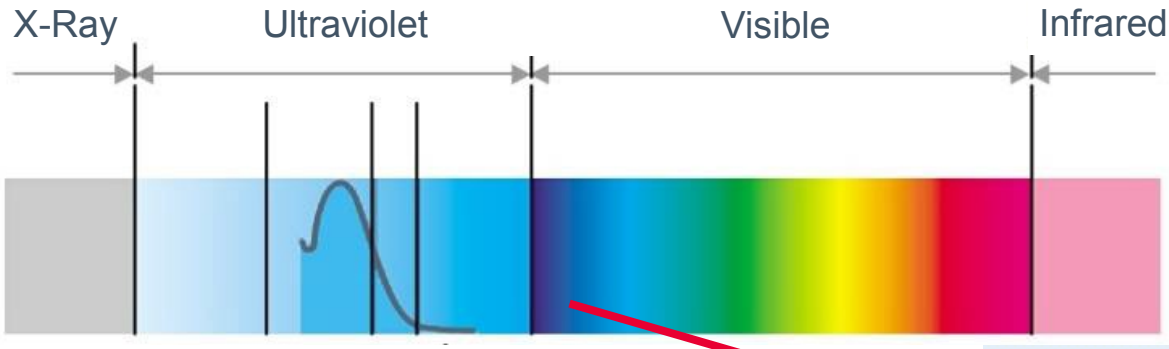
PHILIPS UV-C PURIFICATION MODULE

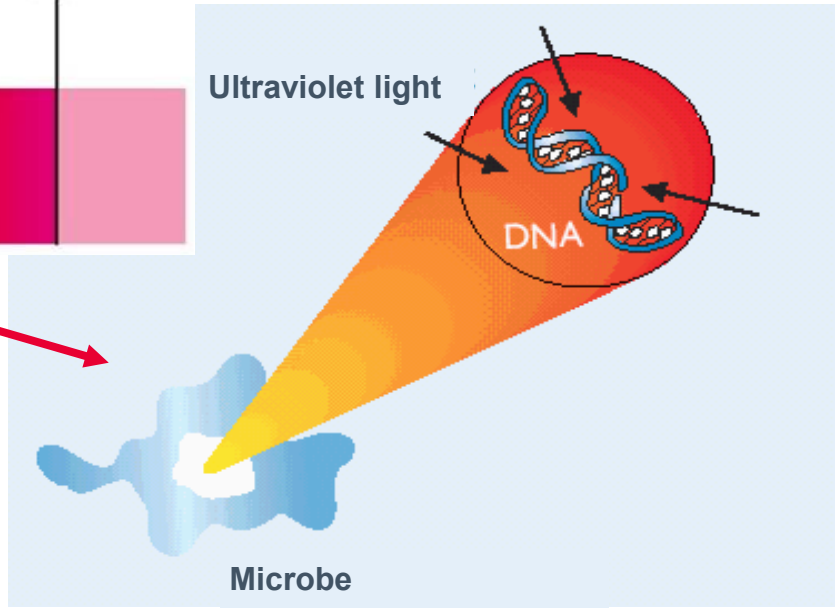
Philips UV-C sterilizing module: microbiological performance



EFFECTS OF UV-C RADIATION

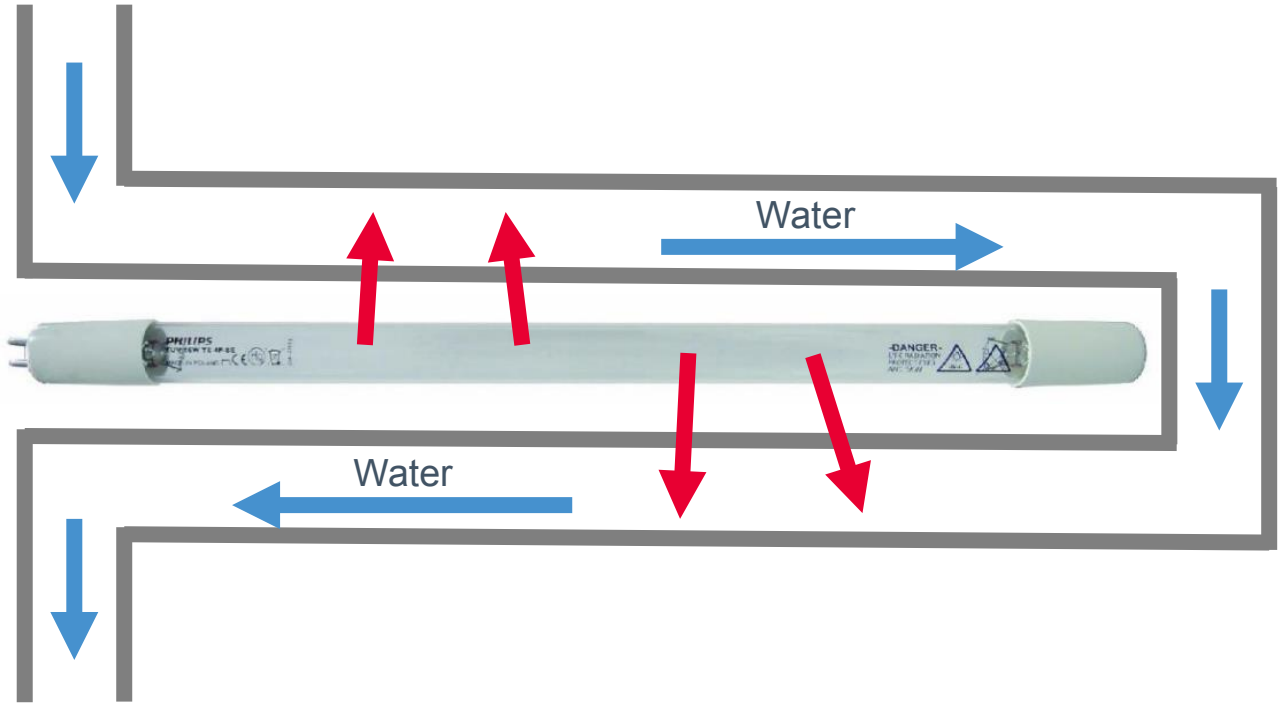
UV-C radiation destroys DNA of micro-organisms





How UV-C radiation is used

Philips Mercury UV-C lamps used to sterilize water (and air)



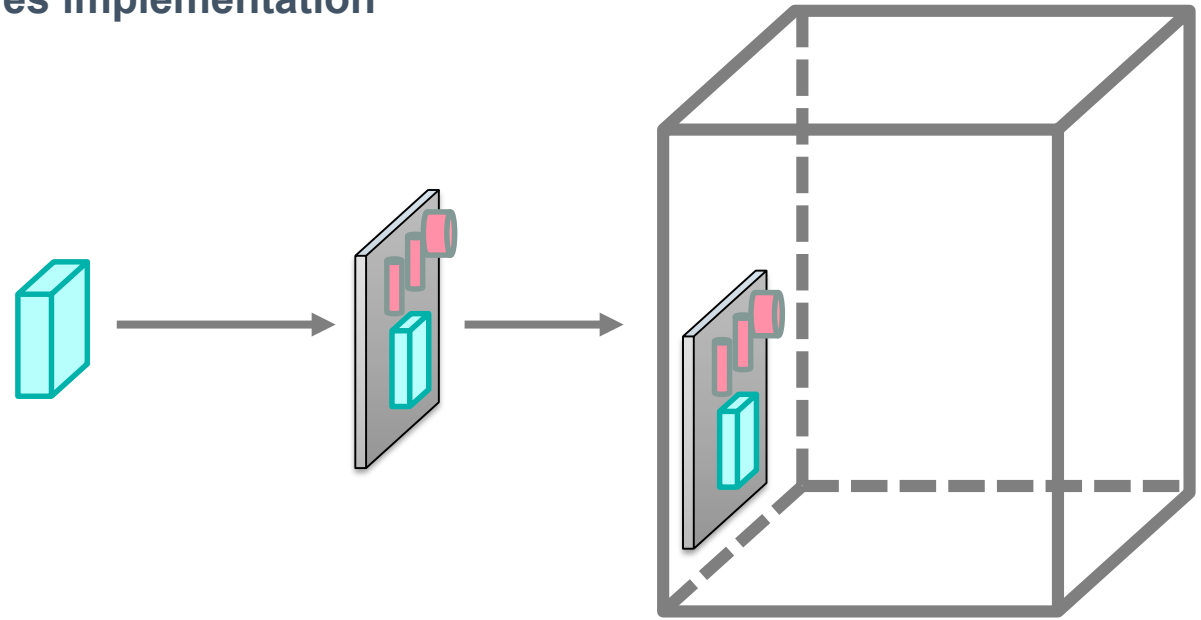
POTENTIAL FOR UV-C LEDS

Small size UV-C LED enables implementation in household appliances

- Coffee maker
- Water pitcher
- Refrigerator
- Ice maker

Obstacles:

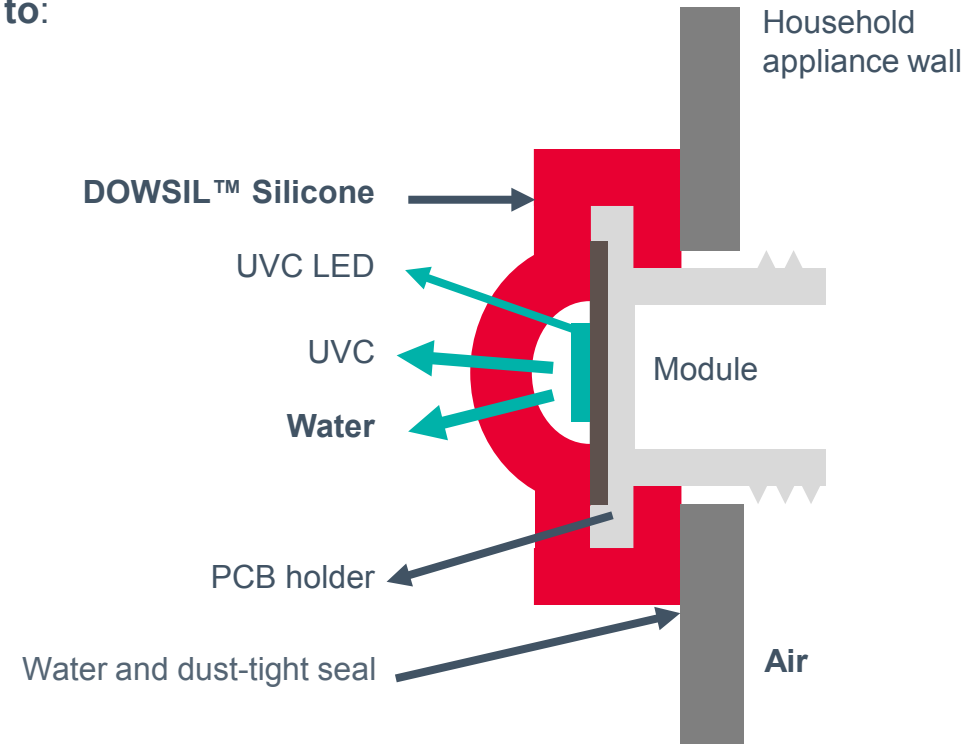
- Driving the LED
- Water-tight component
- Coupling radiation in water
- Thermal issues



PHILIPS UV-C MODULE CONCEPT

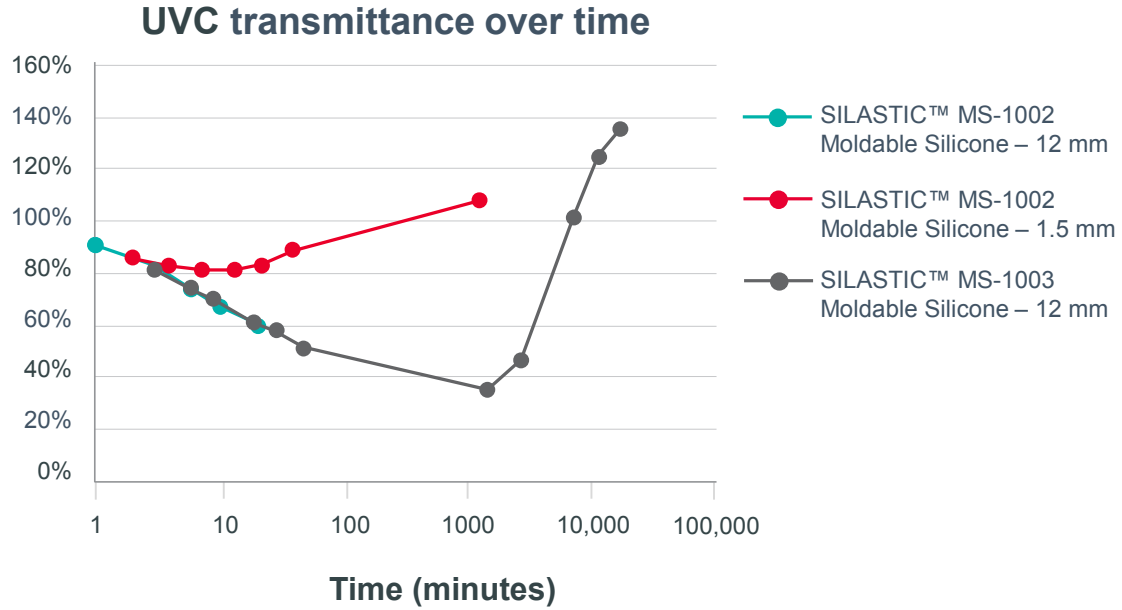
Use SILASTIC™ moldable optical silicones to:

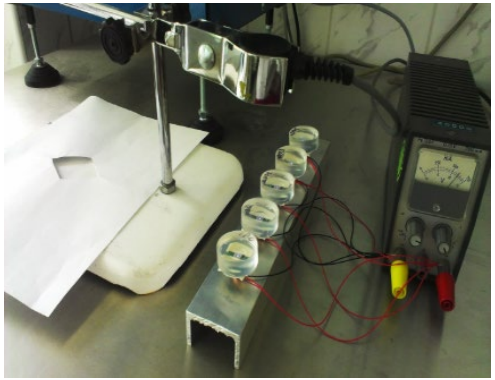
- Couple radiation into the water
- Provide water-tight and dust-tight solution



UV-C TRANSPARENCY SILICONE

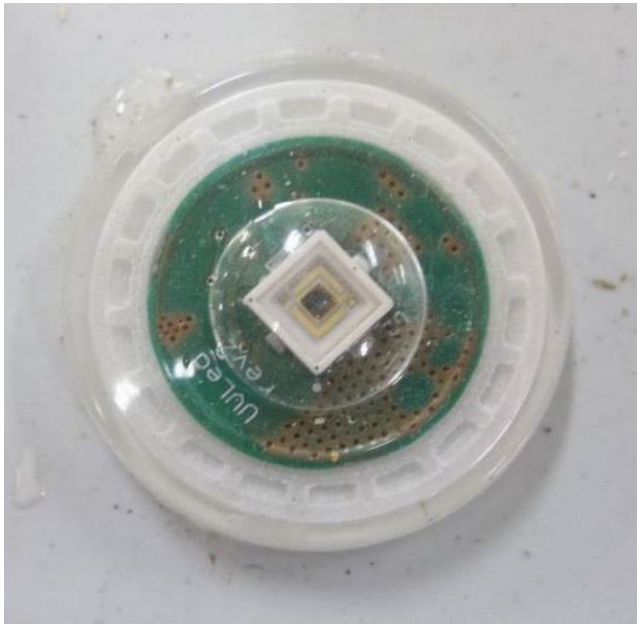
Testing to determine stability of molded silicone specimens of various thicknesses against UV-C LEDs – emitting at 275 nm, 8 mW power





WATER-TIGHT/DUST-TIGHT SEAL

Prototype sent to external lab: confirmed IP68 seal rating



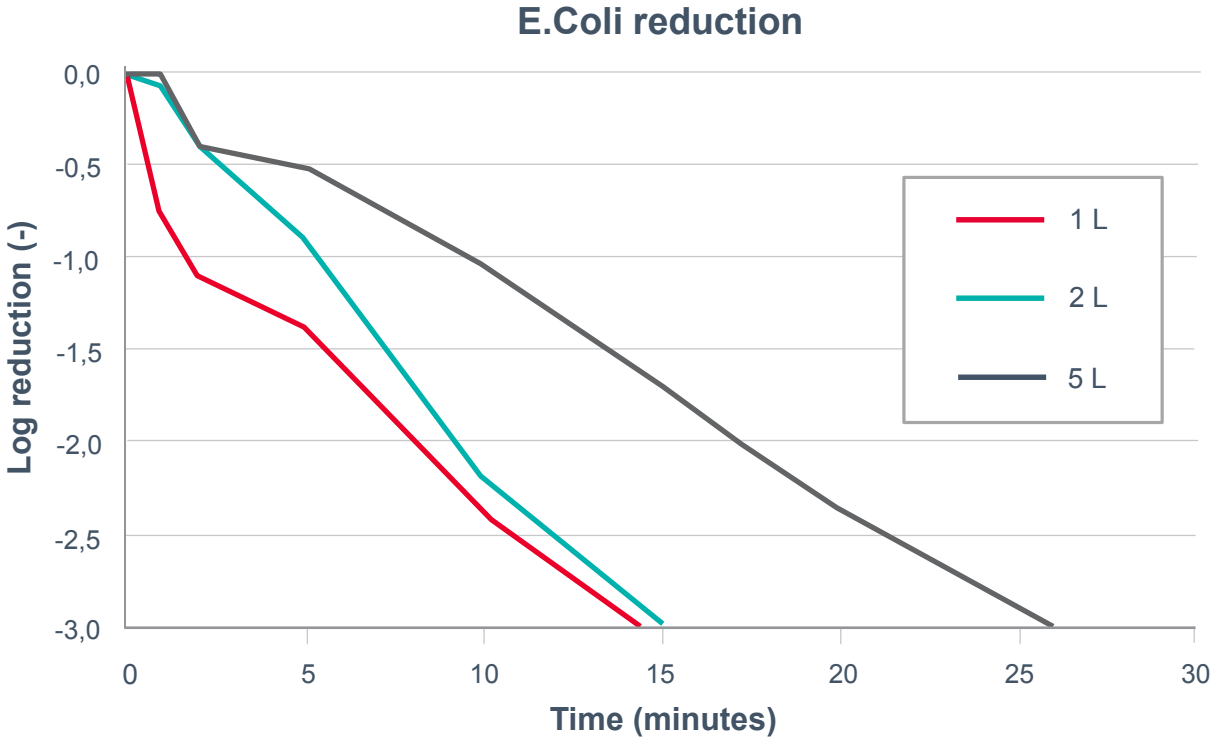
PHILIPS UV-C PURIFICATION MODULE

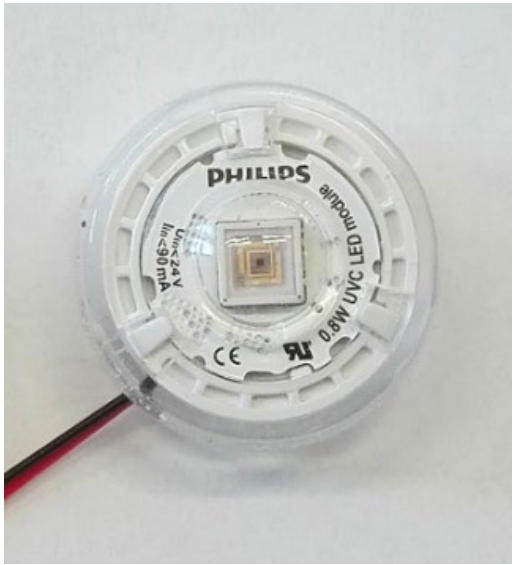
Example of a Philips UV-C sterilizing module (installed).

From left to right, 1-, 2- and 5-liter containers showing efficiency of UV-C sterilizing module in keeping water clean.

PHILIPS UV-C PURIFICATION MODULE

Microbiological test result





LESSONS LEARNED

Open collaboration between supplier and customer leads to:

- Innovation speed
- Knowledge sharing
- Reduced project risk

Proper selection of materials enables innovation in LED modules – beyond illumination.

Our continuous research on the use of moldable optical silicone in visible lighting applications (e.g. auto, retail, outdoor) enabled our innovation for this new technology.

THANK YOU

S2D 91376/E26584

Form No. 11-3860-01 B