



RUSALOX

HIGH THERMAL CONDUCTIVITY PCB SOLUTIONS MANUFACTURING SINCE 2010

RUSALOX is a high-technology developer and producer of substrates and LED modules with high thermal conductivity

- The innovative RUSALOX products based on ALOXIDE technology are in a high demand on Russian LED market
- Efficiency and economic feasibility confirmed by multiple tests results and mass production with over hundreds of installations in Russia.
- RUSALOX collaborates with developers for creating and testing prototypes of the most effective products with outstanding competitive advantages.
- RUSALOX is focused on Russian commercial, industrial and outdoor segments of LED market exceeding \$250 million in 2013
- In 2015 RUSALOX started expansion on international markets

Key advantages:

- Unique aluminum oxide technology – the best solution for efficient thermal management in powerful LED lighting
- Strong partnerships with market leaders
- Strong technical and engineering team

Production facilities are located in Vladimir, 180 km from Moscow:

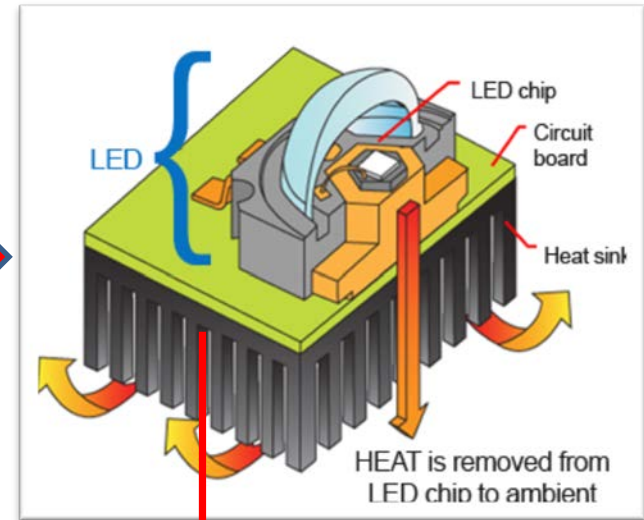
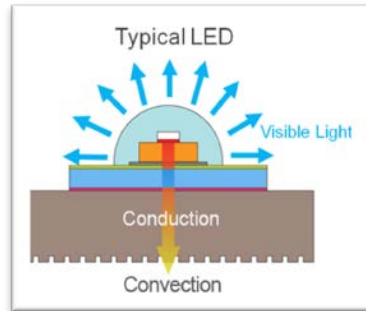
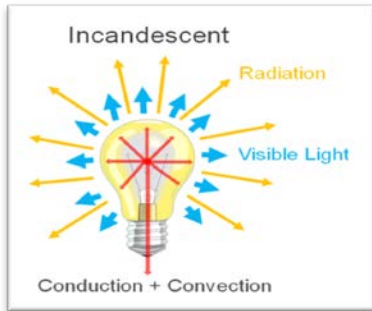
- Production space: 2 500 m²
- Capacity: 1,5 mln dm²

THERMAL MANAGEMENT CHALLENGE AND WELL-KNOWN FACTS

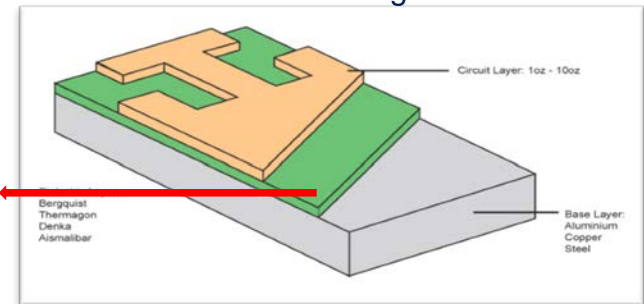
How to dissipate the excess heat?

LED Junction temperature directly affects lifetime and output power

Heat is removed from chip to ambient, but



PCB limits heat removing



Power Conversion for "White" Light Sources

	Incandescent [†] (60W)	Fluorescent [†] (Typical linear CW)	Metal Halide [‡]	LED*
Visible Light	8%	21%	27%	15-25%
IR	73%	37%	17%	- 0%
UV	0%	0%	19%	0%
Total Radiant Energy	81%	58%	63%	15-25%
Heat (Conduction + Convection)	19%	42%	37%	75-85%
Total	100%	100%	100%	100%

IESNA Handbook † Osram Sylvania

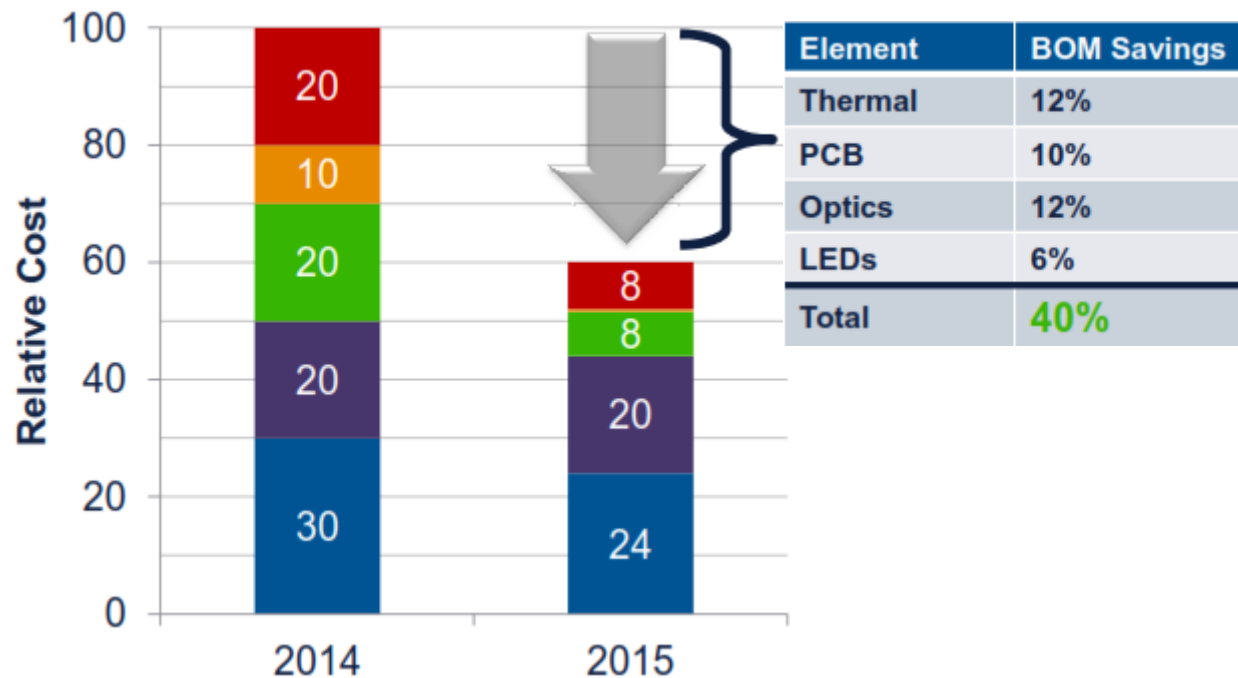
*Varies depending on LED efficacy. This range represents best currently available technology in color temperatures from warm to cool. DOE's SSL Multi-Year Program Plan (Mar 2006) calls for increasing extraction efficiency to more than 50% by 2012.

The dielectric layer degrades its performance by several times in 1-2 years

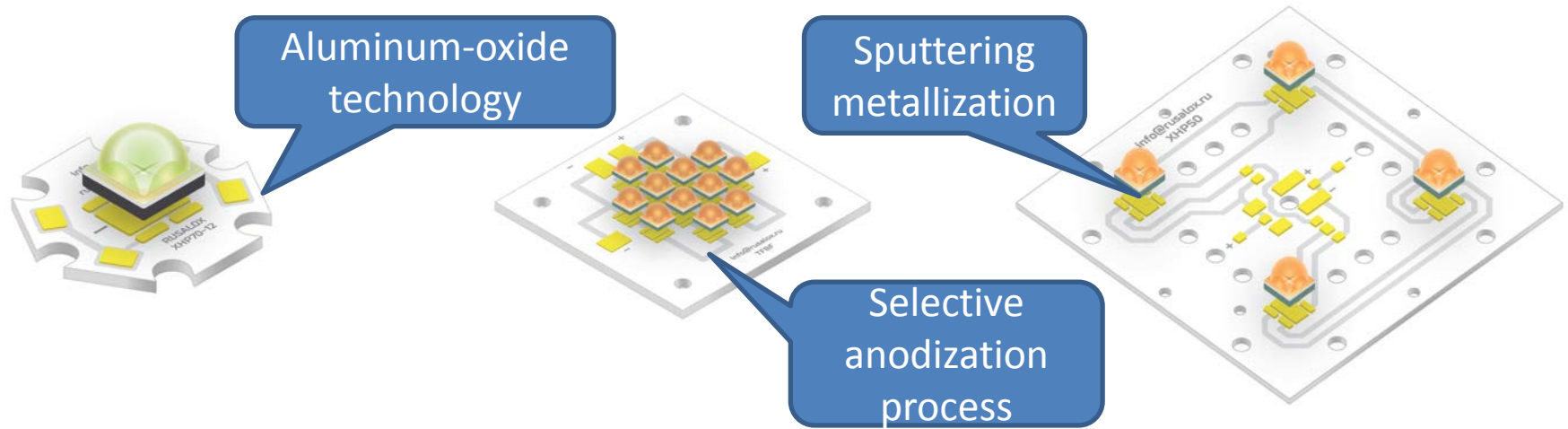
MCPCB thermal conductivity is 1-2Wt/m*Deg

MARKET REQUEST

- Low cost
- High efficiency – max lm/w
- Reliability
- Friendly use



ALOXIDE PCB



ALOXIDE PCB- PERFORMANCE OF CERAMIC WITH MCPCB COST AND MECHANICAL FEATURES OF IMS

- ✓ High thermal conductivity (up to 125 W/m*K) = Longer life and efficiency
- ✓ NO PREPREG - High reliability in all conditions and **ECO FRIENDLY**
- ✓ **No gluing operation**
- ✓ Both sides of substrate are available for mounting
- ✓ BIG PANNELL SIZES
- ✓ SIMPLICITY AND SCALABLE PRODUCTION = LOW COST
- ✓ Recyclable and environmentally friendly due prepreg absence

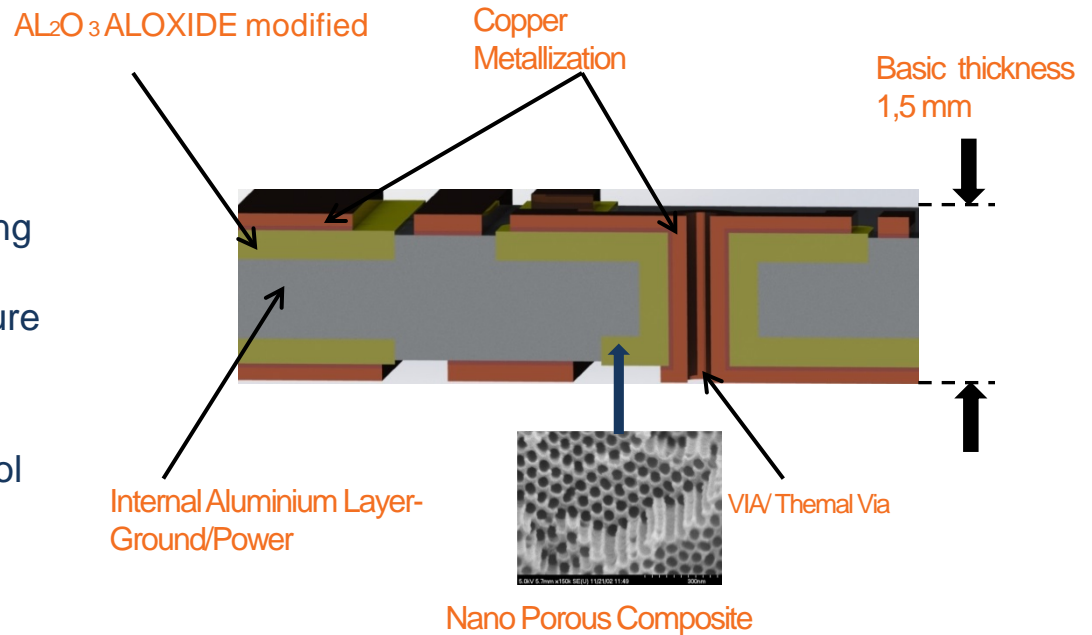


НАНОСЕРТИФИКА



AL OXIDE TECHNOLOGY

- The technology based on the innovative concept of nano-porous material layers constructing multilevel switching combining aluminum and aluminum oxide in their structure
- Method of oxidation – electrochemical
- RUSALOX is capable to control extension of oxide layer on alumina and regulate thermal conductivity and electric breakdown of PCB
- Large panels production
- High density mounting
- Simple technological cycle of production
- **Recyclable and Environmentally friendly due prepreg absence**



Design Features

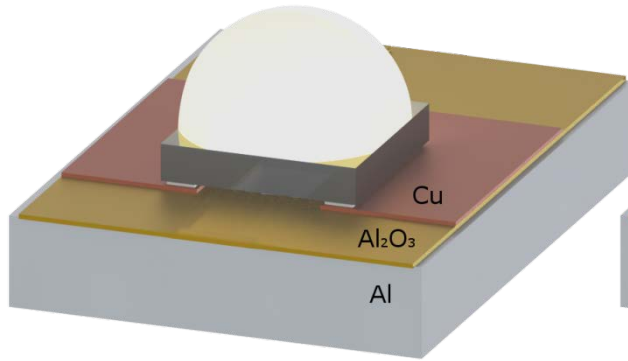
Parameter	Units	Value
Dimensions max.	mm	350x400
Aluminum base	%	98,7
Aluminum base thickness	mm	1,5
Dielectric thickness	µm	70-90
Copper thickness	µm	35-100
Width of the conductor / minimum clearance:	mm	0,2-1,2

COMPARATIVE CHARACTERISTICS

Parameter	MC PCB	DBC (ALN/Al ₂ O ₃)	Al oxide PCB 1,5mm
<i>Thermal conductivity of the PCB, W / (m • K)</i>	<5	170/24	<125
<i>Thermal conductivity coefficient of the dielectric, W / (m • K)</i>	<5	-	>12,8
<i>Vias in layers through insulated holes</i>	YES	YES	YES
<i>Layers</i>	1-4	2	3
<i>Assembling on heat sink</i>	TIM layer	TIM layer	1. TIM layer 2.direct soldering- reduces thermal resistance
<i>Cooper thickness, μm</i>	35	20-25	up to 90
<i>Breakdown voltage</i>	<4	>10	<5
<i>Dielectric constant at 1 MHz</i>	4-7	9/9,8	7
<i>Surface resistance, Ohm</i>	10 ¹³	-	10 ¹³
<i>Volume resistivity, Ohm</i>	10 ¹⁴	10 ¹⁴ /10 ¹³	10 ¹¹
<i>Topology Management of dielectric layer</i>	NO	NO	YES
<i>PRICE</i>	LOW	HIGH	MED

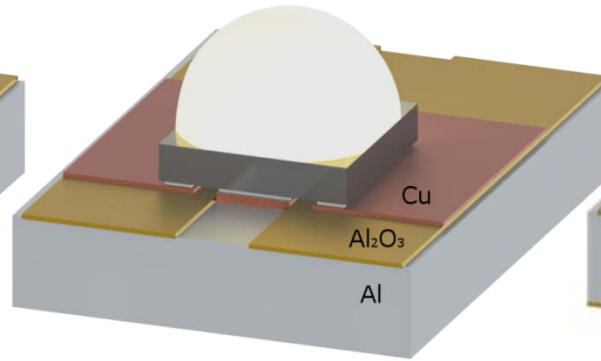
LED AL OXIDE MODULE OPTIONS

Continuous Al oxide layer PCB



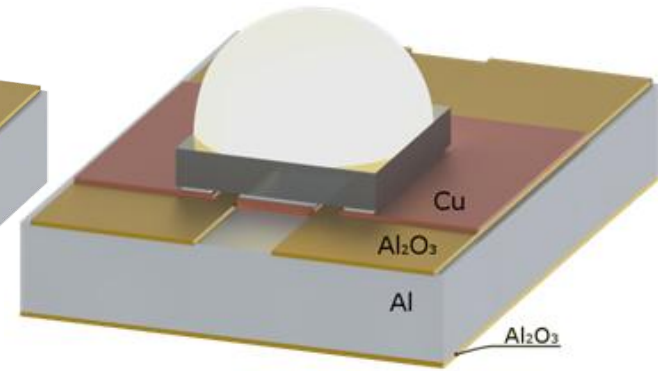
- thermal conductivity of Al oxide dielectric is X 3-10 times higher than prepreg used in MCPCB

Al oxide top layer extrication under LED thermal pad.



- Higher Thermal Conductivity

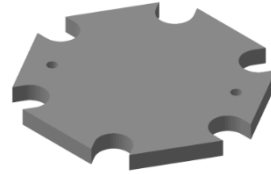
Double sided Al oxide PCB with top layer extrication under LED thermal pad - *recommended*



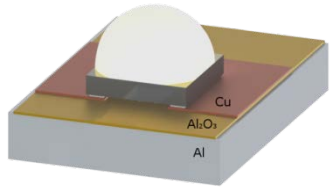
- High Thermal Conductivity
- Increased electric strength

ADVANCED THERMAL MANAGEMENT TECHNOLOGY STAGES

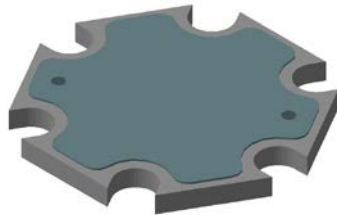
1 AL 98,8 PREPARATION & Tooling



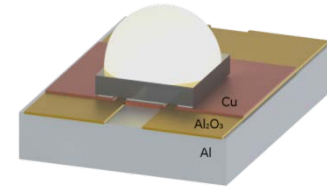
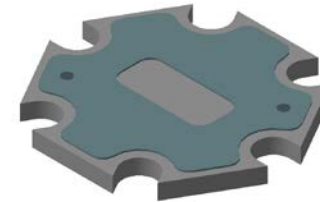
2 Double side SELECTIVE anodization process



Continuous Al oxide layer



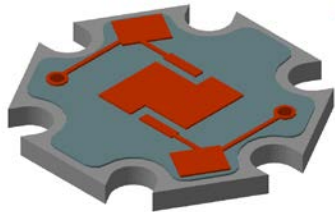
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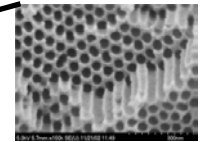
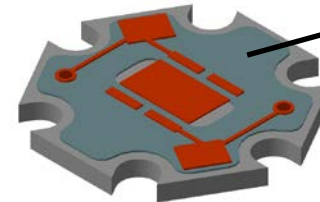
Al oxide top layer extrication under LED thermal pad



3 Cu / Cr sputtering metallization

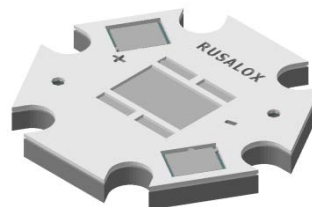


or



Modified Nano Porous Dielectric Composite

4 Solder mask



INSTANT SOLUTION > SAME DESIGN&SIZE



Case:

STRIPE 400 x 35 mm LED 4 x 8 Wt Luxeon M

Substrate Replacement:

MCPCB vs AL OXIDE

Dielectric Thermal conductivity:

2 vs 15 Wt/M*deg

Luminous flux:

3275 lm vs 4080 lm + more than 20 % of LIGHT !

LED temperature :

85-90 C vs 77 C - more than 12° C = less HEAT !

SAME SIZE, SAME DESIGN > MORE LEDs, MORE POWER



AL OXIDE vs MC PCB

Allows increase quantity of LEDs on current space, keeping same thermal performance & required characteristics.

Luminous flux increase MORE 25% !

SAME LEDs, PERFORMANCE & POWER > MORE DENSE DESIGN

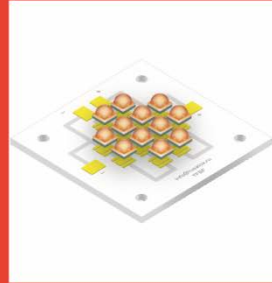


AL OXIDE vs MC PCB

Allows decrease cost price of a fixture for **20% & MORE** by reducing just the size of aluminium heatsink and BOM.

RUSALOX solutions for High Power CREE LEDs Square module with high-density LED

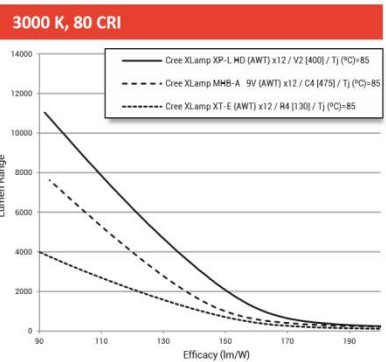
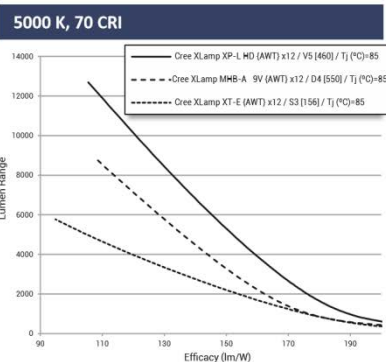
- High flux
- Low thermal resistance ALOXIDE PCB technology
- High Optical Control Factor, 18mm LES
- CREE SC5 LEDs provide industry's Best Lumen Density and Optical Control, Excellent L90 & L70 Lifetimes, Even in High Stress Conditions
- from 200 lm/W efficacy up to 11 000 lm
- Compatible with existing COB ecosystem: drivers, optics, heatsinks



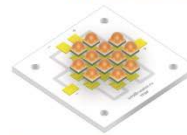
Product Selector Table

	 RSLX LM 12 XT-E	 RSLX LM 12 MHB-A	 RSLX LM 12 XP-L
Configuration	12s CREE Xlamp XT-E	12s CREE Xlamp MHB-A	12s CREE Xlamp XP-L
Light Emitting surface	19 mm	21 mm	19 mm
PCB type	ALOXIDE Continuous insulation layer		
Typical	Current (mA)	350 mA	1 050 mA
	V _f @ 85°C	34 V	107 V
	Power (W)	12 W	37.6 W
Max.	Current (mA)	1 500 mA	3 000 mA
	Power (W)	60 W	80 W

Performance selector (T_j=85°C)



Applications



- High Bay
- Downlight
- Street lighting



Business case: COB replacement

Idea

- Customer looking for opportunity to use UHP LEDs (4...9W) in HD module as alternative to compact chip on board
- Needs to find cost efficient thermal solution

Solution



Results

	Generic 100W 36V COB	Standard MCPCB module	ALOXIDE module
Price	20-30 \$	18 \$	18-19 \$
Flux at 2100mA	9 000 lm	8 600 lm	9 000 lm
T _{sp} /T _c at 2100mA*	55°C	75°C	60°C
Efficiency at 2100 mA	110 lm/W	100 lm/W	115 lm/W
Maximum current	2 500 mA	2 700 mA **	3 000 A
Light Emitting Source	25 mm	19 mm	19 mm
Holder for mounting	Required	Not Required	Not Required

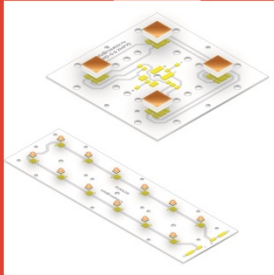
*Same heatsink and operating conditions

**derated at high temperatures

RUSALOX modules for CREE LEDs and LEDiL optics:

LEGO blocks for street and industrial lighting

- Low thermal resistance ALOXIDE PCB technology
- Compatibility with standard LEDiL 2x2 and 2x6 lenses
- CREE SC5 LEDs provide industry's Best Lumen Density and Optical Control, Excellent L90 & L70 Lifetimes, Even in High Stress Conditions
- from 200 lm/W efficacy or up to 11 000 lm from module
- Low solution cost due to smaller heatsink needed

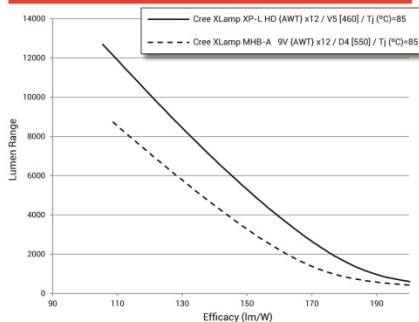


Product Selector Table

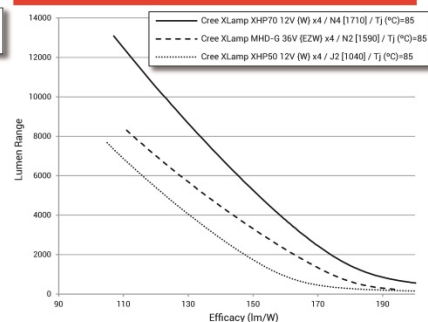
	RSLX 2x6 LM XP-L	RSLX 2x2 LM MHB-A	RSLX 2x2 LM XHP50	RSLX 2x2 LM MHD-G	RSLX 2x2 LM XHP70	
Configuration	12s CREE XP-L SC ⁵ HD	12s CREE MHB-A SC ⁵	4s CREE XHP50 12V SC ⁵	4s CREE MHDG 18V SC ⁵	4s CREE XHP70 12V SC ⁵	
Compatible optics	LEDiL STRADA 2x6		LEDiL STRADA MX 2x2 Family			
PCB type	ALOXIDE Continuous insulation layer					
Typical	Current (mA)	1 050 mA	350 mA	700 mA	700 mA	1 050 mA
	V _f @ 85°C	35.4 V	107 V	46 V	72.8 V	46.4 V
	Power (W)	37.2 W	37.6 W	32 W	51 W	48.7 W
Max.	Current (mA)	3 000 mA	700 mA	1 500 mA	1 000 mA	2 100 mA
	Power (W)	120 W	80 W	73 W	76 W	105 W

Performance selector (T_j=85°C)

5000 K, 70 CRI



5000 K, 70 CRI



Applications

- Low/High Bay
- Street lighting

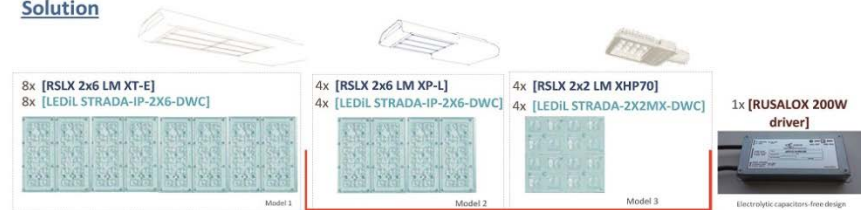


Business case: Optimize solution cost for 20 000lm street design

Idea

- Customer looking for solution how to reduce solution cost and size (>20 000 lm street and highway)
- Needs to find cost efficient thermal solution to use advantages of XHP CREE LEDs with LEDiL PC optics
- Need unification and scalability in wide flux range

Solution



Results

	Model 1	Model 2	Model 3	
Module used:	RSLX 2x6 LM XT-E	RSLX 2x6 LM XP-L	RSLX 2x2 LM XHP70	RSLX 2x2 LM XHP70
LED configuration	8x Modules 96x LEDs	4x Modules 48x LEDs	4x Modules 16x LEDs	4x Modules 16x LEDs
Optics	8x Lenses	4x Lenses	4x Lenses	4x Lenses
PCB type	Generic MCPCB	ALOXIDE	Generic MCPCB	ALOXIDE
Driver type	Generic 200W driver	RUSALOX 230W driver		
Current (mA)	700 mA	1 400 mA	1 050 mA	1 050 mA
T _{fp}	85°C	85°C	120°C	100°C
Total flux	23 200 lm	25 700 lm	23 000 lm	23 000 lm
L ₇₀	>104 000 h	>116 000 h	>50 000 h	>100 000 h
System cost*	100%	70%	65%	65%
Weight, kg*	4.5	3.5	3	3



*Detailed simulation service available by request.

Customer value

- Reduce solution cost up to 35%
- Scalable solution using one PCB type and LED
- Low weight compact design enabled by advanced CREE SC⁵ and ALOXIDE PCB technologies



RUSALOX starboard modules for CREE LEDs:
Fast prototyping and production

- Low thermal resistance ALOXIDE PCB technology
- Industry standard form factor
- CREE SC5 LEDs provide industry's Best Thermal and Optical Control, Excellent L90 & L70 Lifetimes, Even in High Stress Conditions
- from 200 lm/W efficacy or up to 1000 lm from module
- Low solution cost due to smaller heatsink needed

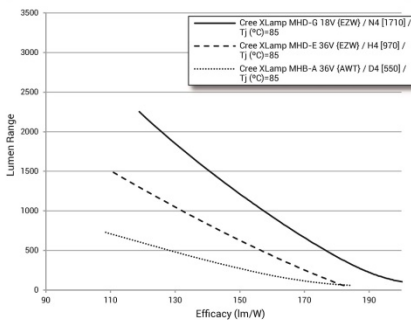


Product Selector Table

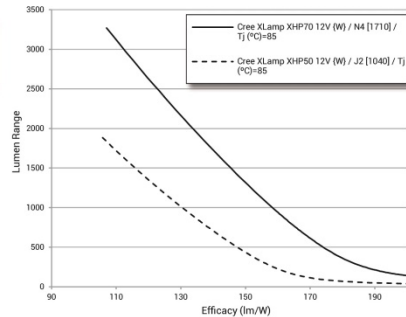
	RSLX STAR MHB-A	RSLX STAR MHD-E	RSLX 2x2 LM XHP50	RSLX 2x2 LM MHD-G	RSLX 2x2 LM XHP70	
Configuration	12s CREE MHB-A 	12s CREE MHB-A 	4s CREE XHP50 12V 	4s CREE MHDG 18V 	4s CREE XHP70 12V 	
Compatible optics	LEDIL MIRELLA 	LEDIL MIRA 	LEDIL MINNIE 	LEDIL IRIS 	LEDIL BOOM-M 	
PCB type	ALOXIDE Continuous insulation layer					
Typical	Current (mA)	1 050 mA	350 mA	700 mA	1 050 mA	
	V _i @ 85°C	35.4 V	107 V	46 V	72.8 V	46.4 V
	Power (W)	37.2 W	37.6 W	32 W	51 W	48.7 W
Max.	Current (mA)	3 000 mA	700 mA	1 500 mA	1 000 mA	2 100 mA
	Power (W)	120 W	80 W	73 W	76 W	105 W

Performance selector (T_j=85°C)

5000 K, 70 CRI



5000 K, 70 CRI



Applications

- Spots
- Downlights
- Portable

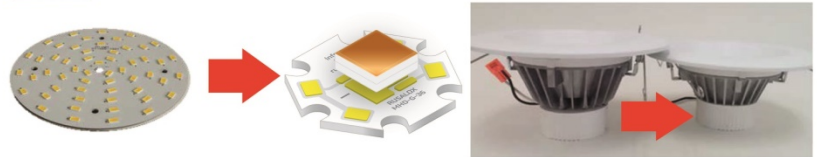


Business case: Reduce cost for Downlight

Idea

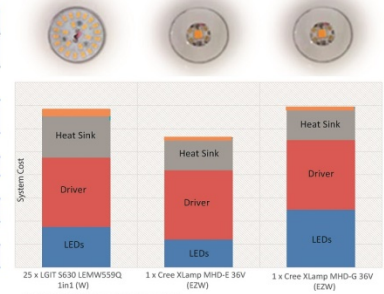
- Customer looking for solution how to reduce solution cost and size (>20 000 lm street and highway)
- Needs to find cost efficient thermal solution to use advantages of XHP CREE LEDs with LEDiL PC optics
- Need unification and scalability in wide flux range

Solution



Results

	Original	Model 2	Model 3	
Module used:	Samsung 5630	RSLX STAR MHD-E	Generic MCPCB MHD-G	RSLX STAR MHD-G
LED configuration	25x LEDs	1x Starboard 1x LED	1x Starboard 16x LED	1x Starboard 1x LED
PCB type	Generic MCPCB	ALOXIDE	Generic MCPCB	ALOXIDE
Current (mA)	150 mA	250 mA	350 mA	350 mA
T _{up}	85°C	73°C	120°C	98°C
Total flux	770 lm	786 lm	1 028 lm	1 080 lm
Efficacy	67 lm/W	79 lm/W	76 lm/W	80 lm/W
L ₅₀	>50 000 h	>100 000 h	>50 000 h	>60 000 h
Lm/\$*	114 lm/\$	138 lm/\$	149 lm/\$	153 lm/\$
Weight, kg*	0.3	0.25	0.25	0.25



Customer value

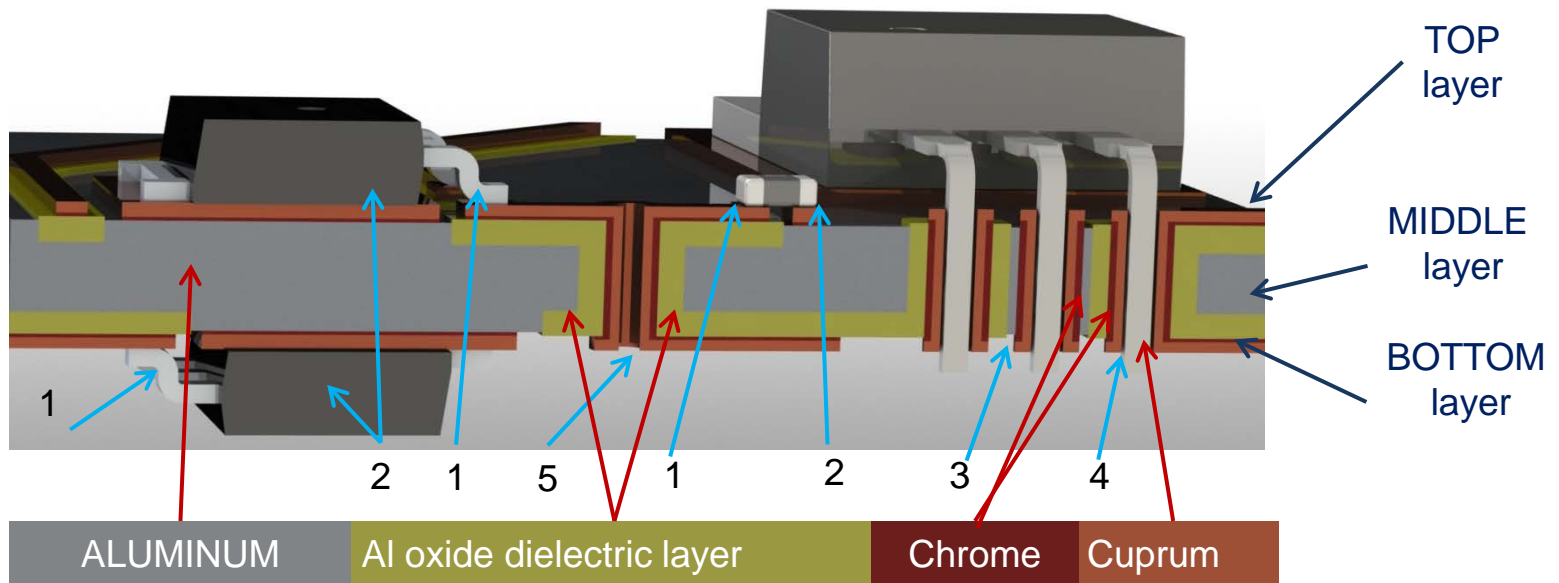
- Reduce solution cost up to 17% with RSLX STAR MHD-E
- Increase flux by 40% in smaller heatsink
- Low weight compact design enabled by advanced CREE SC5 and ALOXIDE PCB technologies
- Simple assembly



HIGH THERMAL CONDUCTIVITY PCB AL OXIDE TECHNOLOGY POSSIBLE APPLICATIONS OVERVIEW

AL OXIDE TECHNOLOGY FEATURES

1. Mounting SMD components on an insulated conductor;
2. Mounting SMD components on a common layer (aluminum base);
3. Assembling PTH components into isolated hole;
4. Assembling PTH components on a common layer (aluminum base);
5. Creation of vias in layers through insulated holes.



KEY ADVANTAGES OF THE TECHNOLOGY

Additional layer (polygon)

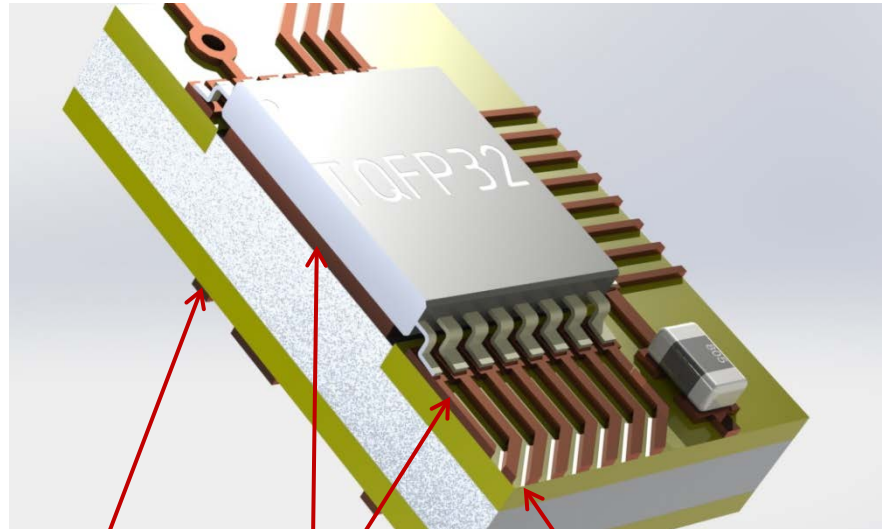
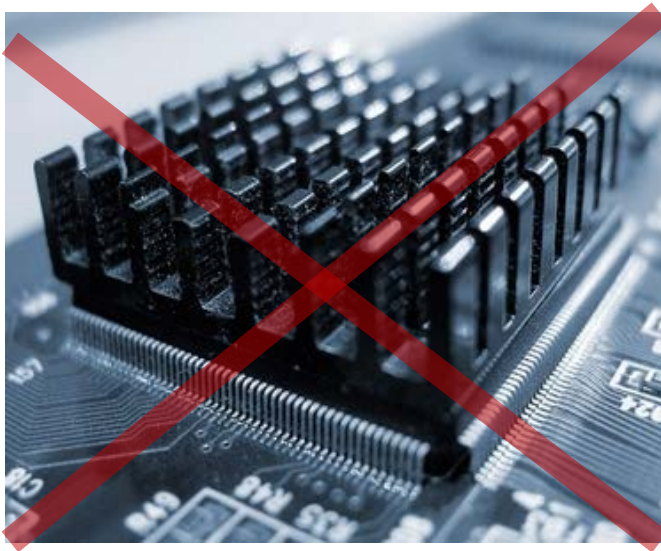
- Simplified wiring board design and decreased size;
- If a polygon is connected to a common conductor:
- Decreases resistance of all connections to polygon, thereby reducing sneak current and noise;
- Increased distributed capacitance for chain scheme helps to suppress emitted noise;
- Polygon might be the screen, overwhelming interferences emitted by the sources.



HEAT SINK ELEMENTS IN CASE WITHOUT THERMAL PAD

Reduces the casing temperature and allows to refuse glued radiators in such elements as chips of power supplies, data processing chips and other elements operating at extreme temperatures.

Installation solution: on thermal glue



Aluminium

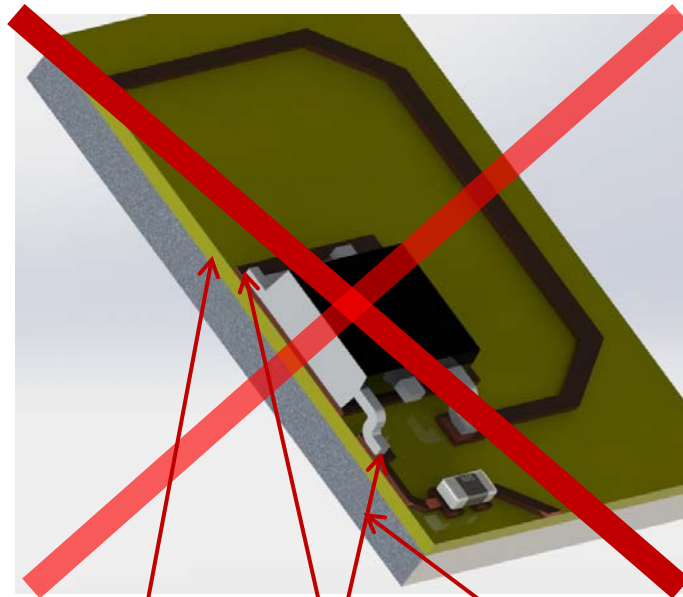
Copper (conductor)

Oxide (dielectric)

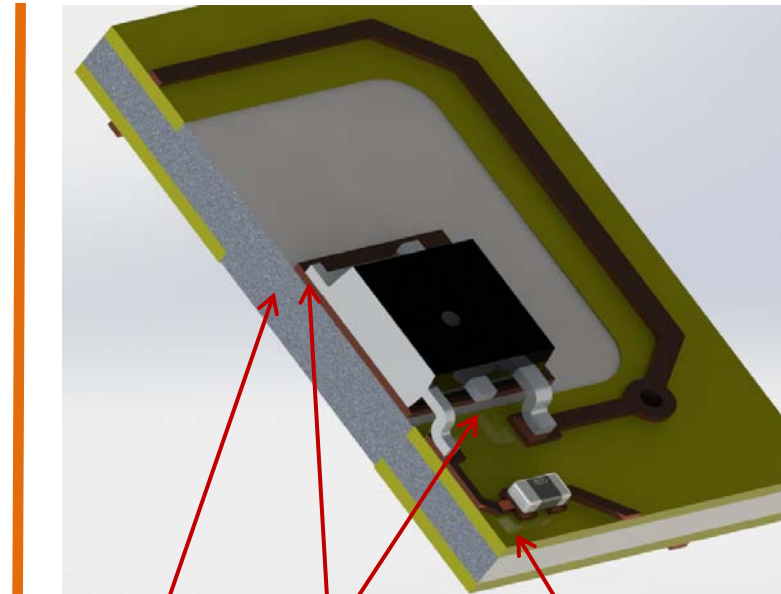
Reduced dimensions and cost

HEATSINK OF SMD ELEMENTS WITH THERMAL PAD

Improves heat sink by reducing the thermal resistance.



Aluminium
Copper(conductor)
Prepreg (dielectric)



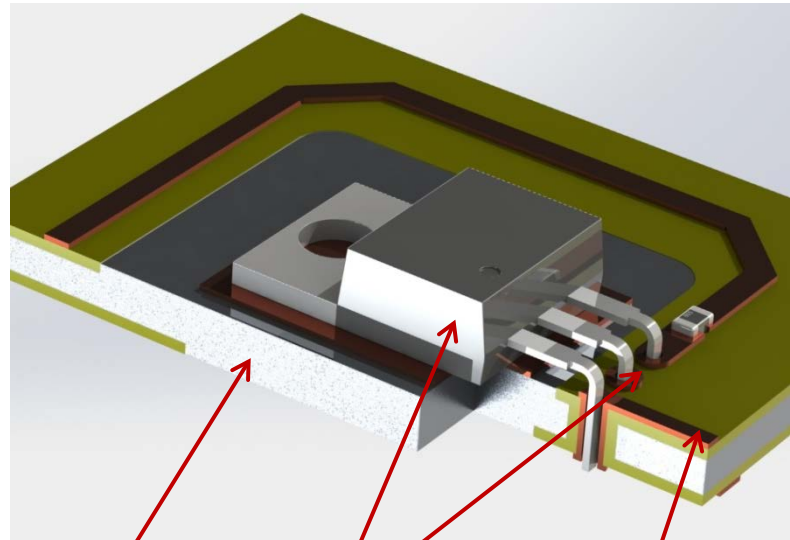
Aluminium
Copper(conductor)
Oxide (dielectric)

Increasing the thermal conductivity and the number of signal layers

HEATSINK OF PTH ELEMENTS WITH THERMAL PAD

Allows to refuse additional heat sink radiator.

Installation solution: on TIM, solder or screw connection



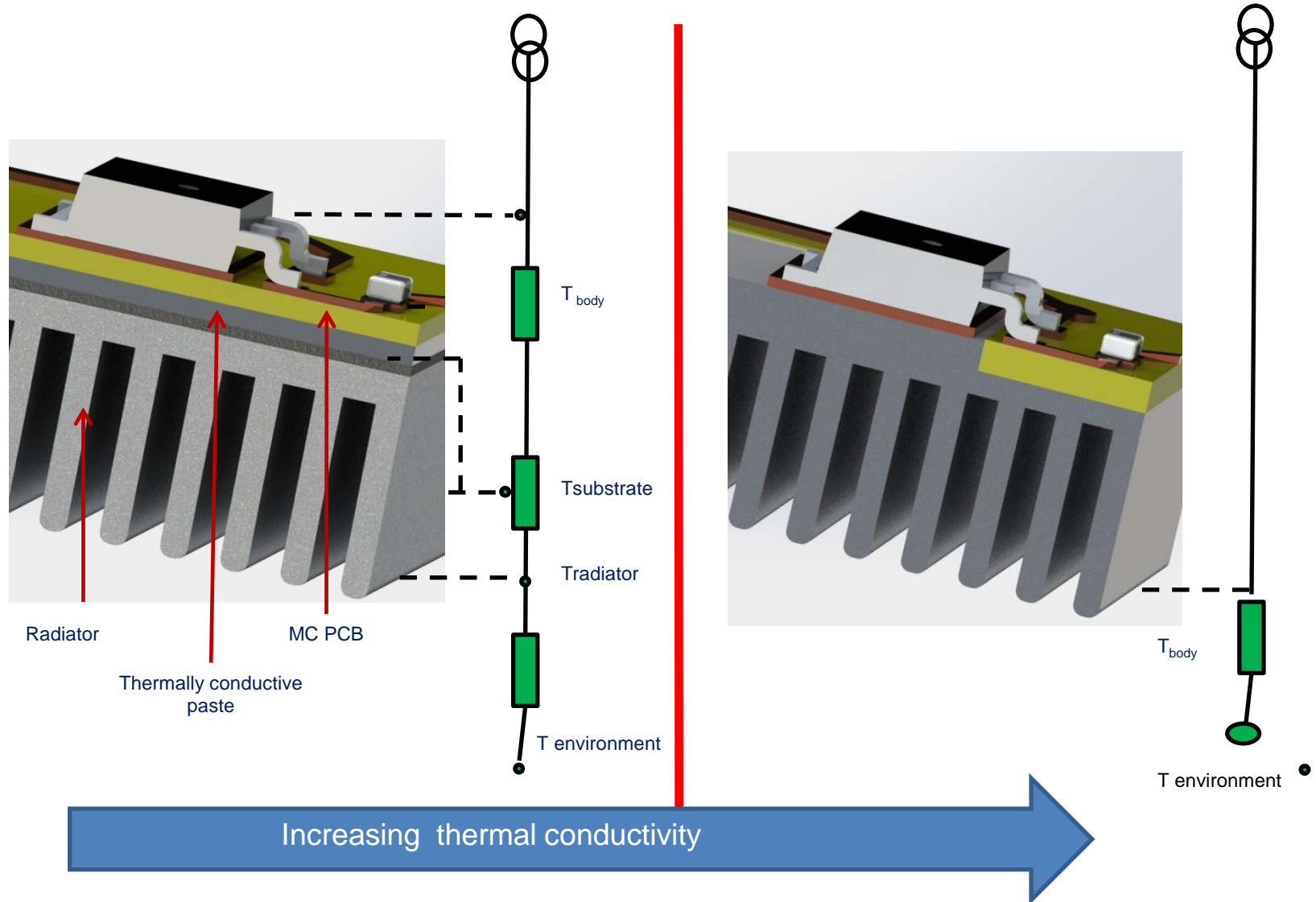
Aluminium

Copper(conductor)

Oxide (dielectric)

Reduced dimensions and cost

PRINTED CIRCUIT BOARD ON THE HEAT SINK RADIATOR

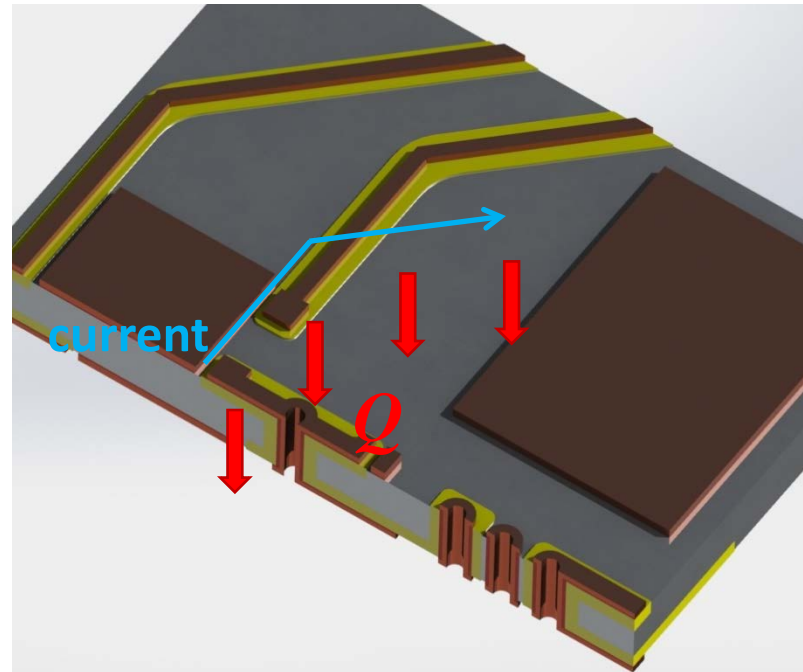


DECREASING THE WIDTH OF THE CONDUCTOR

Allows for the same currents reduce the width of the conductor due to the higher thermal conductivity



The width of the conductor is 20 times less than in FR4 and 5 times less than the MCPCB



Reduced dimensions and cost

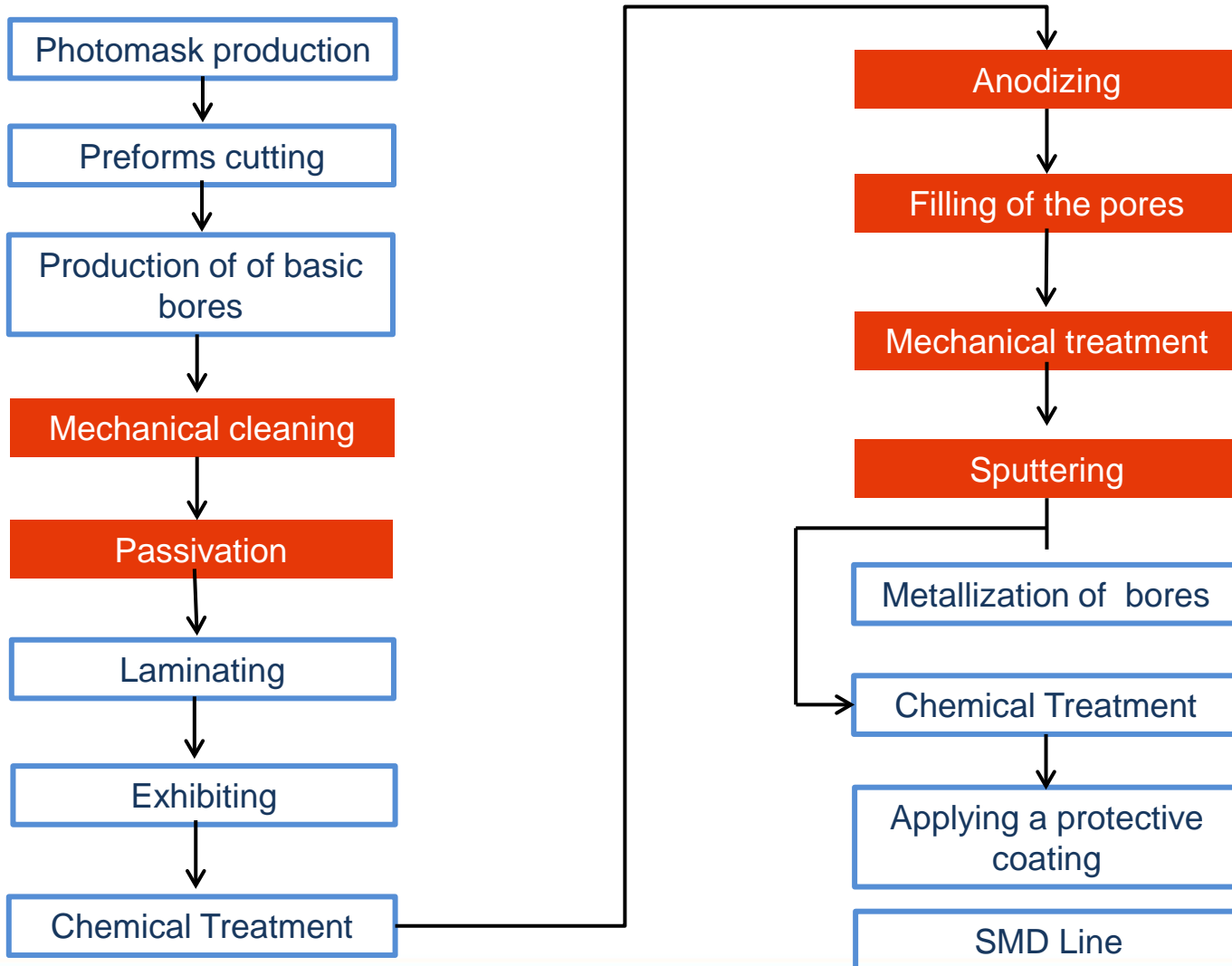
Highest reliability is one of the most important key attributes of ALOXIDE technology and products. ALOXIDE based products, substrates and packages, demonstrate the highest reliability standards required in the semiconductor electronics packaging. All ALOXIDE PCB and LE passed successfully extensive reliability tests.

Tests were done according to the most stringent requirements commonly used in the industry.

- Thermal cycling – substrates and assemblies passed numerous and extensive thermal cycling tests, and reached repeatedly over 1,000 cycles and also (when tested to this level) 3,000 cycles between -55 to +125 °C, without failure.
- HAST tests for molded devices
- Mechanical vibration tests for assemblies
- X-ray analysis following preconditioning and soldering processes
- HTHH tests: Yield degradation following high Temperature and high Humidity preconditioning and high and low temperature storage
- Via chain resistance stability
- Adhesion and delamination tests

PCB CONVENTIONAL PROCESS & INTEGRATED SOLUTIONS

- The core process is based on a proprietary controlled anodization phase that forms nanoporous Aluminum-Oxide (Al_2O_3) inside aluminum plate.
- The process stages adopt standard semiconductor and PCB manufacture procedures that guarantee repeatable high volume production at competitive cost.
- Creating know-hows and firms secrets in this processes, RUSALOX has nurtured it's competitive advantage



FULL PRODUCTION CYCLE

manufacturing team ensures the timely production in required quantities and guarantee reliability



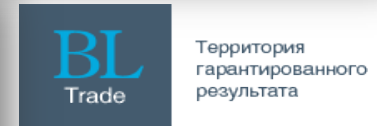
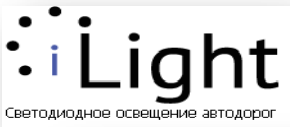
SMD line is designed for a wide range of components and focused on work with high thermal conductivity materials



- Printer DEK Horizon 03ix
- The installer components Samsung Sm482
- 8 zone convection oven ERSA Hotflow 2/12
- The system of visual control of Vision. • Air jet and ultrasonic cleaning AquaTerm 9200
- Coils 8, 12, 16, 24mm
- Cases of any width
- Matrix trays for chips
- Components of frame sizes from 0102 to chip type QFN and BGA
- Pin assembly and soldering
- The maximum size of PCB 460H550mm
- Separation of group blanks

CUSTOMERS & PARTNERS

OVER 100,000 LUMINAIRES WITH RUSALOX MODULES SAVING UP TO 70% OF THE ENERGY IN RUSSIA AND EUROPE



CERTIFICATES



LOCATION



**Moscow
office**



**Vladimir
production**



**Nizhny
Novgorod**

Interstate M7



Located - in 8 km from the federal highway Moscow – Vladimir - Nizhny Novgorod (M7), in 180 km from Moscow and in 250 km from Nizhny Novgorod.

The convenient transport – comfortable trains "Sapsan" , "Lastochka" and "Burevestnik" daily ply.



Production space 2500 m²
Capacity 150 000 dm² \ month

Manufacture is carried at the industrial park of VPO "Tochmash".

Technopark has advanced logistics infrastructure, including railway.



TEAM



Mikhail Naish

CEO

Ph.D. degree in the sphere of physics in the University of Israel (Tel-Aviv)

Mikhail has 10+ years of work experience in the sphere of high technology, investments and industry, including positions:

VTB, VEBInvest;

OptiLine

(Development Director);

Industrial Metallurgic Holding

(Head of New Technology Department);

Tower Semiconductor

(implementation of recent trends).



Efim Besprozvaniy

Production Manager

BA and B.Sc in electronics of Academic College in Israel (Karmiel city)

Efim has more than 11 years of experience in electronics manufacturing , in particular PCB&SMD, including engineering and management positions in:

DAF;

Melta elektronik (head of the technical department&engineering);

Elbit systems (group chief NPI);

Taberu (Deputy chief Technologist).



Shmuel Goldin

Development Director

BA degree for Enterprise Management of Moscow Institute of Finance and Economics

Shmuel has over 20 years of experience in different areas of business including successful launching and promotion of brands & products in Europe and Russian Federation.

Marketing, PR, international trade and logistic.



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