WORLD MATERIALS FORUM

INTRODUCTION TO LIGHTWEIGHT MATERIALS

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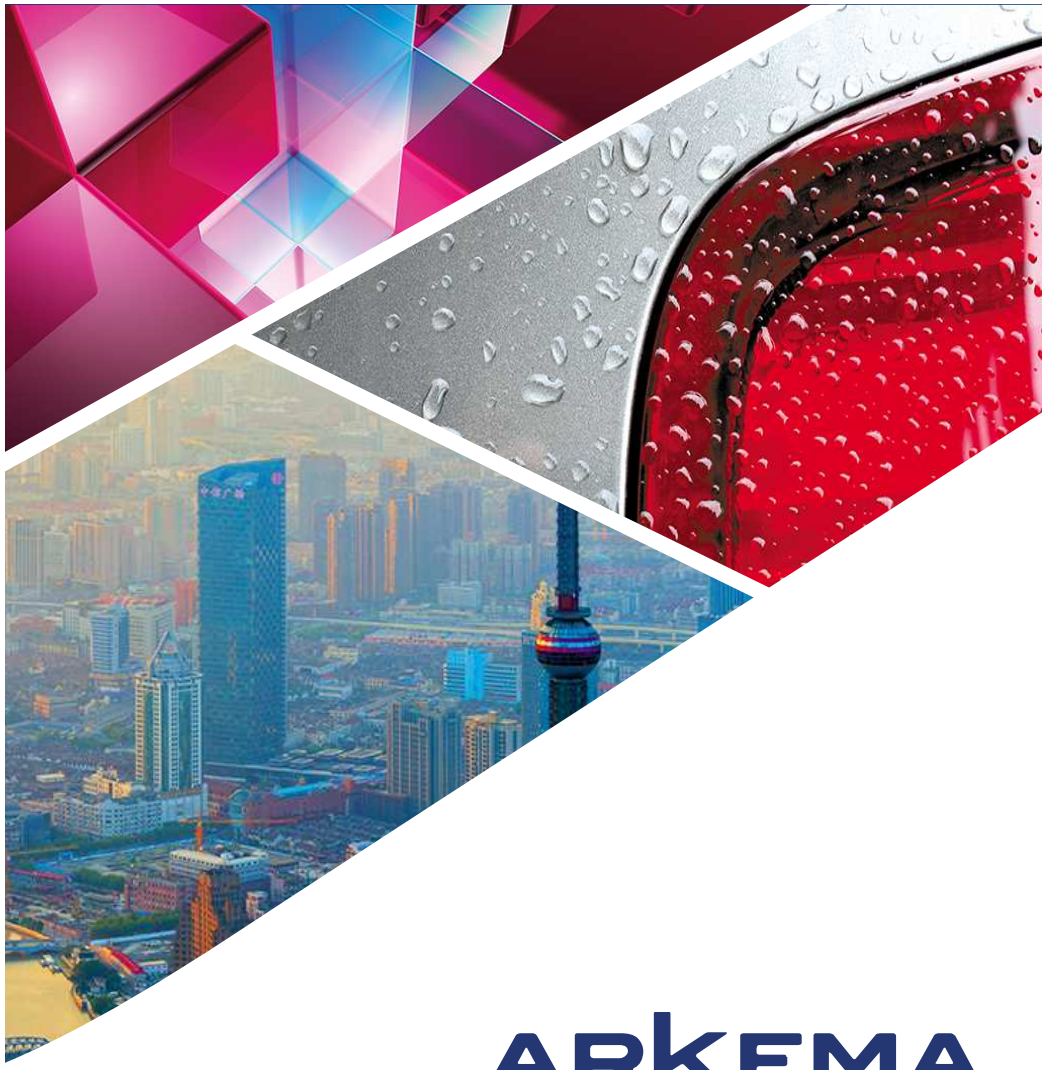
Chairman and CEO Arkema

9 & 10 June 2016



ARKEMA
INNOVATIVE CHEMISTRY

THE HEAVY IMPACT OF LIGHTWEIGHT MATERIALS

- **Efficiency**
  Gains in manufacturing process
- **Sustainability**
  Reduction in energy consumption and CO_2 emissions
- **Functionality**

A GROWING INDUSTRY DOMINATED BY FIBER REINFORCED PLASTICS

METALLIC MATRIX COMPOSITES

Market value
$ 0.4 billion

CAGR 2015-2020
7%

Cylinder sleeves in the engine block

CERAMIC MATRIX COMPOSITES

Market value
$ 1.5 billion

CAGR 2015-2020
14%

Engine exhaust cone for jet engines

ORGANIC MATRIX COMPOSITES
(or Fiber Reinforced Plastics)

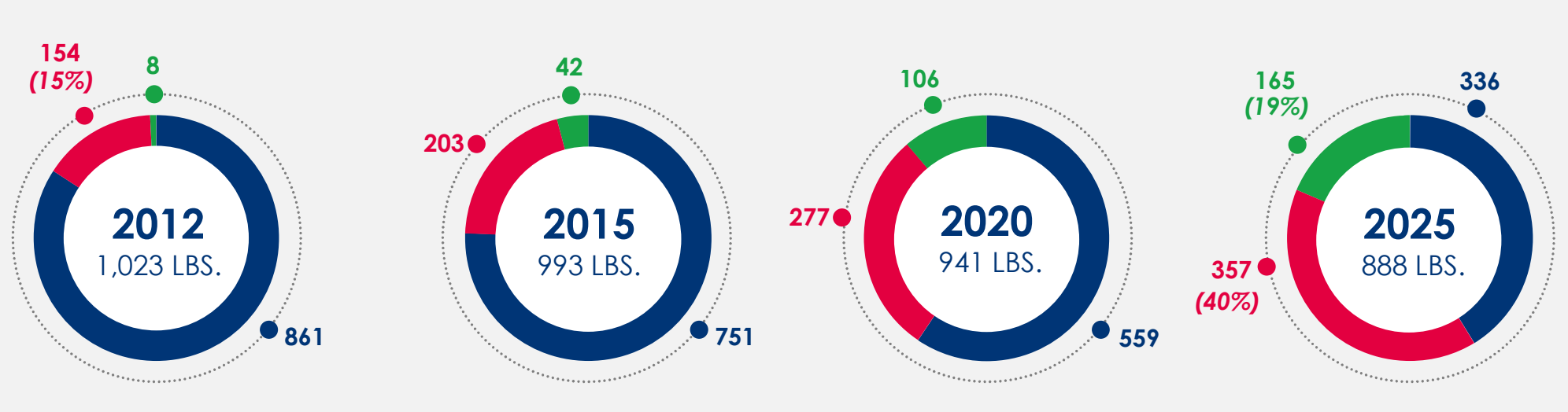
Market value
$ 40 billion

CAGR 2015-2020
7%

Wind mill blades and nacelle covers

NORTH AMERICAN AUTOMOTIVE INDUSTRY

Aluminium and high strength steel alloys to make lighter vehicles



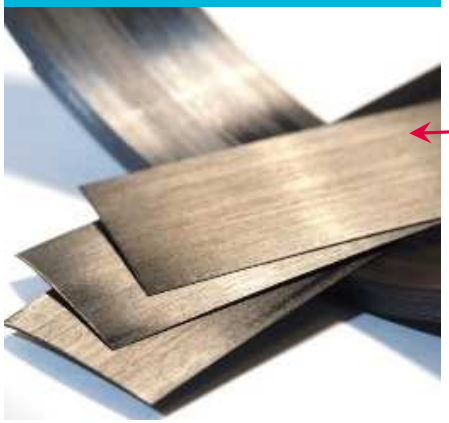
Steel AHSS Aluminum

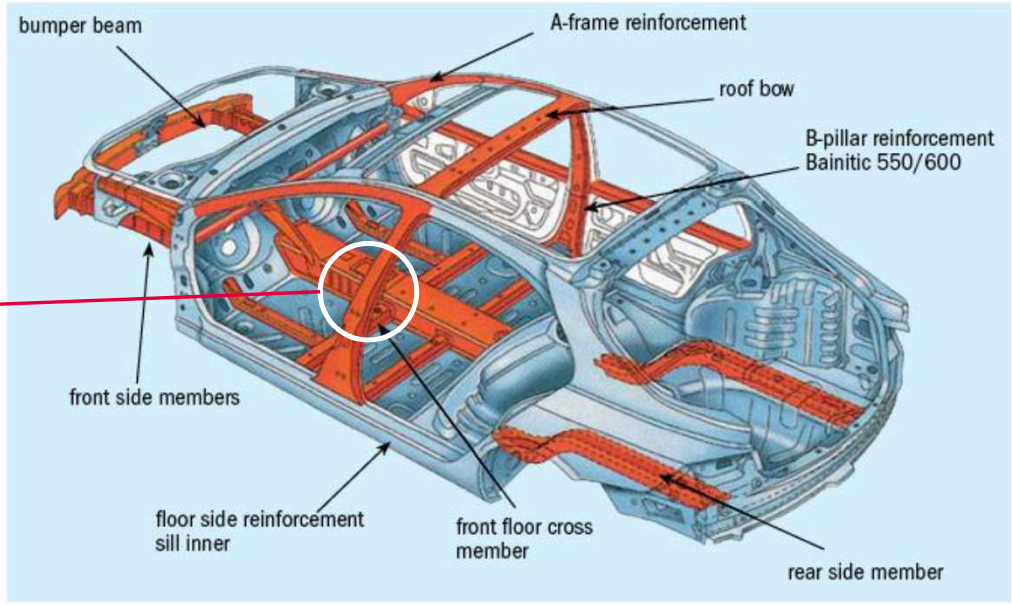
Source: Drucker Worldwide

EUROPEAN AUTOMOTIVE INDUSTRY

Towards mixing steel, metallic alloys and organic composites

SEMI-PRODUCTS
(prepregs, tapes)





STAKES IN AERONAUTICS

1

28,000 new large commercial aircrafts needed in next 20 years

2

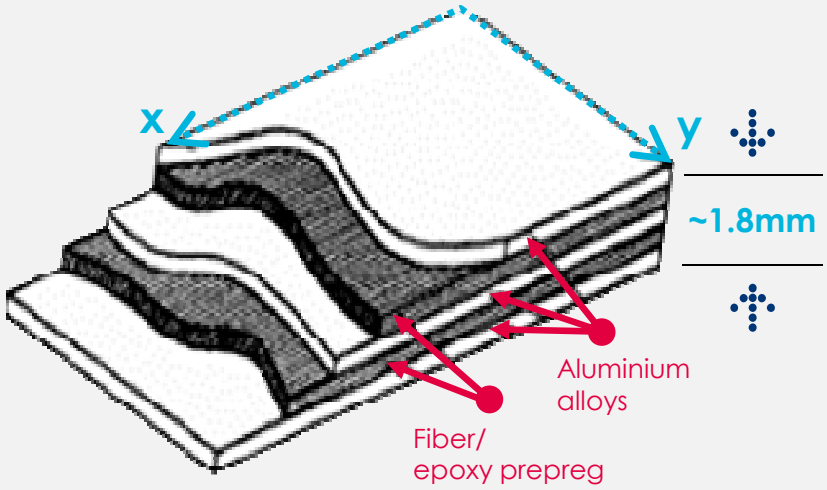
Lightweight materials already make up roughly 80% of all materials

3

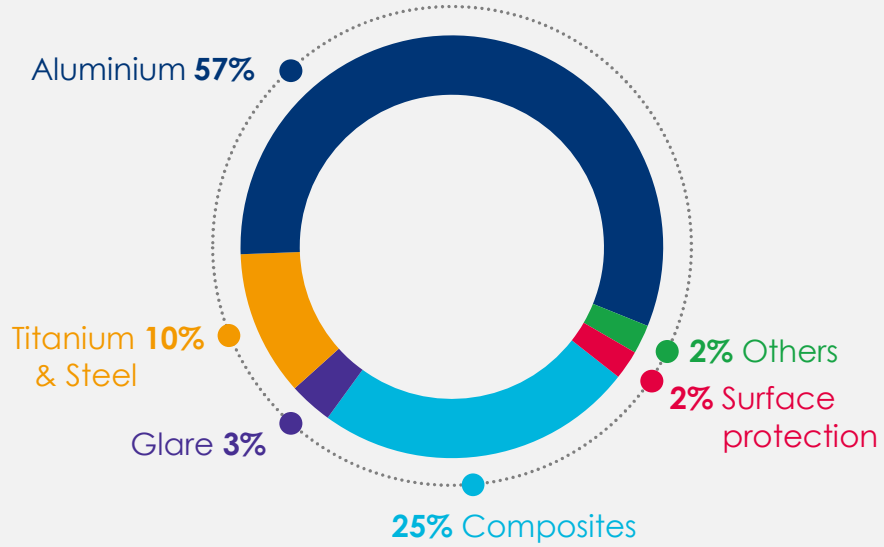
Market expected to grow from 21,000 Tons ($1.4bn) in 2012 to 46,000 Tons ($4.5bn) in 2022

COMPLEX MATERIALS FOR AERONAUTICS

GLARE: ALUMINIUM/GLASS FIBERS LAMINATES
Upper fuselage panels of A380



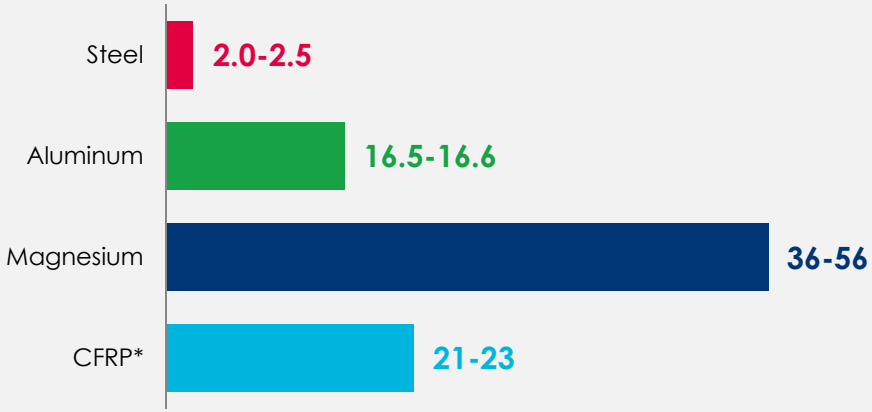
MATERIAL'S REPARTITION IN THE STRUCTURE OF AN A380



GREENHOUSE GAS (GHG) EMISSION DURING MATERIAL PRODUCTION IS LARGELY IN FAVOR OF STEEL

AVERAGE GHG EMISSIONS DURING MATERIAL PRODUCTION

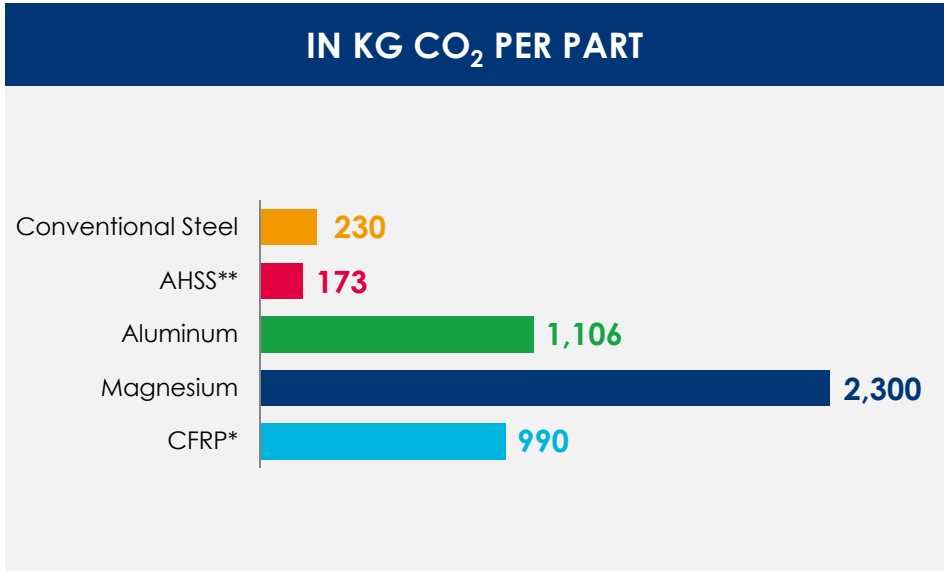
(in kg CO_2/kg of material)



* Carbon Fibre Reinforced Plastic

FUNCTIONALITIES OF EACH MATERIAL ARE DIFFERENT

	Mid-Range CO_2 (kg CO_2/kg of material)	Estimated Part Weight (kg)
Conventional steel	2.3	**100**
AHSS**	2.3	**75**
Aluminium	16.5	**67**
Magnesium	46.0	**50**
CFRP*	22.0	**45**



* Carbon Fibre Reinforced Plastic

** Advanced High-Strength Steel

LIGHTWEIGHTING ALWAYS TARGETS REDUCTION IN ENERGY CONSUMPTION AND CO_2 EMISSIONS

-100kg -0.35 l/100km -9g/km

2T

REDUCTION OF CO_2 EMISSIONS

DURING THE CAR'S LIFE TIME

-100kg -3 l/100 km -90g/km

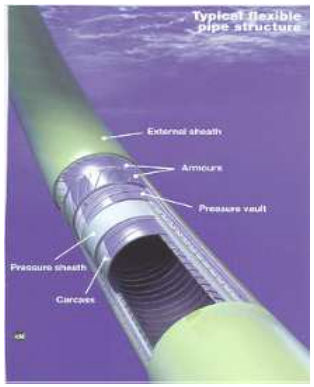
2,000T

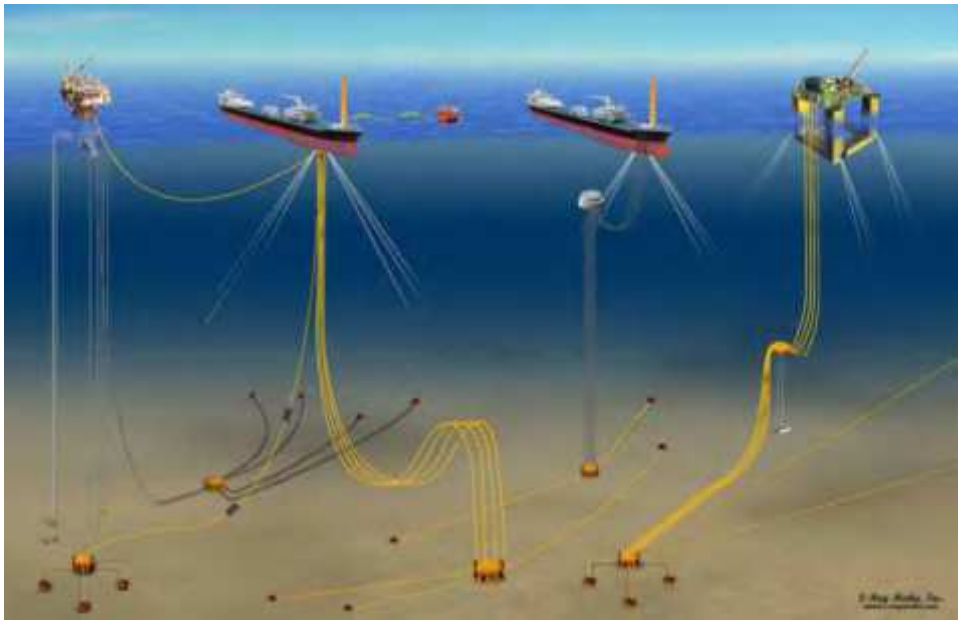
REDUCTION OF CO_2 EMISSIONS

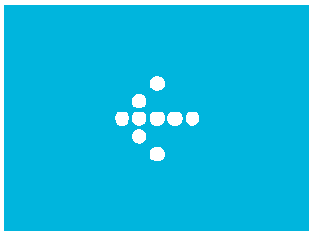
DURING THE PLANE'S LIFETIME

LIGHTWEIGHTING HAS OTHER GOALS THAN JUST ENERGY SAVING

Example of the offshore Oil and Gas exploitation

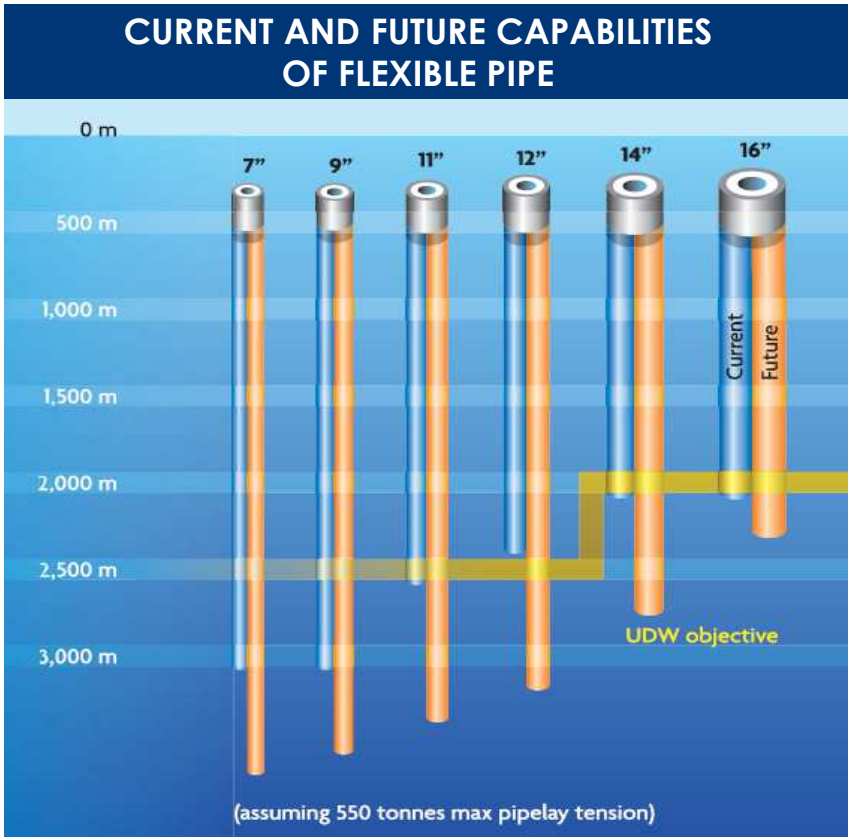




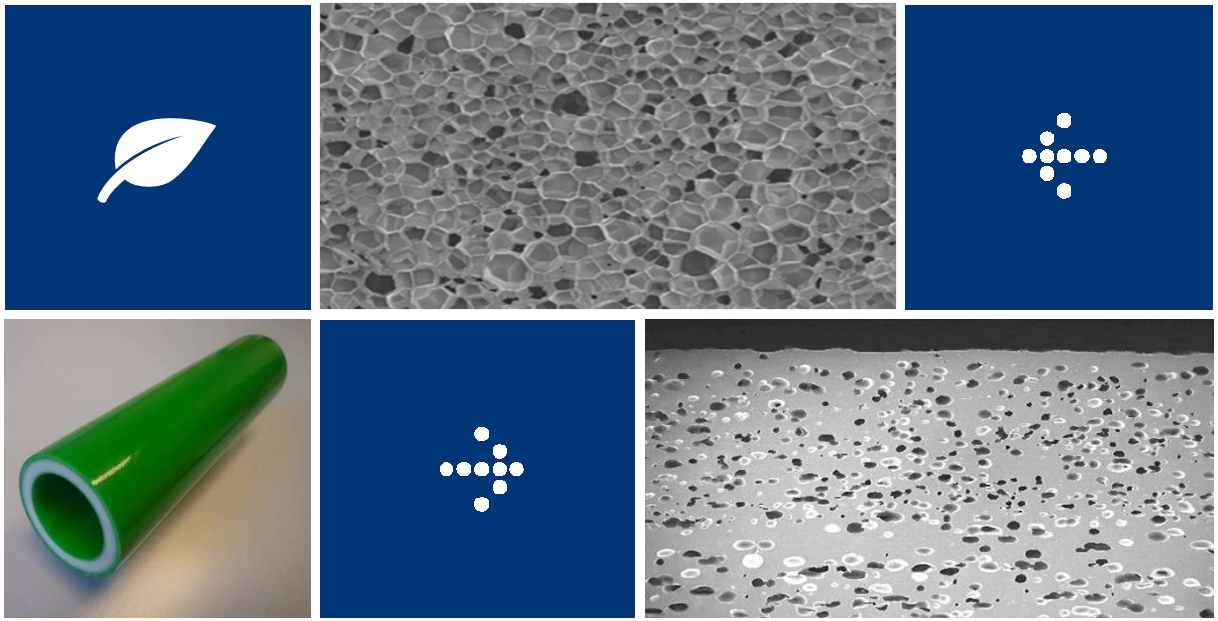


Technip

TOWARDS ULTRA DEEP WATER



LIGHTWEIGHTING CAN ALSO MEAN COST REDUCTION



- Higher acoustic Insulation
- Fire resistance
- UV resistance
- Higher flexibility
- Lower thermal conductivity
- Equivalent mechanical properties

Kynar® (PVDF) foam: 10 to 50% weight reduction

AND LIGHTWEIGHTING CAN EVEN BRING BETTER PERFORMANCES

Composite benefits in sport equipments

- Lightweight
- Flexural fatigue
- Energy return
- Toughness
- Aesthetic

	Stand	PEBAX® BY ARKEMA	RILSAN® CLEAR BY ARKEMA	RILSAN® BY ARKEMA
Thickness (mm)	2,00	1,93	1,72	1,60
Rigidity (N.mm)	31	31	32	31
Weight saved (g)		**-8,7 (-3%)**	**-34,8 (-13%)**	**-40,7 (-15%)**

- **Carbon Insert**
  Stiffness & Reactivity

ARKEMA 6.5 METER SAILING BOAT

A world first: construction of a boat in recyclable thermoplastic composite

NEW THERMOPLASTIC COMPOSITE FOR WINDMILLS

2030-2034

1,000,000 T

to be recycled

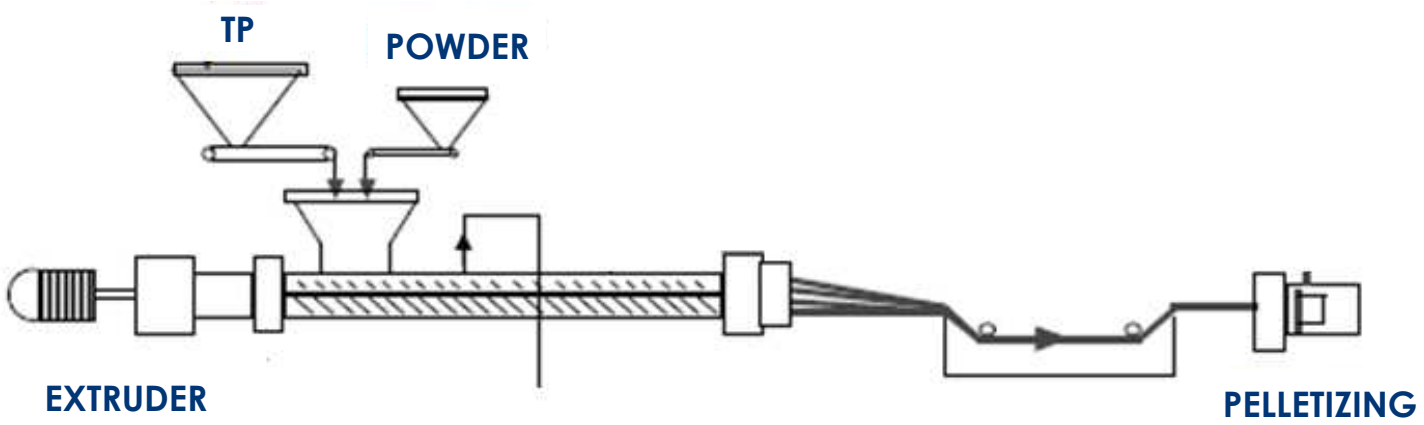
- A lower manufacturing cost vs epoxy
- Better fatigue properties
- Recyclable
- No process change

AN EASY RECYCLING PROCESS

STEP 1 Composite crushing

STEP 2 Mix 30% to 40% of the obtained powder with new resin in an extruder

- PMMA, ABS, PVC, PC/ABS, PLA, PVDF



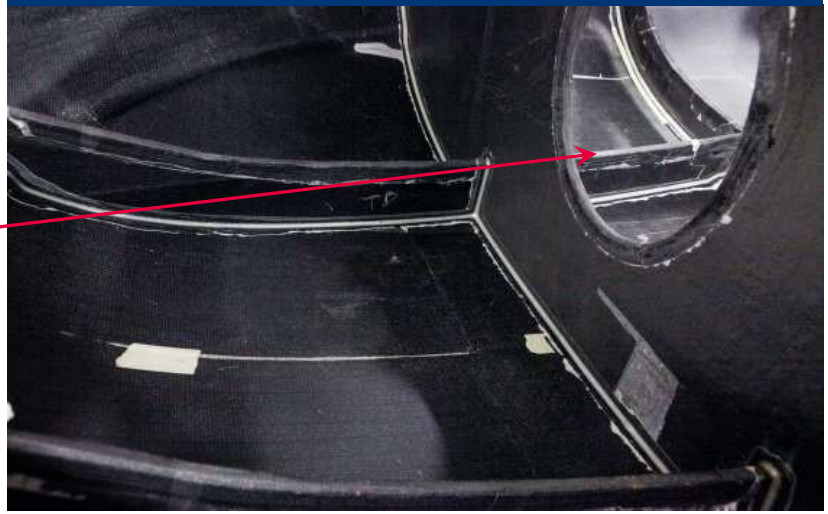
The obtained short fiber granules are used in injection/moulding or overmolding

STRUCTURAL ADHESIVES APPLICATIONS

ARKEMA TRIMARAN BONDED WITH BOSTIK MMA ADHESIVES

100kg
SAVED

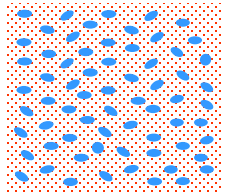
PORTHOLE OF THE TRIMARAN



NANOSTRUCTURED PMMA FOR GLASS SUBSTITUTION

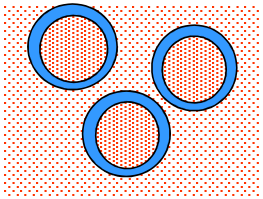
Two sheets heated at 80°C

30nm

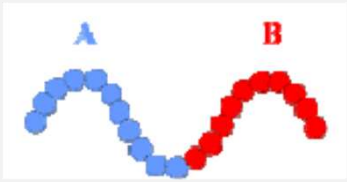


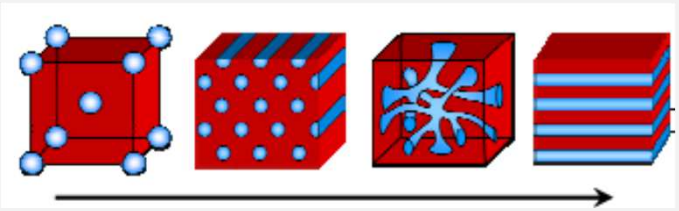
Nanodomains

300nm



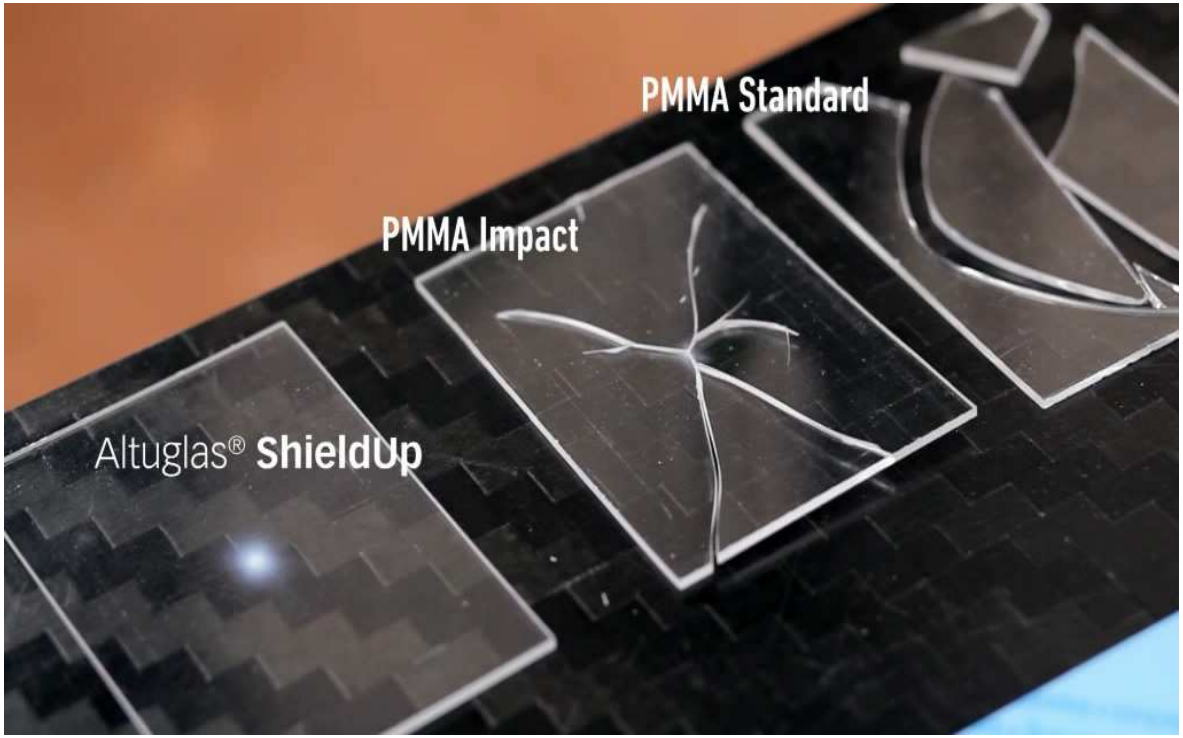
Structure core/shell

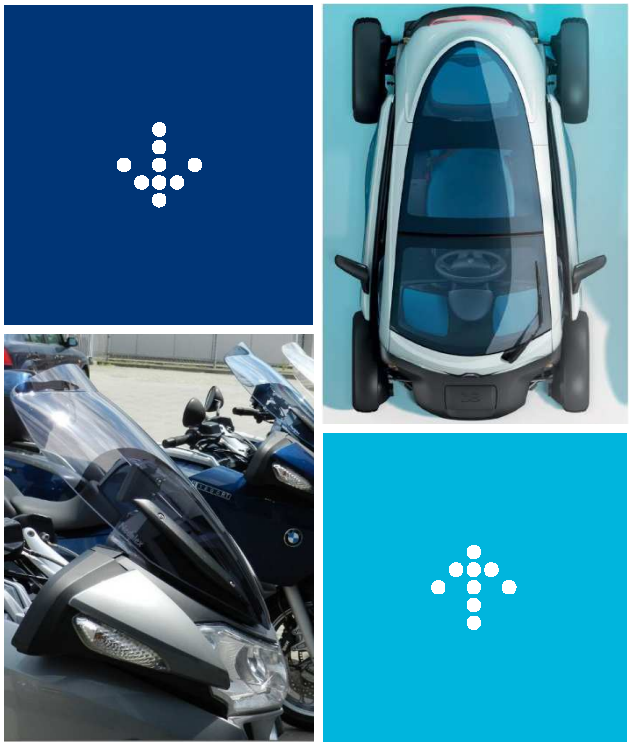




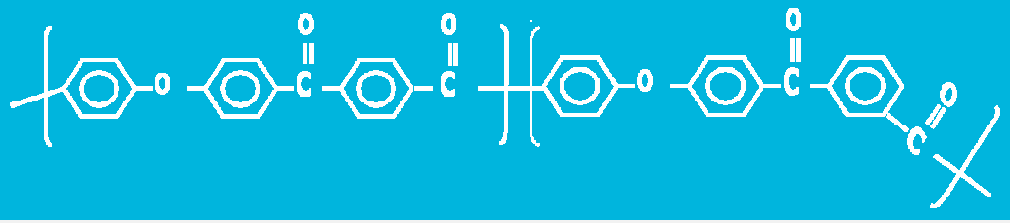
Bloc copolymers self organize in nanodomains with a critical size smaller than the wavelength of the light

VERY HIGH IMPACT RESISTANCE





KEPSTAN® PEKK-POLY(ETHER KETONE KETONE)



Exceptional resistance to:

High temperature
(continuous use temperature 260°C)

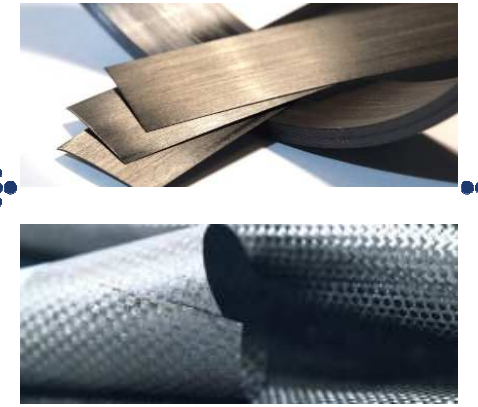
Combustion

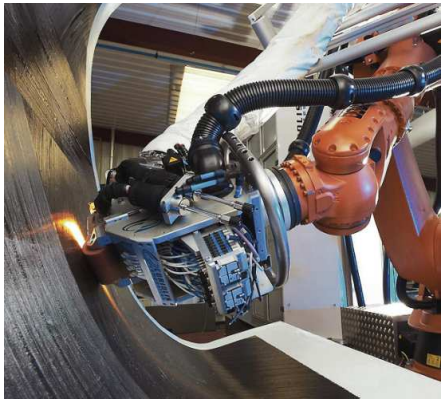
All chemicals

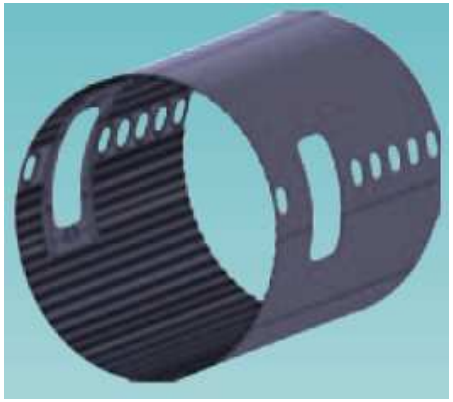
Unique combination of strength, stiffness, impact and wear resistance

KEPSTAN® IN CARBON FIBER REINFORCED THERMOPLASTIC COMPOSITES

Raw materials	Semi-products (tapes, prepreg)	Manufacturing	Airframe







KEPSTAN™ BY ARKEMA