DOMAMID Z

THERMAL CONDUCTIVE SOLUTIONS FOR METAL REPLACEMENT AND LIGHTWEIGHT

A DOMO-NETZSCH WEBINAR

DOMO caring is our formula

NETZSCH Proven Excellence.

1

DOMO CHEMICALS STRATEGIC VISION

DOMO CHEMICALS' STORY OF ACCELERATION

SUSTAINABILITY

INNOVATION

SUSTAINABLE INNOVATOR

STRONG FOUNDATION
A fully integrated player with global presence

CONNECTED GROWTH
A diversified and connected portfolio

TALENT ENGAGEMENT
A sustainable company based on trust, agility and commitment

MATERIAL ENGINEERING

NYLON SPECIALIST

1994 Caprolactam, Leuna

2004 Engineering Plastics, PA 2000 – Premnitz

2013 Engineering Plastics, Aquafil – Italy/US/China

2015 Flexible Packaging, Cfp – Italy
Engineering Plastics, Technical Polymers – US

2018 Michiels Advanced Materials (M.A.M) participation – Belgium

2019 Solvay Performance Polyamides Europe

2028 →

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OUR AMBITION

TO ENGINEER POLYAMIDE SOLUTIONS THAT CONTRIBUTE TO CHANGE THE WORLD, SUSTAINABLY AND FOR THE BETTER

DOMO legacy

- The polyamide 6 specialist
- Fully integrated, from benzene to engineering plastics and nylon film
- CIG market and automotive
- Worldwide Presence
- DOMAMID – ECONAMID – THERMEC

SOLVAY legacy

- One of Europe's PA66 market leader
- PA66 technology know how & innovation
- Automotive and E&E market
- Strong European presence
- TECHNYL / TECHNYL 4EARTH

NEW DOMO

- Leader in high-performance engineering polyamide materials
- A complementary offering of PA6 / PA6.6 / PAHT / PA6.10 / PPA /PPS
- Strong focus on sustainability and innovation.

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DOMO CHEMICALS

AT A GLANCE

2,150

€1.5 Bill.

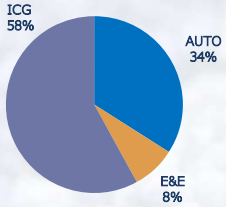
10 OPERATION sites

6 INNOVATION & TECHNICAL centres

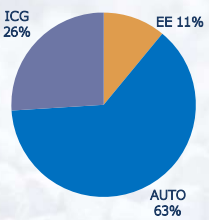
BUSINESS areas

- Polymers & Intermediates
- Engineering Plastics
- Nylon Film
- Performance Fibers
- Trading & Distribution

PA6 VOLUME by MARKET (2019)

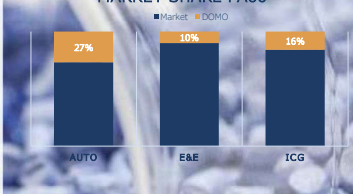


PA66 VOLUME by MARKET (2019)



MARKET SHARE PA6

MARKET SHARE PA66



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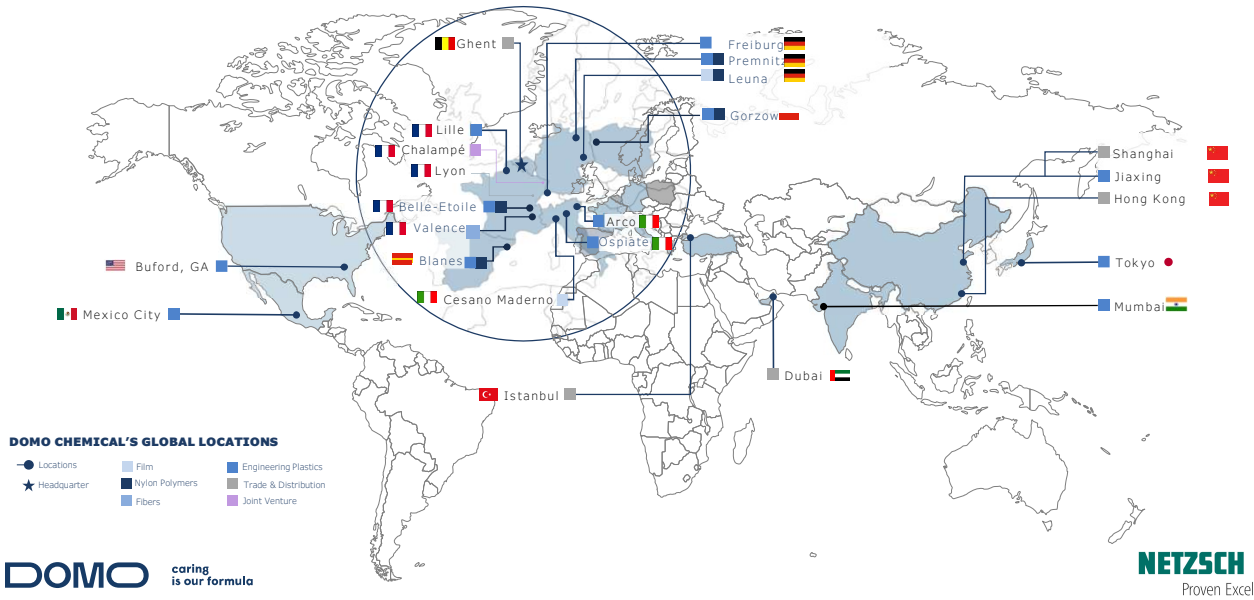
OUR FOOTPRINT

A GLOBAL PRESENCE ANSWERING LOCAL BUSINESS NEEDS



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ENGINEERING PLASTICS

FOR A BROAD BASE OF APPLICATIONS

PRODUCTS

- Extensive standard and customized PA6 and PA66 compound portfolio
- Enhanced performance compounds
- Leader in sustainable polyamides

SOLUTIONS FOR

- Lightweight
- E-mobility
- CO_2 reduction
- Mass customization
- Miniaturization
- Eco-design
- PA66 replacement

AUTOMOTIVE

INDUSTRIAL & CONSUMER GOODS

ELECTRIC & ELECTRONIC

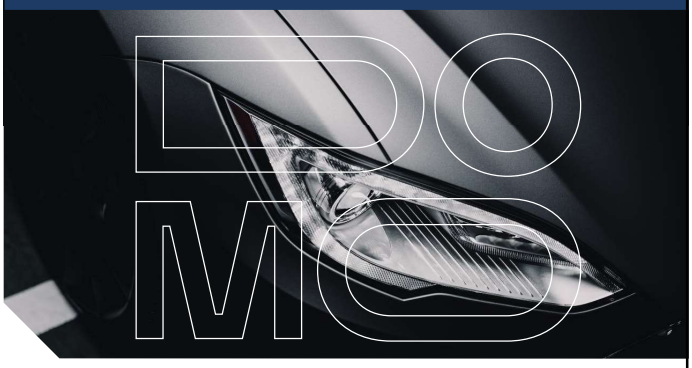
DOMO ENGINEERING PLASTICS AT A GLANCE

Compounding Capacity: 200kT

Recycled material sales (% of 2019 sales volume): 10%

Production units :
Germany, Italy, France, Poland, China(*), USA, India.

(*)New Pinghu site China – Operational ~Q4 2020



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7

INTRODUCTION TO
DOMO CHEMICALS

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CONDUCTIVE SOLUTIONS

DOMAMID® Z — Thermal conductive

ECONAMID® AIR — Electrical conductive

THERMEC™ — Enhanced performance polymers

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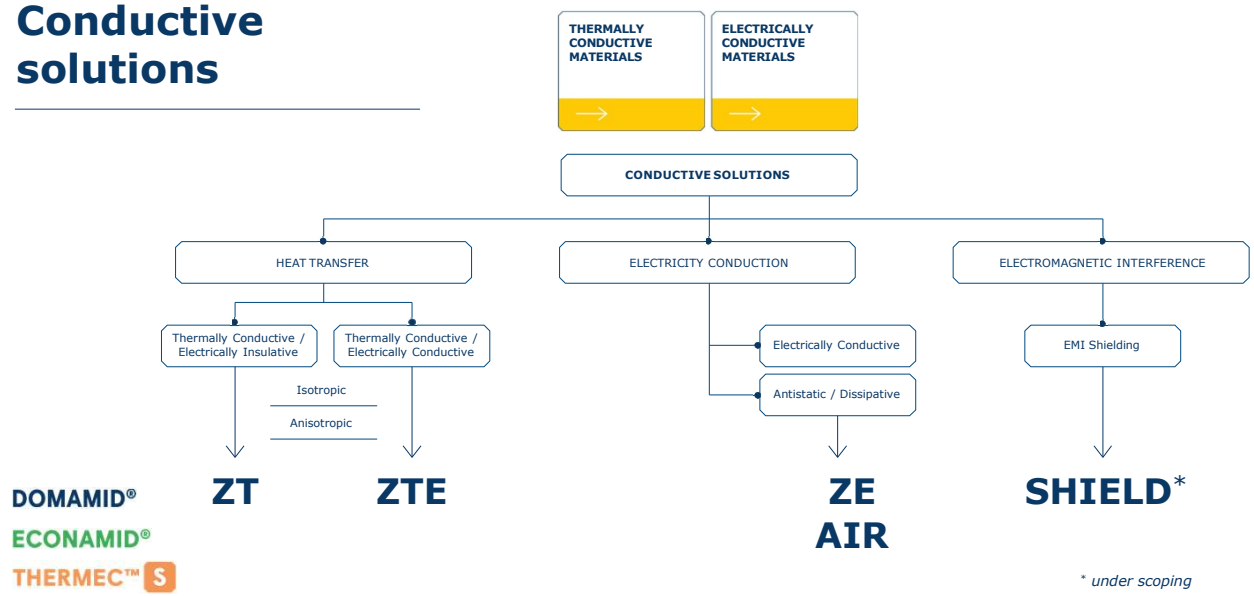
Conductive solutions



DOMAMID®
ECONAMID®
THERMEC™ S

* under scoping

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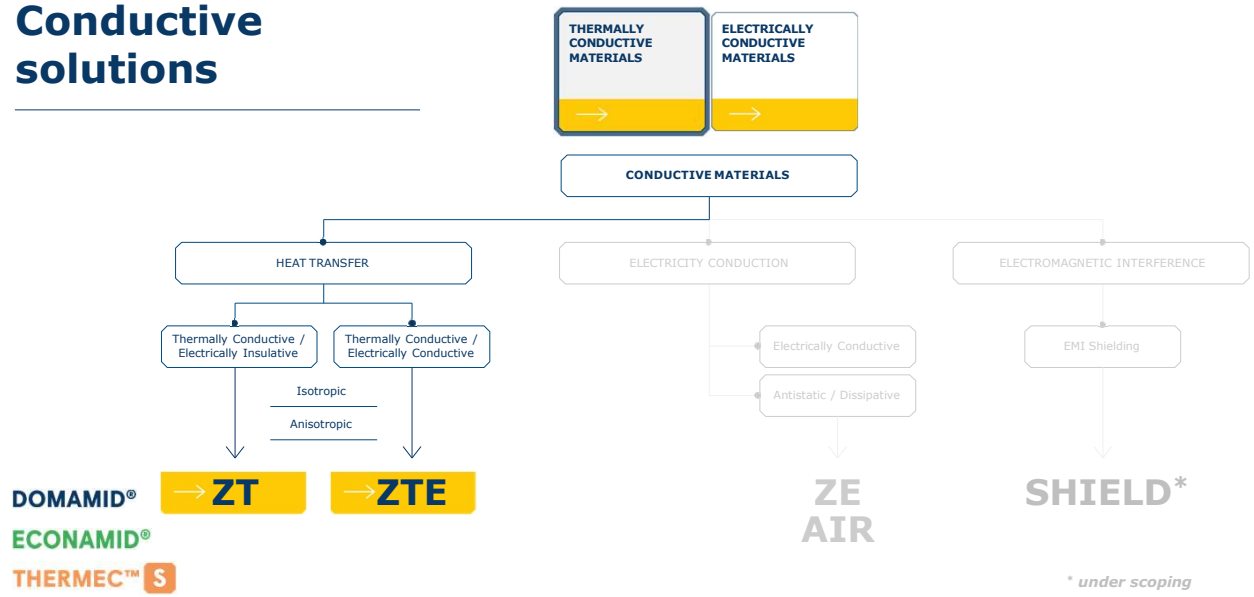
Conductive solutions



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ECONAMID®
THERMEC™ S

* under scoping

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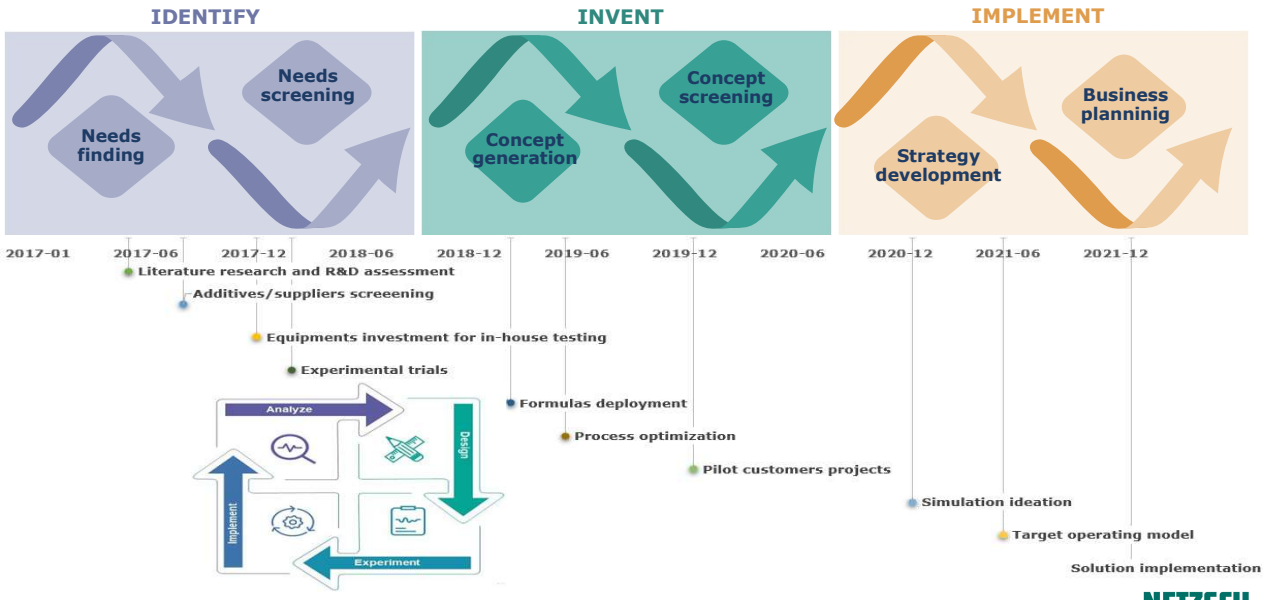
DOMO CONDUCTIVE SOLUTIONS

DEVELOPMENT ROADMAP



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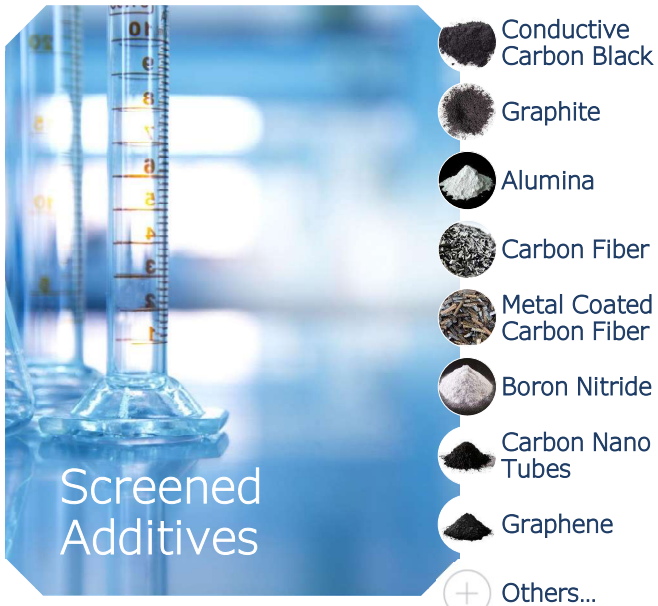
DOMO CONDUCTIVE SOLUTIONS

ADDITIVES TO IMPROVE THERMAL & ELECTRICAL CONDUCTIVITY



- Conductive Carbon Black
- Graphite
- Alumina
- Carbon Fiber
- Metal Coated Carbon Fiber
- Boron Nitride
- Carbon Nano Tubes
- Graphene
- Others...

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DOMO CONDUCTIVE SOLUTIONS

TESTING METHODS

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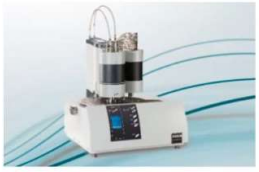
PRODUCT PORTFOLIO

INTRODUCTION TO THE NETZSCH GROUP

Erich NETZSCH GmbH & Co. Holding KG

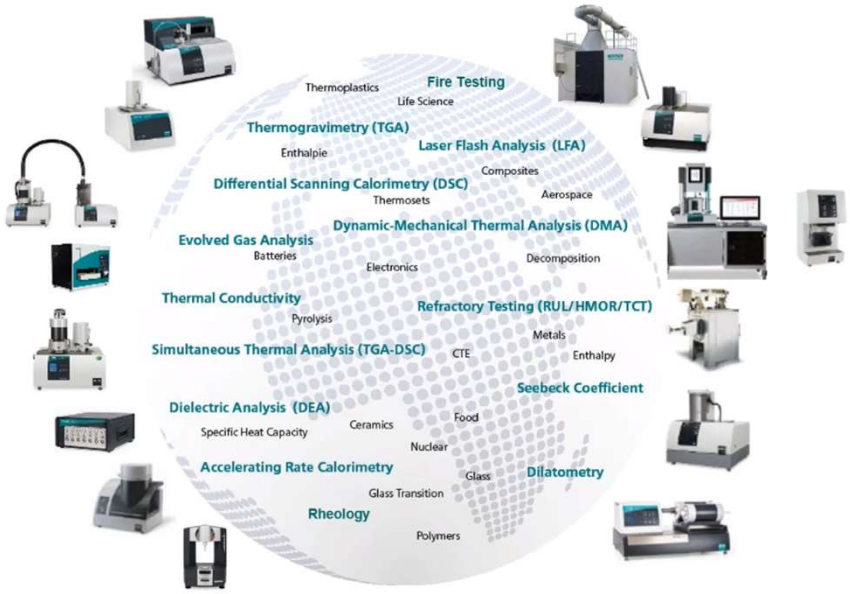
Analyzing & Testing	Grinding & Dispersing	Pumps & Systems
Thermal analysis instruments and instruments for the determination of thermophysical properties	Comprehensive machine program for wet and dry grinding technologies	Pump program for industrial pumping applications – Manufacturer of the world famous NEMO® progressing cavity pump



- Established: in 1873 by Thomas and Christian Netzsch in Selb, Germany
- Turnover: > 530M €
- Employees: around 3500 worldwide, 1500 in Germany
- Subsidiaries: 215 worldwide in 35 countries

PRODUCT PORTFOLIO

NETZSCH ANALIZING & TESTING PRODUCT PORTFOLIO



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15

NETZSCH ANALYZING & TESTING WORLDWIDE

Europe

Austria
Graz
Czech Republic
Prague
France
Lyon
Troarn
Germany
HQ Selb
Ahlden
Italy
Verona
Poland
Krakow
Spain
Barcelona
Sweden
Malmö
UK
Wolverhampton

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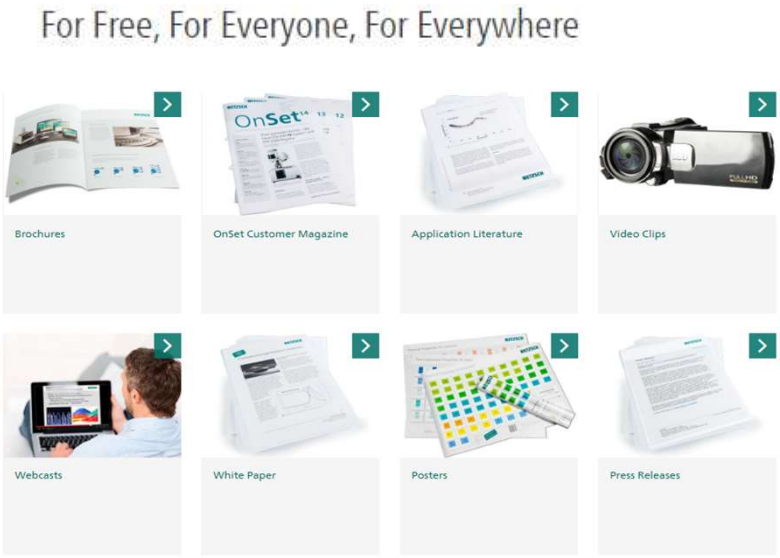
16

WEBSITE

Visit us at www.netzsch-thermal-analysis.com



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17

BLOG

Visit us at https://ta-netzsch.com

- **POLYMERS**
- GLASS – CERAMICS
- BUILDING MATERIALS
- ALLOYS
- PHARMA/FOOD …

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18

HEAT TRANSFER IS ALL AROUND …

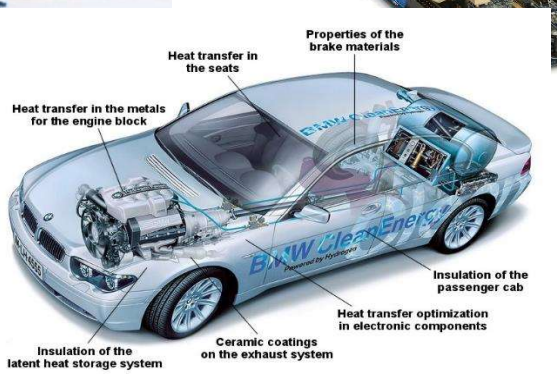

Photo: BMW AG – Photo-Gallery: 3 Series

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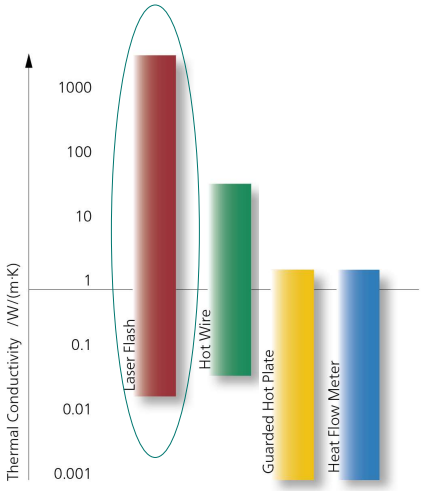
19

MEASURING METHODS



Light/Laser Flash Analysis can cover a wide range
Thermal Conductivity: 0.1 W/mK – 4000 W/mK

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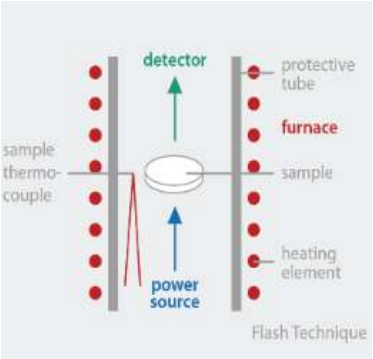
LFA METHOD

Measuring principle introduced by Parker et al. 1961

- A plane parallel sample of defined thickness
  (i.e. a small disc) is stabilized at a defined temperature
- Front surface is heated by a short energy pulse (flash lamp o laser)
- Energy is absorbed and transferred through the material
- Temperature rise on the rear face of the sample is measured versus **time**
  by an IR detector



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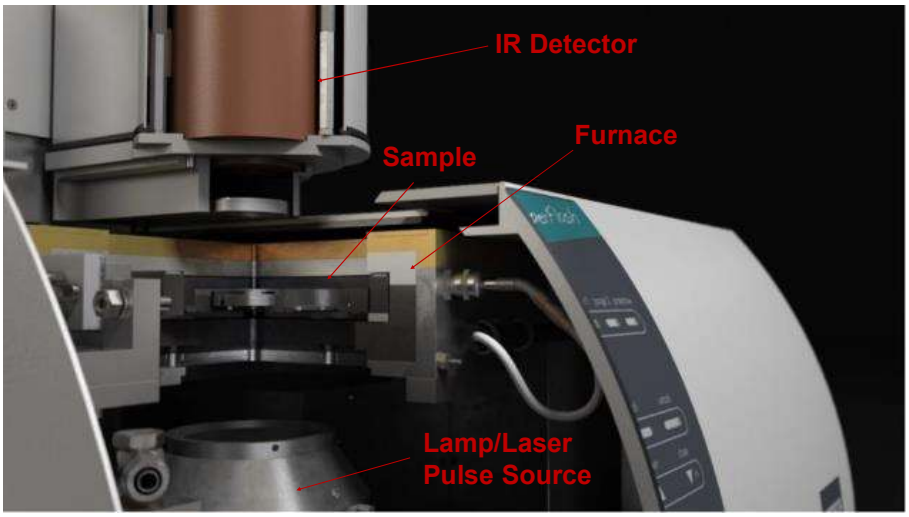
THE BEATING HEART OF LFA
BASIC COMPONENTS



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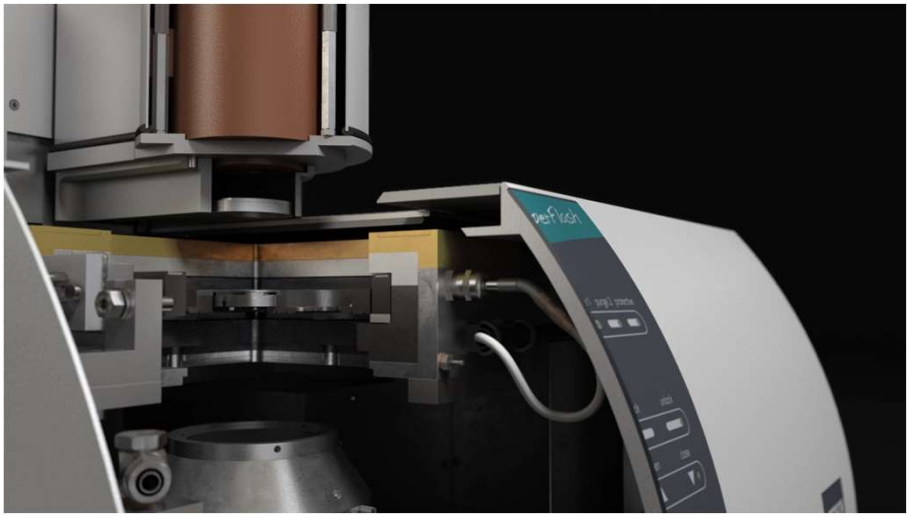
THE BEATING HEART OF LFA
PULSE AND DETECTOR SIGNAL



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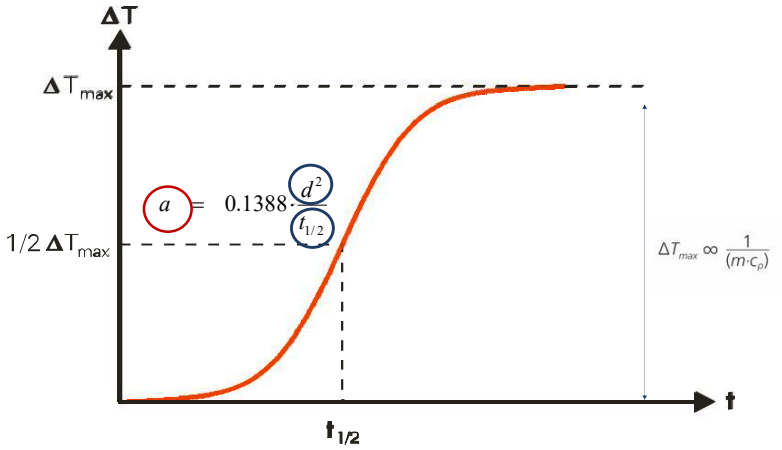
METHOD AND INFORMATION

a = Thermal Diffusivity

d = sample thickness

$\mathbf{t_{1/2}}$ = «Half Time»
time to reach half of the maximum temperature increase



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METHOD AND INFORMATION

$$\lambda(T) = a(T) \cdot c_p(T) \cdot \rho(T)$$

calculated by LFA

measured by LFA

measured or known (literature)

λ = thermal conductivity
a = thermal diffusivity
c_p = specific heat
ρ = density

- **Specific Heat** can be measured by:
  - LFA, "ratio method", comparison with a standard (known Cp)
  - Differential Scanning Calorimetry, DSC

- **Density** can be measured by
  - Balance (bulk density)
  - Dilatometry/TMA, Volume Change vs Temperature

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LFA 467 HYPERFLASH SERIES

Visit us at www.netzsch-thermal-analysis.com

	LFA 467 *HyperFlash*®	LFA 467 *HT HyperFlash*®
Temperature range	-100°C ... 500°C room temperature version available	RT ... 1250°C (furnace temperature 1500°C)
Heating rate (max.)	50 K/min	50 K/min
Furnace cooling device	External chiller (RT... 500°C), Optional: ▪ Liquid nitrogen cooling (-100 ... 500°C) ▪ Pressurized air (0°C ... 500°C)	External chiller
Thermal diffusivity	0.01 mm^2/s ... 2000 mm^2/s	0.01 mm^2/s ... 2000 mm^2/s
Thermal conductivity	0.1 W/(m·K) ... 4000 W/(m·K)	0.1 W/(m·K) ... 4000 W/(m·K)
Accuracy	▪ Thermal diffusivity[1]: ± 3% ▪ Specific heat[2]: ± 5%	▪ Thermal diffusivity[1]: ± 3% ▪ Specific heat[2]: ± 5%
Repeatability	▪ Thermal diffusivity[1]: ± 2% ▪ Specific heat capacity[2]: ± 3%	▪ Thermal diffusivity[1]: ± 2% ▪ Specific heat capacity[2]: ± 3%
Xenon flash lamp	▪ Pulse energy[3]: up to 10 Joules/pulse (variable), software-controlled ▪ Pulse width[4]: 10 to 1500 µs	▪ Pulse energy[3]: up to 10 Joules/pulse (variable), software-controlled ▪ Pulse width[4]: 10 to 1500 µs

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SAMPLE HOLDERS

- Sample shape: round or square
- Sizes: from **10 mm to 25.4 mm** (diameter/edge)
- Autosampler from 4 **to 16 positions** depending on sample holder and sample sizes
- Special sample holders for
  - **Laminates → anisotropic materials**
  - Liquids
  - Pastes/Resins
  - Powder
  - Fibres

Note on sample preparation:

- Plane parallel faces → **well define thickness (d)!**
- Graphite coating (spray/sputtering) enhanced sample absorption/emission, better S/N

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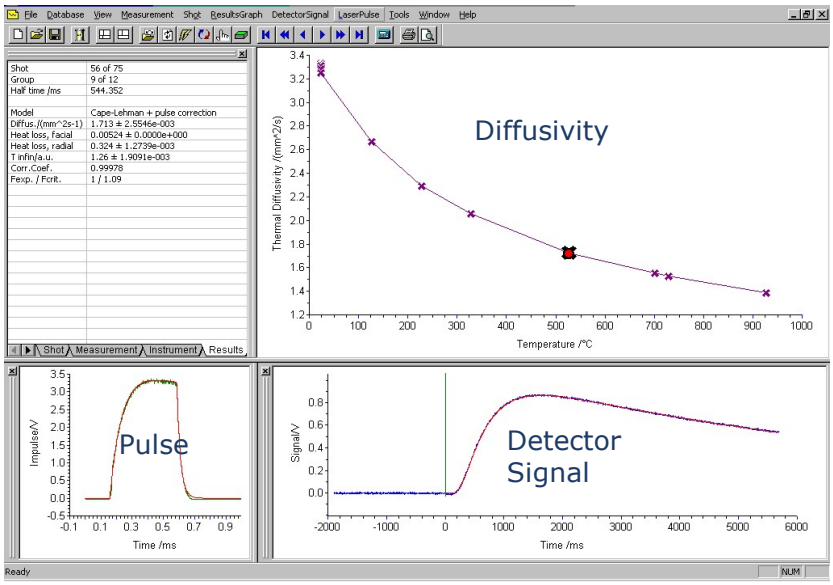
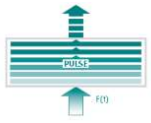
27

SOFTWARE INTERFACE



Detector Signal must be fitted with a Model

Only a correct model leads to a correct fit → **correct results**



Finite Pulse Correction

Patent US7038209B2, US20040079886; DE 1024241

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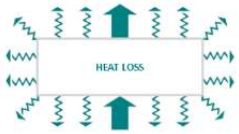
28

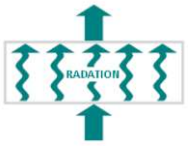
SOFTWARE – MODELS

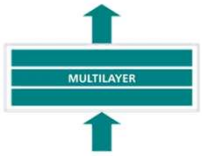


Improved Cape-Lehman
(it considers multi-dimensional heat loss and non-linear regression)

Other classic models, i.e. Parker, Cowan, Azumi, Clark-Taylor
…

Radiation, transparent or translucent samples (accounting for non-conductive heat transfer effects)





Multilayer, 2/3 layers
(contact resistance)

In-plane, heat transfer in the plane of the sample (for film and highly conductive materials)

Software Proteus® → «WIZARD»

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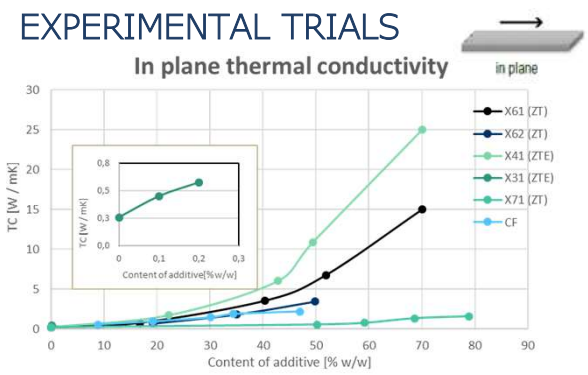
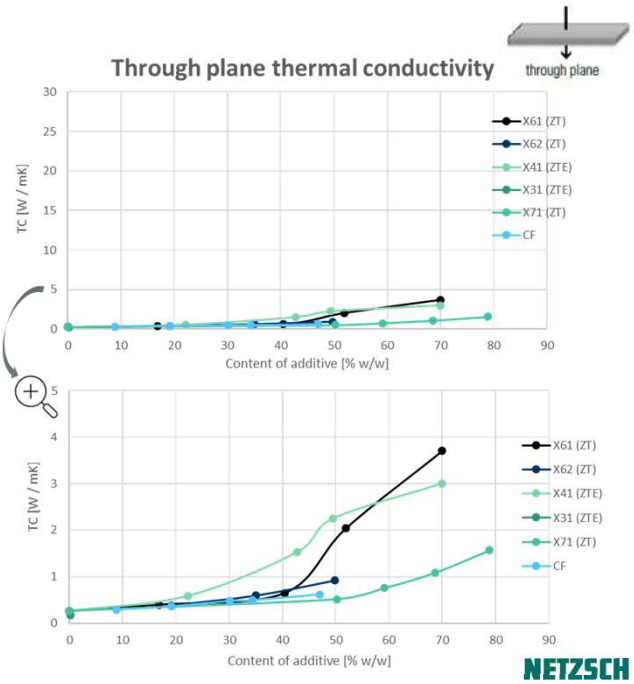
29

DOMO CONDUCTIVE SOLUTIONS

EXPERIMENTAL TRIALS





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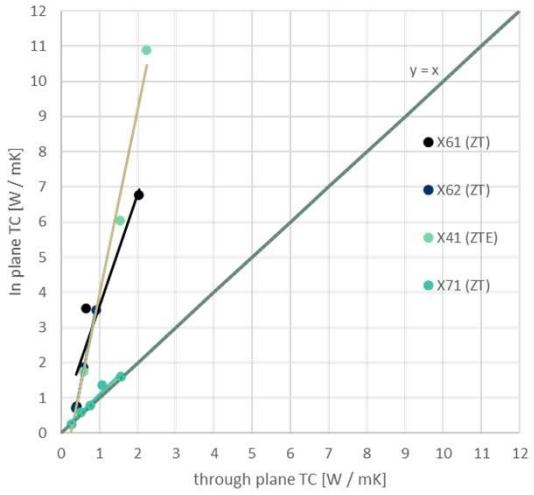
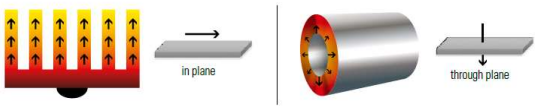
DOMO CONDUCTIVE SOLUTIONS

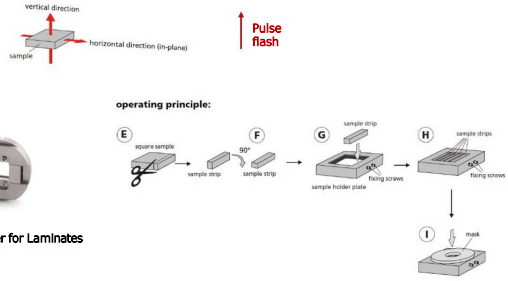
EXPERIMENTAL TRIALS

In-plane *vs* through plane TC





Samples preparation and analysis



Sample holder for Laminates

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31

DOMO CONDUCTIVE SOLUTIONS

ADDITIVES SELECTION

ZT additives			ZTE additives	
hBN	**Alumina**	**Others / Combinations**	**Graphite**	**Others / Combinations**
		⊕		⊕

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NEW PRODUCTS

ZT / ZTE

TECHNICAL DATA PRODUCT DESCRIPTION	Density ISO 1183 [g/cm³]	Tensile modulus ISO 527 1 mm/min [MPa]	Charpy notched ISO 179/1eA +23 °C [kJ/m²]	Thermal conductivity, through plan ASTM E1461 +25 °C [W/(mK)]	Thermal conductivity, in plan ASTM E1461 +25 °C [W/(mK)]	Volume resistivity IEC 62631-3-1 [Ω·cm]	Flammability UL 94 0.75 mm [Class]
DOMAMID® ZT 6X50H1 X62	1,55	11.000	3	1,2	3,9	1E+15	HB
DOMAMID® ZT 6X60H1 X61	1,80	13.000	1,5	3,5	15	1E+15	HB
DOMAMID® ZT 6X70H1 X71	2,25	8.700	8	1,2	1,2	1E+15	HB
DOMAMID® ZT 6X80H1 X71	2,6	10.000	4	1,6	1,6	1E+15	HB
DOMAMID® ZTE 6X60H1 X41	1,62	14.000	3	3,5	20	1E+01	HB
DOMAMID® ZTE 6X70H1 X41 (*)	1,75	16.000	2,6	4	25	1E+01	HB
DOMAMID® ZTE 66X40H1 X41	1,43	9.500	2,4	1,3	7	1E+04	HB
DOMAMID® ZTE 66X50H1 X41	1,50	10.000	2,2	2	12	1E+02	HB
DOMAMID® ZTE 66X60H1 X41 (*)	1,60	13.000	2	4	20	1E+01	HB
THERMEC™ S ZTE X40H1 X41 (*)	1,59	10.500	2,4	1,1	7,5	1E+03	V-0
THERMEC™ S ZTE X50H1 X41 (*)	1,68	11.800	2,3	2,2	11	1E+01	V-0
THERMEC™ S ZTE X70H1 X41 (*)	1,78	18.000	2	5	25	1E+01	V-0

(*) = UNDER DEVELOPMENT

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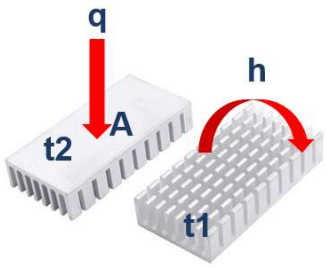
33

CONDUCTIVE SOLUTIONS

WHY IS THERMAL CONDUCTIVITY REQUIRED?



	Free convection				Forced convection			
q (W)	3	3	3	3	15	15	15	15
h (W/m².K)	7	7	7	7	50	50	50	50
Conduct (W/m.K)	0.1	2	10	100	0.1	2	25	100
t1 (ºC)	120.5	120.5	120.5	120.5	118.4	118.4	118.4	118.4
t 2(ºC)	142.0	122.9	120.9	120.5	264.1	134.3	121.0	118.5
delta t (ºC)	21.5	2.4	0.4	0.0	145.7	15.9	2.6	0.1
	Std plastics	TC plastics		Metal	Std plastics	TC plastics		Metal

- ✓ LED or IC is in plane A with specific power source (q)
- ✓ Heat build up can damage LED or decrease performance or life span
- ✓ No need to equal metal TC to perform (in free convection)

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34

CONDUCTIVE SOLUTIONS

THERMAL CONDUCTIVE PLASTICS – ADDED VALUES

What Domo offers	Benefits
• **An injection moldable thermoplastic solution:** ➢ 10 to 100 times higher thermal conductivity vs traditional plastics	• **Lower system costs by replacing the aluminum used in heat dissipative components with additional benefits:** ✓ High design flexibility for more complex and more compact parts ✓ No secondary operation such as machining, drilling etc. ✓ Shorter cycle time (up to 50%) ✓ Higher production yield and cost savings ✓ Lowers maintenance cost through lower corrosion on tools and longer tool life
• **Low density vs metal** ➢ Density < 1.8 g/cm3	• **Help to fulfill the light weighting challenge in automotive** ✓ Potential weight saving vs aluminum : minimum 33% ✓ Lower fuel consumption and lower CO2 emissions ✓ Less vibration load vs heat dissipating elements in aluminum

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35

CONDUCTIVE SOLUTIONS

THERMAL CONDUCTIVE PLASTICS – ADDED VALUES

What DOMO offers	Benefits
• **High thermal conductivity** ➢ Up to 25 W/m.K ➢ Similar system thermal performance vs aluminum heat sinks	• **Allow differentiation vs competitors by freeing up the design and keeping an excellent Weight/Cost balance** ✓ Avoids hot spots, avoiding metal heat shields, and/or high priced specialty thermoplastics ✓ Extends part performances in the upper limit of their in-use heat levels
• **Electrical conductivity** ➢ Surface resistivity <1E4 Ohm	• **Increase the overall safety and reliability** ✓ More conductive than standard thermoplastics ✓ Limits the risk of electrostatic build up

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36

CONDUCTIVE SOLUTIONS

THERMAL CONDUCTIVE PLASTICS – ADDED VALUES

What DOMO offers	Benefits
• **Various base resins with balanced mechanical properties and performances** ➢ PA6, PA6.6 and PPS	• **Meet various customer requirements with optimized cost thanks to:** ✓ Appropriate chemical resistance for occasional contact with typical automotive fluids ✓ Flammability in line with automotive FMVSS302 norm ✓ Adequate mechanical performances
• **CAE thermal simulations needed** ➢ (per project)	• **Speed development process and reduce the investment** ✓ Feasibility and comparative studies on concepts and early designs ✓ Advise on design and material choice

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CONDUCTIVE SOLUTIONS

MAIN FEATURES OF THERMAL CONDUCTIVE COMPOUNDS

DOMO product range	Filler	Filler content	Density [g/cm³]	Thermal conductivity [W/m K]	Surface resistivity [Ω]	Mechanical Performances	Colourability	Processing	Cost level indication
DOMAMID ZT 6X6..	BN	40%-70%	1,2 - 1,7	IP: 3,5 - 15 TP: 0,4 - 3,5	10^15				↑↑↑
DOMAMID ZT 6X7..	Alumina	50% -80%	1,7 - 2,6	0,6 - 1,7	10^15				↑
DOMAMID ZTE 6X4..	Graphite	40%- 70%	1,4 - 1,6	IP: 5 - 25 TP: 0,6 - 3,5	10^6 - 10				↑
DOMAMID ZTE 6X3..	CNT	0,1% - 5,0%	1,14 – 1,2	IP:1-15 TP: 0,2- 5	10^6 - 10				↑↑
DOMAMID ZTE 6X1..	CB	30% -50%	1,2 – 1,45	0,3 - 0,6	10^9 – 10^3				↑
ECONAMID AIR	CF	10% - 50%	1,2 – 1,35	IP: 0,6 -2,0 TP: 0,3-0,7	10^4-10				↑

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38

ELECTRICALLY CONDUCTIVE POLYAMIDE

Target applications

FUEL FILTERS

FAN WHEELS

ELECTRICAL HOUSINGS

VALVES

ATEX APPLICATIONS

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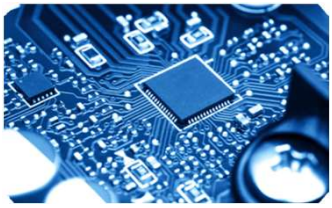
THERMALLY CONDUCTIVE POLYAMIDE

Target applications

HEAT SINKS E&E

FLUID MANAGEMENT

LED LIGHTING SYSTEMS



ELECTRONICS MINIATURIZATION

AD BLUE MANAGEMENT

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40

AUTOMOTIVE

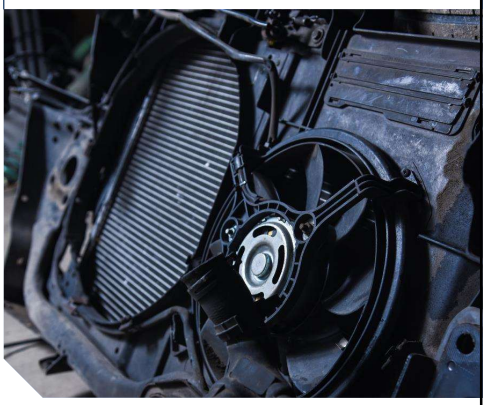
COOLING SYSTEMS

MARKET NEEDS:

- LONG TERM HEAT RESISTANCE
- RESISTANCE AGAINST OIL & COOLING LIQUID AND OTHERS
- IMPROVED FLOW ABILITY
- THERMALLY CONDUCTIVE

Material	Application
DOMAMID® ZT 6X70H1 X71 NC91 PA6 / 1,2W/mK	cover for electrical engine / heat protection for electronical equipment in interior & UTH

UNDER THE HOOD



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41

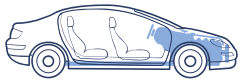
AUTOMOTIVE

COOLING SYSTEMS

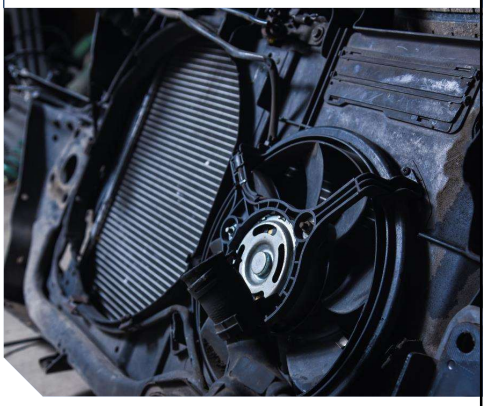
MARKET NEEDS:

- THERMAL CONDUCTIVE AND ELECTRICAL CONDUCTIVE
- THERMAL CONDUCTIVITY THROUGH PLANE: ≥2,5 W.M.K-1
- HIGH FLOW (MINIMUM THICKNESS IS 1 mm AND LENGTH IS 50 mm)
- HEAT STABILIZED (T° IN PEAK IS 210°C)
- TENSILE STRESS AT BREAK: AROUND 70 MPa

Material	Application
DOMAMID ZTE 66X50H1 X41 NC99 PA66 / 2W/mK TP - 12W/mK IP	Cooling circuit parts



UNDER THE HOOD



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42

CONDUCTIVE SOLUTIONS

KEY TAKEAWAYS

- ✓ **New trends** are pushing boundaries in lightweight and functional materials in all segments
- ✓ DOMO commitment to **Sustainable Innovation**
- ✓ **Full range** of thermally and/or Ellectrically conductive solutions
- ✓ **LFA analysis of choice as quick, precise and reliable test method**
- ✓ **Leader in sustainable solutions** with Econamid

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43

THANK YOU

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44

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CONDUCTIVE SOLUTIONS

GET IN CONTACT WITH US FOR ANY ADDITIONAL INFORMATION

Q&A

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45