Final report

1.1 Project details

Project title	Energieffektiv UV-lysdioder til den globale hærdningsindustri
Project identification (program abbrev. and file)	64013-0124
Name of the programme which has funded the project	EUDP
Project managing company/institution (name and address)	Othonia Curing Technology A/S Cortex Park 26 5230 Odense M
Project partners	Othonia Curing Technology A/S Glunz & Jensen A/S Teknos A/S OneWood A/S Syddansk Universitet
CVR (central business register)	34727112 (Othonia Curing Technology)
Date for submission	

1.2 Short description of project objective and results

1.3 Executive summary

1.4 Project objectives

1.5 Project results and dissemination of results

1.6 Utilization of project results

1.7 Project conclusion and perspective

Annex

Relevant links

1.2 Short description of project objective and results

I en række industrier arbejdes der med at hærde overflader – eks. i møbelindustrien, den grafiske industri eller medico-industrien. Anvendelsen af bredspektret UV-lys frembragt af kviksølvslamper er en hyppig anvendt teknologi hertil. Den medfører dog et stort strømforbrug og miljømæssige udfordringer med ozon og kviksølv.

Med fremkomsten af stadig mere effektive UV-dioder (LED), er praktiske, tekniske og økonomiske forudsætninger for et teknologiskift til industriel hærdning undervejs. Det vil betyde – mindst – halvering af strømforbrug, langt mere miljøvenlig produktion og større fleksibilitet i produktionen.

Projektet har udviklet, bygget og testet flere generationer hærdearmaturer baseret på UV-dioder. Armaturerne er testet hos projektdeltagerne og er pt. under test-installation på regulære produktionslinier hos en stor international underleverandør i møbelbranchen

---

A number of industries are working with surface curing/hardening - eg. the furniture industry, the graphics industry or the medical equipment industry.
The use of broad-spectrum ultraviolet light generated by mercury lamps is a common technology used for this. It causes, however, a large power consumption and environmental challenges with ozone and mercury.

With the advent of ever more effective UV-emitting diodes (LEDs) is practical, technical and economic conditions for a shift in technology for industrial hardening present. This would mean - at least - half the power consumption, more environmentally friendly production and greater flexibility in production.

The project has developed, built and tested several generations curing luminaires based on UV-emitting diodes. The luminaires are tested by the project participants and is currently installed on regular production lines at a major international subcontractor in the furniture industry.

1.3 Executive summary

The project has developed and tested UV-LED based luminaires to be used for UV-light curing/hardening in industry. The technology and proto types have been applied and tested in the furniture manufacturing industry. The LED luminaires replaces existing and widely used mercury UV based luminaires.

The LED luminaires proved to deliver substantial energy (electricity) savings of around 75%, much longer lifetime (20.000 hours) and a much more environmental friendly production compared to traditional mercury lamps.

Furthermore – and very important for customers - the LED based products offers more flexibility in production (no heat up time and no heat exposure to surface of items to be cured.)

In short the advantages of the UV-LED technology allow customers to pay 3X the purchasing price of existing products based on mercury technology.

It is not an easy job to replace existing technology with UV-LEDs.
Knowledge of coating chemistry, photo initiators, UV bandwiths are needed to develop in build in to products. However, as the price/effect ratio of commercially available UV-LED´s are constantly improving the UV-LED technology will probably crowd out the existing technology before 2020.

1.4 Project objectives

The project was broken down in 5 connected work packages

WP0:
Developing theoretic framework.

- Understanding curing and chemical structures of paints and lacquers (especially photo initiators, UV-wavelengths and effects)
- Carry out initial pre-prototype tests to confirm theoretic framework.

Central finding was that chemical composition of standard paints and lacquers needed to be changed in order to trigger chemical curing reaction at a level corresponding to industrial requirements

Curing process needed to be split in two processes – surface and bottom curing each with different UV bandwith, effects and process time.

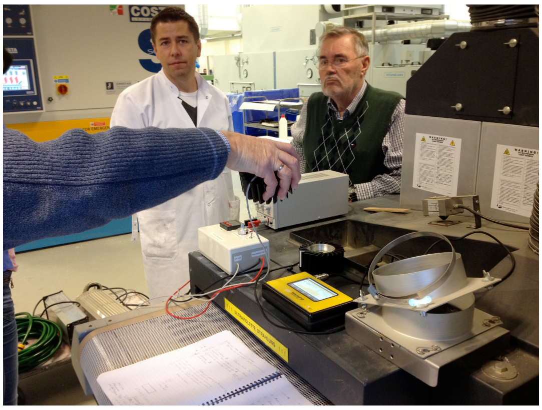
WP1:
Establish and use small-scale curing testing units.

- Developing and testing pre-prototypes units based on findings in WP0
- Several generations of pre-prototypes with different specifications and suppliers were tested in the lab.

Only a handful of suppliers on the global market of UV-diodes could be found meeting our specifications. Price and effect for especially surface curing UV-diodes made the technology a non-commercial viable solution.

Different elements of the theoretical understanding developed in WP0 was either confirmed or challenged.

Entering partnership with a European global chemical supplier to the coating industry and high-tech UV-diode producing companies in US. Deeper cost/benefit rooted understanding of technological links between the coating industry on the one side (changing chemical trigger point for photo initiators) and the LED industry (more, cheaper effect at low nM).



Pre-prototype testing.
Dealing with the hardest job – UVC/LED curing of top-surfaces.

Testing at the Teknos factory site in Vamdrup, Denmark.

WP2:
Build and qualify UV-LED luminaires for curing

- Full scale UV-LED luminaires were build end tested by the project partners.
- In parallel proto-type development and initial test of entire system (diode module, power supply, cooling, process management, optics)

Commercial UV-LED suppliers were not able to deliver diodes fulfilling our specifications as we "designed" them in WP1. Therefore luminaires had to be mounted with "diode engineering samples" tailor made for us and at that time not commercially available.

Different module designs were tested and a software/process management system was build in order to control and optimize operation of the luminaires.

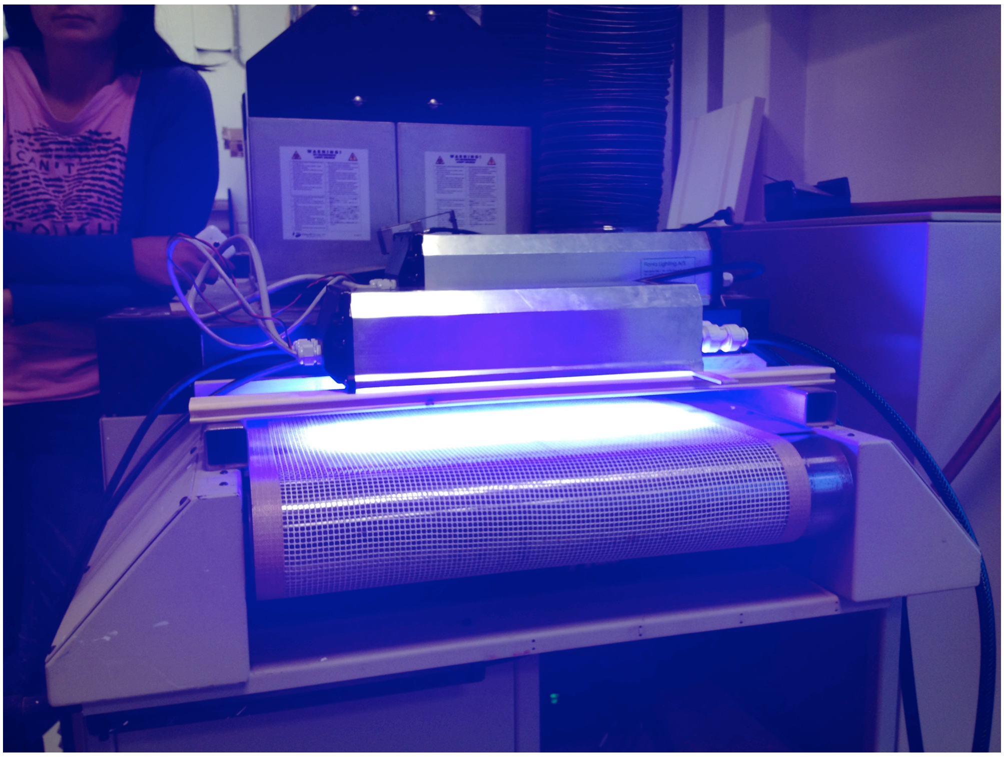
Basically the results were encouraging. Tests partners were surprised about the quality of the hardening.

Challenges at that time remaining on the commercial side were price of the diodes (more than US$ 600/piece) and weak, small and specialized suppliers.

Challenges on the technical side were focused on two issues.
Too low diode output in the UVC area, meaning that curing of the top of the coating surface still did not meet industry requirements. And industry requirements of high speed of conveyer belts carrying curing items meaning that UV-light exposure time was a challenge.

UV-diodes had to – and still have to - be supported by a traditional UV-light source to secure acceptable curing of the surface top.

2nd generation prototypes with water cooling being installed at industrial test site. New generation of UV-LEDs with improved price/effect ratio. After these tests researchers at project partner University of Southern Denmark worked directly with UV-diode suppliers to develop tailer made diodes for the project.



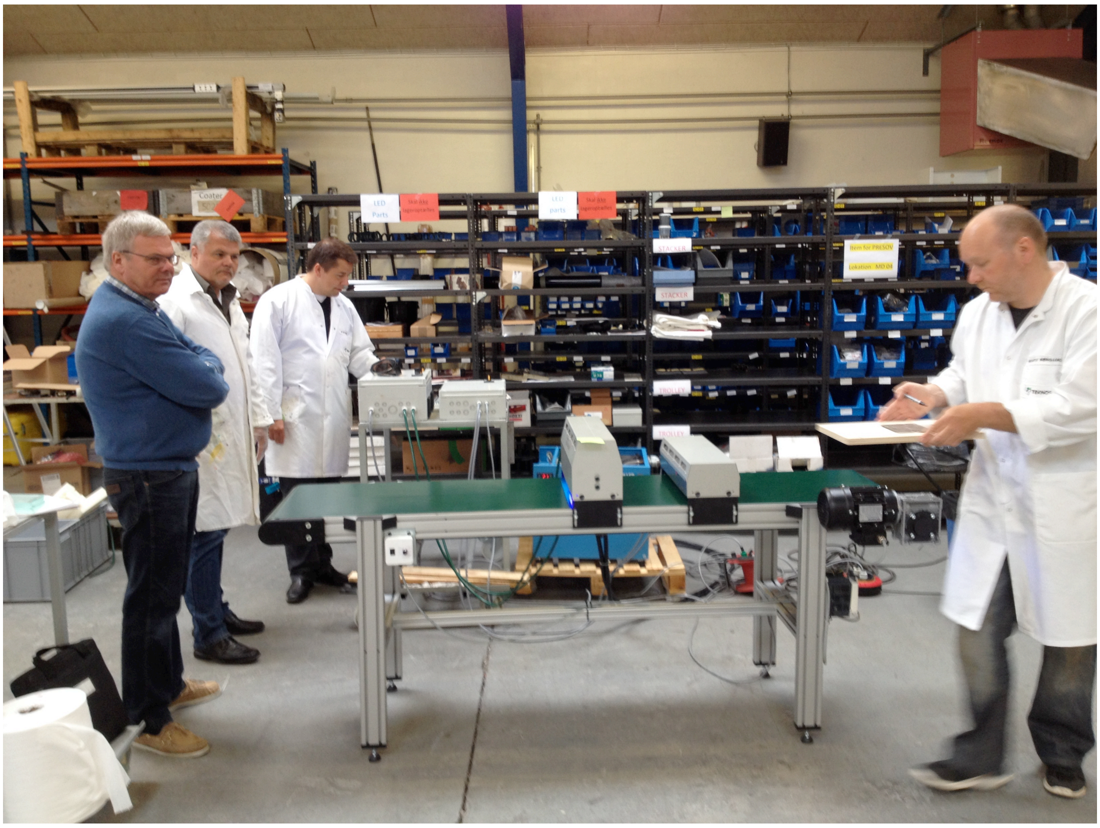
WP3:
Test and documentation of UV-LED luminaires on curing production lines.

- 3rd. generation prototypes installed and tested at production site
- Evaluation, redesign
- 4th generation prototypes installed and tested at production site
- Evaluation and documentation
- Redesign of system, new cooling system, new power supply

Our own tailor designed diodes proved to secure curing in high quality. Price of diodes has droped to US$ 75/piece

The curing quality was further improved – but it was still a bit challenging to meet requirements of conveyer belt speed.

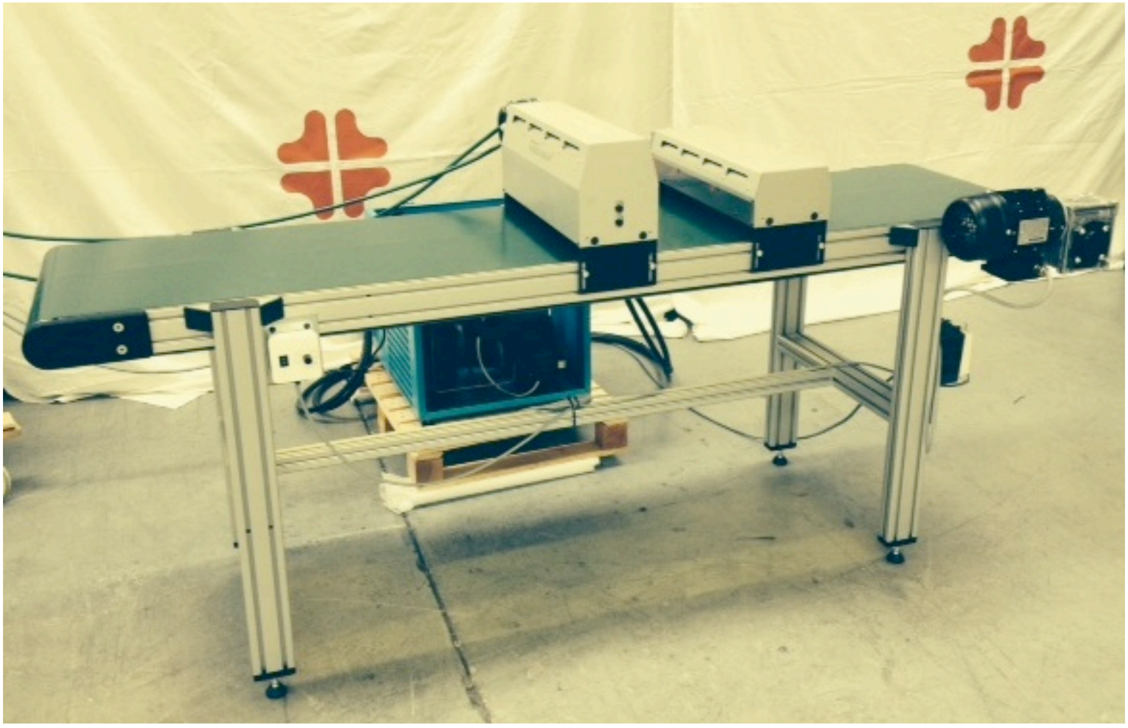
However, with additional diodes mounted in the luminaires a commercial viable system and product seems within reach!



Quality control at industrial test site. UV-LED cured glas plates are compared with traditional UV cured glas plates.

WP 4:
Commercialization plan for bringing the UV-LED on the curing market

- Work in order to fulfill industry standardisation requirements are in process (UL standard)
- First commercial test installations are made at site of a market leader within the furniture industry.
- UV-LED luminaires will be marketed at b2b market by Glunz & Jensen from late Q1 2016.



1.5 Project results and dissemination of results

The project almost succeed in meeting its objectives and it gave answers to the problems stated in the projects proposal.

Full-scale tested and commercially ready UV-LED luminaires are currently installed abroad at a main supplier for one of the worlds largest furniture producers.

The fundamental challenge is that UV-curing rely on a number of different UV-wave lengths. Bottom and middle-layer curing of coating surfaces proved to be suitable with high power UV-LEDs with wave lengths in the UVA and AVB area.

But to secure curing of the top of the surface wave lengths in the UVC area is needed. UV-C diodes are very expensive and have very low effect.

So – either:

- UVC diodes must be build much cheaper (factor 10) and with much more effect (factor 10)
- Photo initiator chemistry must be twisted in way so that the curing is triggered by high wave lengths only (UV B or UV A areas were diode effect is much higher and purchase price much lower)
- UV-diode luminaries must be supported by a traditional UVC light source.

In the project we worked with UV-diode producers to develop a new generation of UVC diodes (which will also have applications in disinfection as DNA is destroyed when exposed to 256Nm UV-light) and with large chemical suppliers to twist the photo initiator chemistry.

We are not at the finishing line yet. However, the coating industry is now developing UV-LED specific coatings hopefully allowing the LED technology to completely overtake the existing mercury lamps.

With this project we demonstrated that UV-LED technology is technical and commercially viable when curing the bottom and the middle layers of a coating surface. As for curing the top of the surface the UV-LED technology still needs assistance from traditional UV-lighting.

Thus, the new generation of curing luminaries will be equipped with both UV-LEDs and traditional UV-lighting.

Next generation curing luminaires (+10 years) will be UV-LEDs only. Either because new photo initiator chemistry will "move" the curing trigger point to the UVB or even UVA area – or the UV-diode industry can supply cheap, powerful and reliable UVC diodes.

So far the project has resulted in increased turnover, exports and employment.

Within the next 4-5 years we expect directly from this project to se a turnover of more than € 4-5 mio, hereof 75% export and to create 20 new high tech jobs.

Project results are being presented at trade fairs/conferences, to potential customers and partners in industry.

1.6 Utilization of project results

The project managing company – Othonia Curing Technology A/S – is a university spin-out company. Initially it was funded by 2 venture capital organisations: a corporate capital venture company belonging to a energy utility company and a government venture fund.

The business model was to develop, patent and user test LED luminaires and subsequently license the technology/products to a larger industrial player with established sales. Othonia entered a collaborative R&D agreement with University of Southern Denmark and collaboration agreements with Teknos (coating/paint/ producer) and One-Wood (furniture producer).

Project plans and findings were also discussed with and partly evaluated by 3 large global chemical companies during the project.

A larger Danish public traded company – Glunz & Jensen – invested directly in Othonia in order to secure an exclusive product license.
They already were familiar with some aspects of the technology from the use of LED in the printing industry.

Glunz & Jensen will therefore be responsible for commercialization of the project results on the basis of a licensing agreement with Othonia.

As described above the UV-LED luminares are currently being installed for commercial test operation at a major player in the furniture industry.

We expect the LED-luminaires ready for purchase in late Q1 2016. Sales will be supported by b2b marketing and we expect to install the first product lines on a "no cure – no pay" basis at the sites of key reference customers.

In total we are looking at a "multi-million € market". However, it is our experience that it is easy to overestimate penetration speed of new technologies. So, our conservative estimate is that within the next 4-5 years we expect - directly from this project - to se a turnover of around € 4-5 mio, hereof 75% export and to create 20 new high tech jobs.

And, almost as important, the project produced a potentially strong IP position and general know-how of the design and use of UV-LED based lighting in industrial settings and network with suppliers and partners. That is making it feasible for us to look at applications in other industries.

1.7 Project conclusion and perspective

The fundamental conclusions of the project are:

- In industrial UV surface curing/hardening UV-LEDs can technically replace mercury lamps curing bottom and middle layer of coatings (UVA and UVB bandwidths)

- The advantages of UV-LED equipped luminaires over mercury lamps were documented:
    - 75% electricity consumption saving (3,2 kW/h against 13 kW/h measured in specific tests)
    - No need for ventilation to remove ozone (additional savings)
    - Very long lifetime – 20,000 hours against 1,000-2,000 hours for mercury lamps
    - Low heat exposure on curing items
    - Increased production flexibility (no heat up time)

- Besides the UV diodes and process control software the luminaires can be build on existing off-the shelf hard ware (cooling, power supply, electronics)

however,

- UV-LEDs still need "mercury-assistance" in order to cure top of the surface to a quality meeting industry specifications (UVC bandwidths)

- Either UV-LED luminaires (or their operating mode) must be tailor made to individuals coatings – or coating must be produced to fit requirements from a fixed set of UV-LEDs. In other words – either the luminaires must be adaptive and "intelligent" in order to cure different coatings – or the producers of the coating must design coatings to be cureable under a defined set of specifications.

- The role of the different chemical components in coatings (binders, color pigments, additives and photo initiators) and their interaction are not fully understood in relation to UV-LED curing.

In general pay back time of the 3x more expensive UV-LED luminaires will be between 1-3 years depending on electricity cost and hours of operation. The more expensive electricity cost and the more hours of operation – the lower pay back time.

There are many different application for the use of UV-LED - powder coating, wood coating and finishing, fiber optics, medical devices, automotive, adhesives, digital printing, digital display, narrow web and offset. There are also many other substrates, such as plastics, glass composites, floor tiles all very well fitted for the UV-LED technology.

We believe that benefits documented in the this project in the furniture/wood business will also apply to other industries as well.

It means that the cost/benefit ratio of a technology shift will indeed by attractive on both micro/companies and macro/society level.