UVC-based biofouling prevention solutions for ship hulls

RunWell

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PHILIPS innovation + you

AkzoNobel

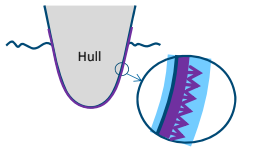
Australian Government Department of Defence Science and Technology

RunWell goal & concept for biofouling prevention

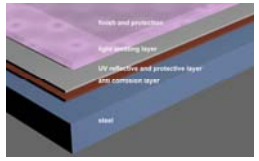
AkzoNobel and Philips are teaming up to develop an UVC-based biofouling prevention solution:

- Environmentally friendly solution for keeping the hull of ships clean
- Lower sailing fuel consumption by at least 7-9%, if compared to ships with biofouled hulls.
- Active when the ship is anchored, and at slow or high speed cruising.

Single UVC LED (1mW output) keeps ~110 cm² clean (Philips proof of principle, 2014)



Hull coated with tiles / "wallpaper" with UVC LEDs embedded (275nm wavelength).



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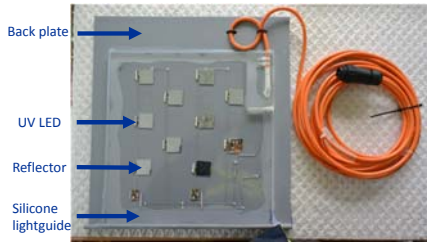
RunWell: Typical panel prototype used for concept testing



30x30cm² RunWell panel prototypes with 10mm thickness,

used for fouling prevention testing in sea environment (harbor sites).

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Effectiveness of RunWell biofouling prevention (Zeeland, NL, 2017)

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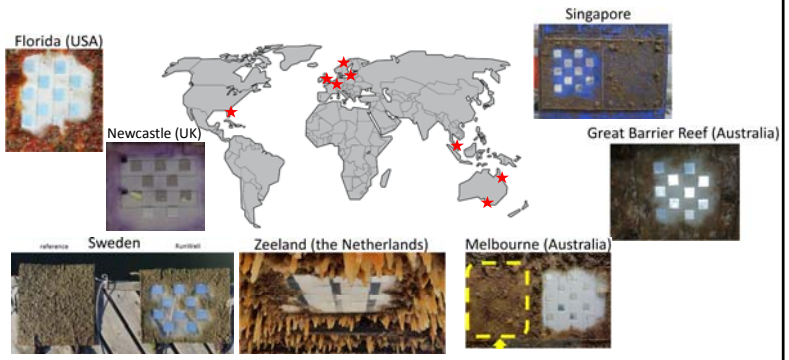
World-wide effectiveness of RunWell biofouling prevention



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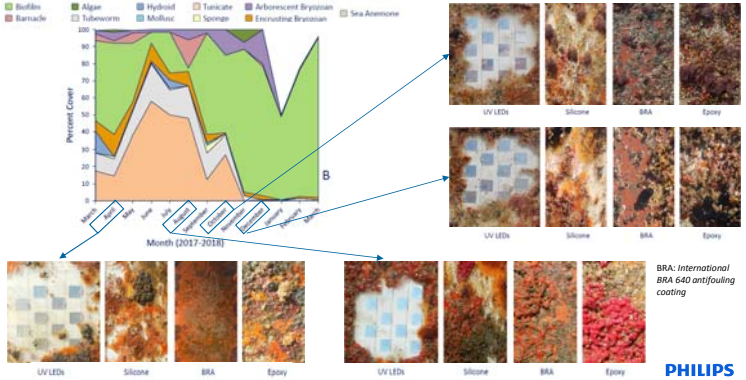
RunWell effectiveness in all seasons (Florida, US, 2017)



BRA: *International BRA 640 antifouling coating*

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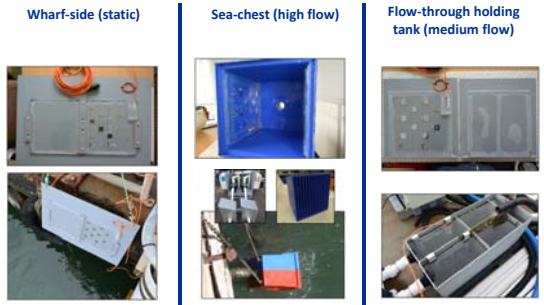
First extended duration bio-exposure test (Melbourne, Aus)

Prototypes containing a first generation of UVC LEDs, with limited lifetime



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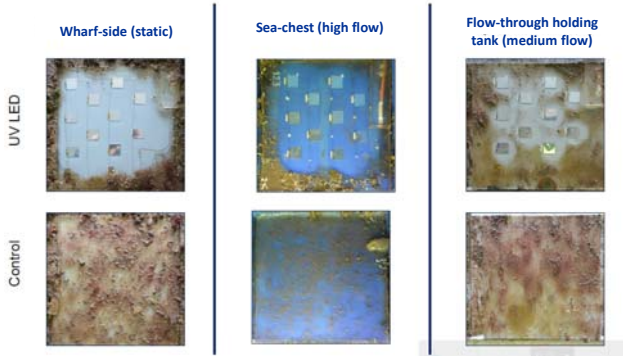
Test results after 19 weeks exposure



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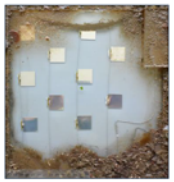
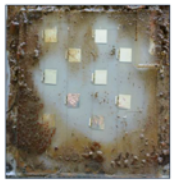
Test results after 38 weeks exposure

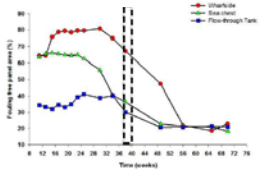


Wharf-side (static)

Sea-chest (high flow)



Flow-through holding tank (medium flow)



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Fouling prevention achieved for two years (Zeeland, NL)

RunWell panel with a second generation of UVC LEDs

26 Sep 2016 | 16 June 2017 | 26 July 2017 | 25 Sep 2017 | 15 May 2018

Conclusions:

- **RunWell panel continuously worked successfully for ~21months (~15000h)**
- Biofouling prevented area size did not change (UVC light output was found to have decreased only slightly)
- No delamination or corrosion of the panel. Panel still adhered strongly to the ship (after static and regular sailing).

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Principle of the RunWell concept

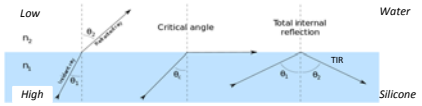
Waveguiding principle:

Top-side UVC reflection:

- Total internal reflection (TIR)

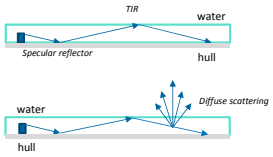
Bottom-side UVC reflection:

- TIR or reflector



RunWell approach:

- Side-wards emitting UVC LED
- UVC light transport through silicone waveguide
- Part of the guided UVC is diffusely scattered
- The scattered UVC emitted towards the top surface ensures anti-fouling



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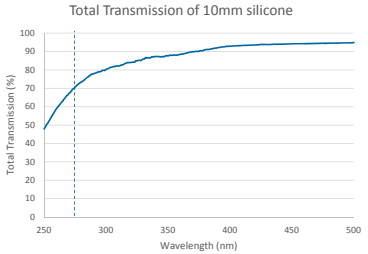
High UVC transmission of silicone

Silicone Optical Characterization



Bulk transmission at UVC:

Ti (275 nm) = 78%/cm

Dry silicone

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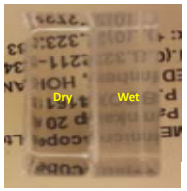
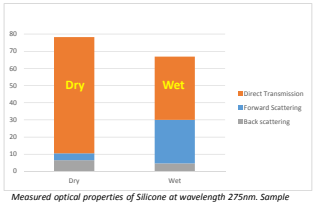
UVC light scattering, different in dry and wet silicone

Silicone Optical Characterization





Measured optical properties of Silicone at wavelength 275nm. Sample thickness is 10mm.

	Simulation			Measurement		
mfp	T_direct	T_scatter	Backwards	T_direct	T_scatter	Backwards
3	9%	28%				
10	34%	26%	5%	37%	25%	5%
30	56%	13%				
100	68%	4%				

Best fit:
Mean free path (mfp)
= 10 mm

Wet silicone

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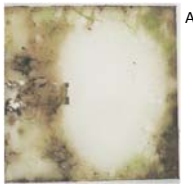
UVC intensity threshold for biofouling prevention

Threshold

- Tests in sea water aquaria
- Silicone slab (15x15cm²; 3 mm)
- Containing one UVC LED

Original (top view)

Sideward emitting LED



After 7 weeks (top view)

Stable clean area: 7.5 x 11 cm²

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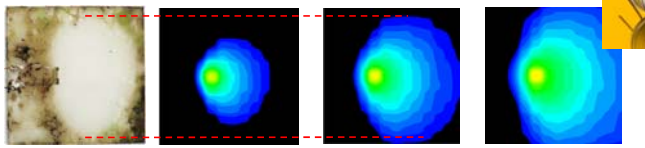
Photodiode UVC measurement versus Biofouling

Threshold

Biofouling

UVC output measurement



Threshold 10^{-9} W/mm²

Threshold $3 \cdot 10^{-10}$ W/mm²

Threshold 10^{-10} W/mm²

➔ **Fouling prevention UVC threshold $3x10^{-10}$ W/mm² (sea aquarium)**

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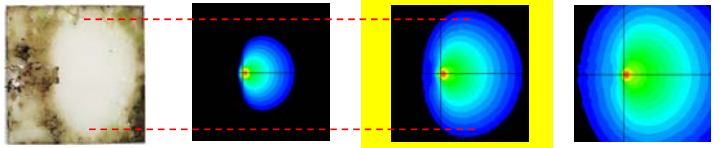
Simulation model verified

Biofouling

Model calculation



Threshold 10^{-9} W/mm²

Threshold 10^{-10} W/mm²

Threshold 10^{-11} W/mm²

Ti=78%/cm; mfp=10mm

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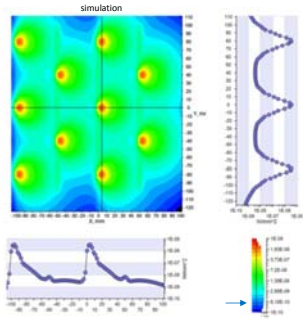
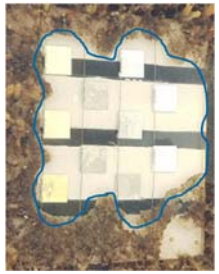
Validated model prediction for prototype tested in Zeeland, NL





$3x10^{-10}$ W/mm² (from simulation)

➔ **Fouling prevention UVC intensity threshold equal to lab aquarium ≈ $3x10^{-10}$ W/mm²**

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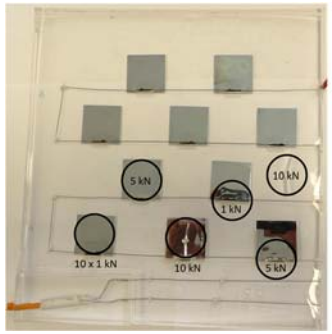
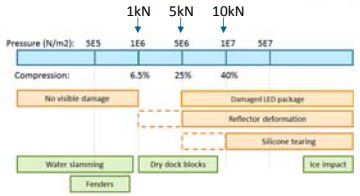
RunWell panel expected to survive harbor fender impact

Compressive forces test on RunWell prototype panel



Test speed 5 mm/min
Hold 1 min at max force



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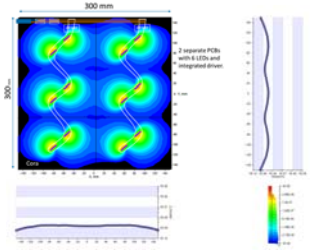
Cora generation concept: a step toward ease of manufacturing

Design

- Simplified back mirror design
- Printed-circuit board based electronics



Experiment

Biofouling prevention achieved after two months exposure (summer 2018)

Cora installed on the boat in Zeeland

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Successful fouling prevention on sea ship in continuous operation

Fouling prevention on Cora confirmed, except at some local surface areas above the pcb's and at the panel edges, which correlate with low UV intensity area's in the panel design.

After 3 months (July 25th)

After 5 months (September 21th)

Navy patrol vessel

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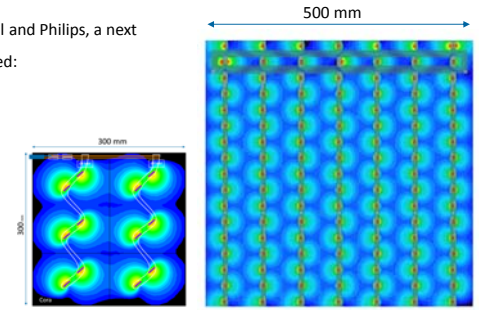
Next generation Donna: toward larger and thinner panels

In a joint development of AkzoNobel and Philips, a next generation system has been prepared:

- Matured manufacturing processes (e.g. injection molding)
- Low power, long lifetime, side-emitting UVC LEDs
- Inductive energy coupling to panel
- Manufacturing of larger series of trial panels
- Multiple panel patches on the hulls of commercial vessels for feasibility testing



Cora (10mm thick) → Donna (4mm thick)

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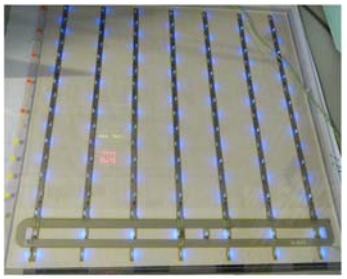
First Donna panels ready for in-situ functional testing



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Donna vessel trials to begin in 2019-H2

UV-LED array (conventional coatings used for the main hull area)

- **Technology demonstrator of interconnected arrays of tiles**
  - Demonstration that full ship coverage is feasible
- **Identification of yard and operational considerations**
  - Vertical sides, permanently immersed areas, near to engine room
- **Generation of in-service track record**
  - Equivalent to early test patching of conventional coatings

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Conclusions

- Effectiveness of RunWell shown at various sea locations and in multiple seasons.
- Simulation model has been validated and is available for designing RunWell panels.
- RunWell panels predicted to withstand compression from standard fender impact on the hull (< 700 kN/m^2).
- Simplified panel design realized (Cora) and tested (in lab., on small boat, and on marine vessels)
- First larger and thinner panels (Donna) available for vessel testing.

RunWell Newco under construction for development and upscaling to commercialisation

If you/your company is interested in taking part in the investment opportunity, please contact us!

Acknowledgements

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