

## ACRYLITE® Aviation Grade

-

Acrylic sheets as transparent  
glazing for the aviation industry

Marcus Freyer  
September 2009



**EVONIK**  
INDUSTRIES

**Evonik is the creative  
industrial group from  
Germany active in over  
100 countries throughout  
the world.**

**Evonik. Power to create.**

# Business Areas



## Chemicals

- Focus: specialty chemicals
- A global leader
- 2007 sales: €10.8 billion
- Leading market positions in over 80% of sales
- Market-driven R&D and modern innovation management
- Over 100 production facilities in some 30 countries



## Energy

- Focus: hard coal-fired power plants and renewable energies
- A technology leader in planning, building and operating power plants
- 2007 sales: €2.8 billion
- Grid-independent power producer with around 9,500 MW installed global capacity
- Strong position in the fields of biomass and geothermal energy in Germany



## Real Estate

- Focus: residential property
- One of the largest private residential property companies in Germany
- Manages about 60,000 own residential units plus a 50% stake in THS with more than 75,000 units
- 2006 sales: €0.4 billion
- Active property owner with strong regional focus

# The new industrial group



SALES IN 2007	<b>€14.4 billion</b>
EBITDA IN 2007	<b>€2.2 billion</b>
PROFITABILITY (EBITDA MARGIN)	<b>15.4%</b>
RETURN ON CAPITAL EMPLOYED (ROCE)	<b>9.5%</b>
EMPLOYEES IN 2007	<b>about 43,000</b>
ACTIVE IN	<b>over 100 countries</b>



**Who makes lightweight  
construction light?**

**We do.**

**Business Unit Performance Polymers**

# The Business Unit in Figures

## PERFORMANCE POLYMERS

HEAD OFFICE Darmstadt, Germany

SALES €1.40 billion

EMPLOYEES Over 3,700

PRODUCTION SITES  
 China  
 Germany  
 Japan  
 Taiwan  
 Austria  
 Russia  
 USA



Status: 2008

# Integrated Methacrylates Production Network



**External customers**



**Acrylic Monomers**



**Molding Compounds**



**Cast / Extruded Acrylic Sheet**

**Methyl methacrylate (MMA)**

**Pharma Polymers**



**Oil Additives**



**Binders & Additives**



**Films & Foams**





## Application of Acrylic Sheets in Aviation

# Application of Acrylic Sheets in Aviation



# Application of Acrylic Sheets in Aviation



Eurocopter: EC 135

# Application of Acrylic Sheets in Aviation



Diamond Aircraft: Diamond DA40

# Application of Acrylic Sheets in Aviation



EADS: Eurofighter Typhoon

# Application of Acrylic Sheets in Aviation

## Requirements for application in the aviation industry:

- Excellent transparency
- Light weight
- UV stable
- Resistance to alternating temperature
- Long-term weather resistance
- Easy to form (complex shapes)

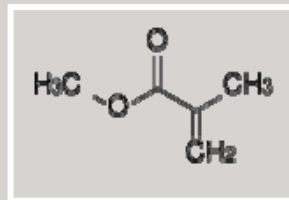
# Chemistry of Acrylic Polymers

# Chemistry of Acrylic Polymers

## Polymerization:

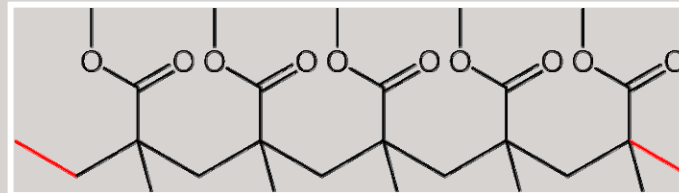
- **Monomer** - molecule with minimum functionality of two that reacts to form the structural units of the polymer

### Methyl Methacrylate (MMA)

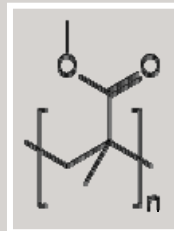


- **Polymer** - macromolecule generated through sequential reaction of a small number of elementary units

### Polymethyl Methacrylate (PMMA)



- **Repeating unit** - structure composed of the minimum number of structural units necessary to generate the Polymer

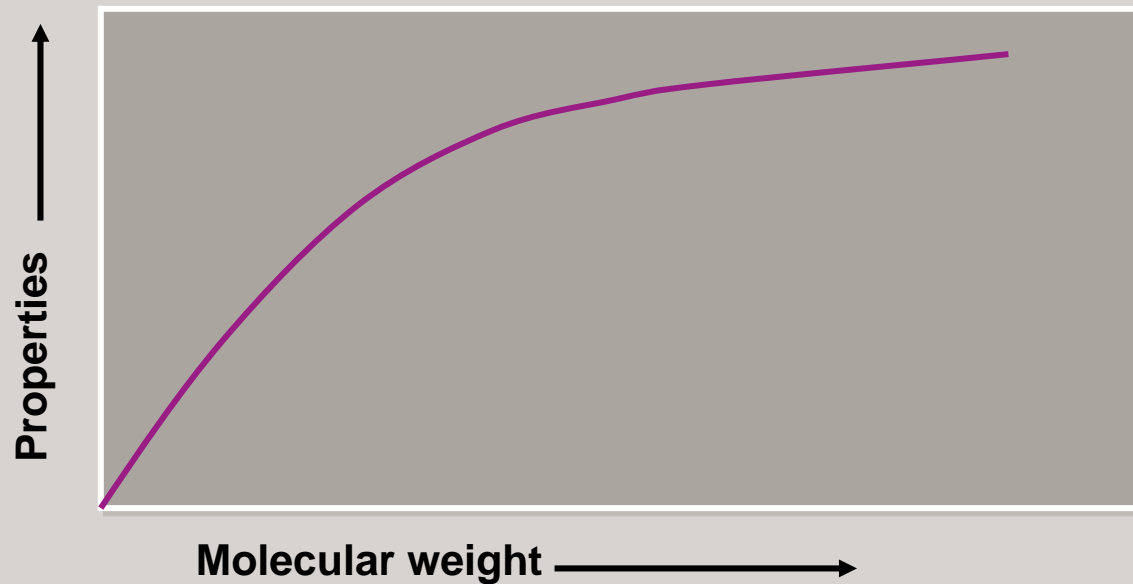


- **Degree of polymerization** - number of repeating unit



# Chemistry of Acrylic Polymers

Influence of the molecular weight:



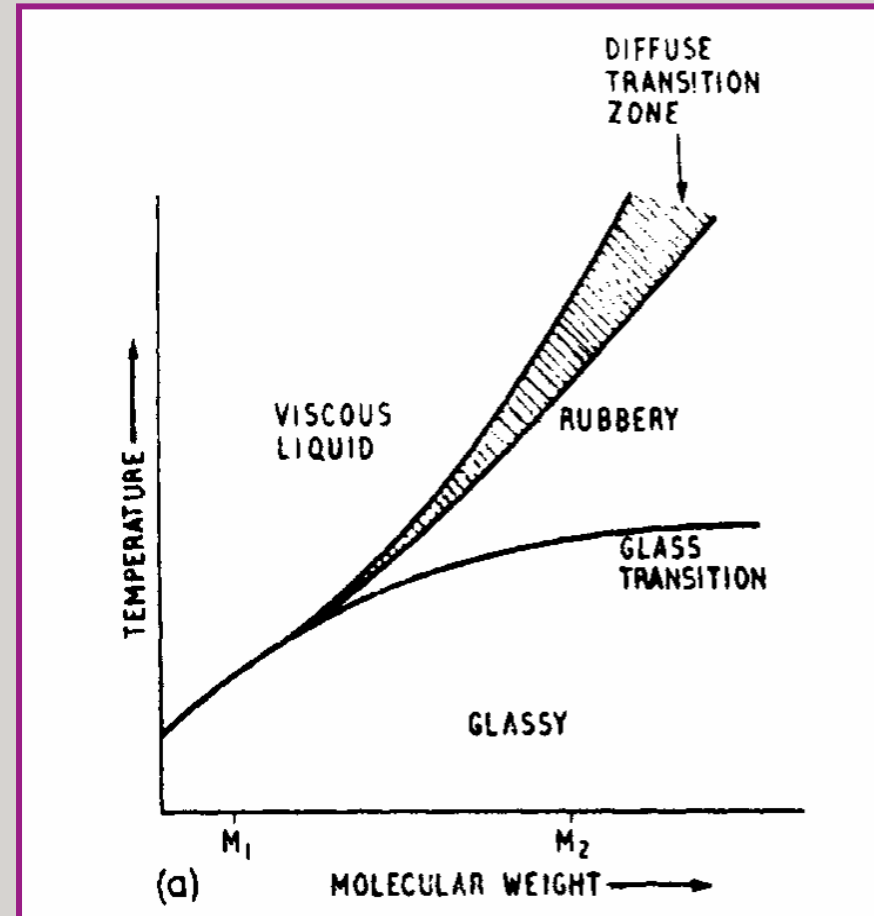
Increase of molecular weight means :

- Higher strength
- Higher toughness
- Better long term behavior
- Higher chemical resistance
- Higher stress resistance

# Chemistry of Acrylic Polymers

## Thermoplastics:

- Materials become fluid and processible upon heating
- Can be transformed into desired shapes stabilized by cooling
- No chemical change, or cross linking of molecules, occurs during heating and cooling
- When a thermoformed object is re-heated, it will soften again and can be re-formed or left to return to its original shape.

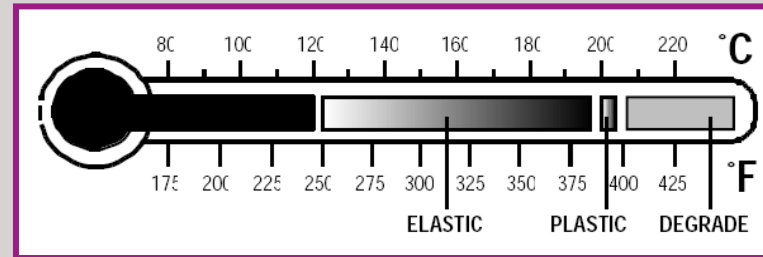


# Chemistry of Acrylic Polymers

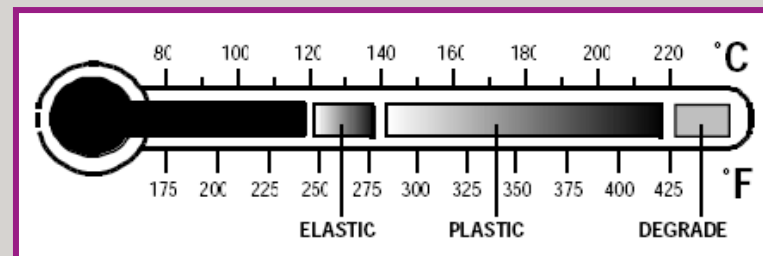


## Thermoplastics:

Cast Acrylic Sheet



Extruded acrylic is made from the same monomer as cast acrylic, but the different production process gives it some different characteristics.



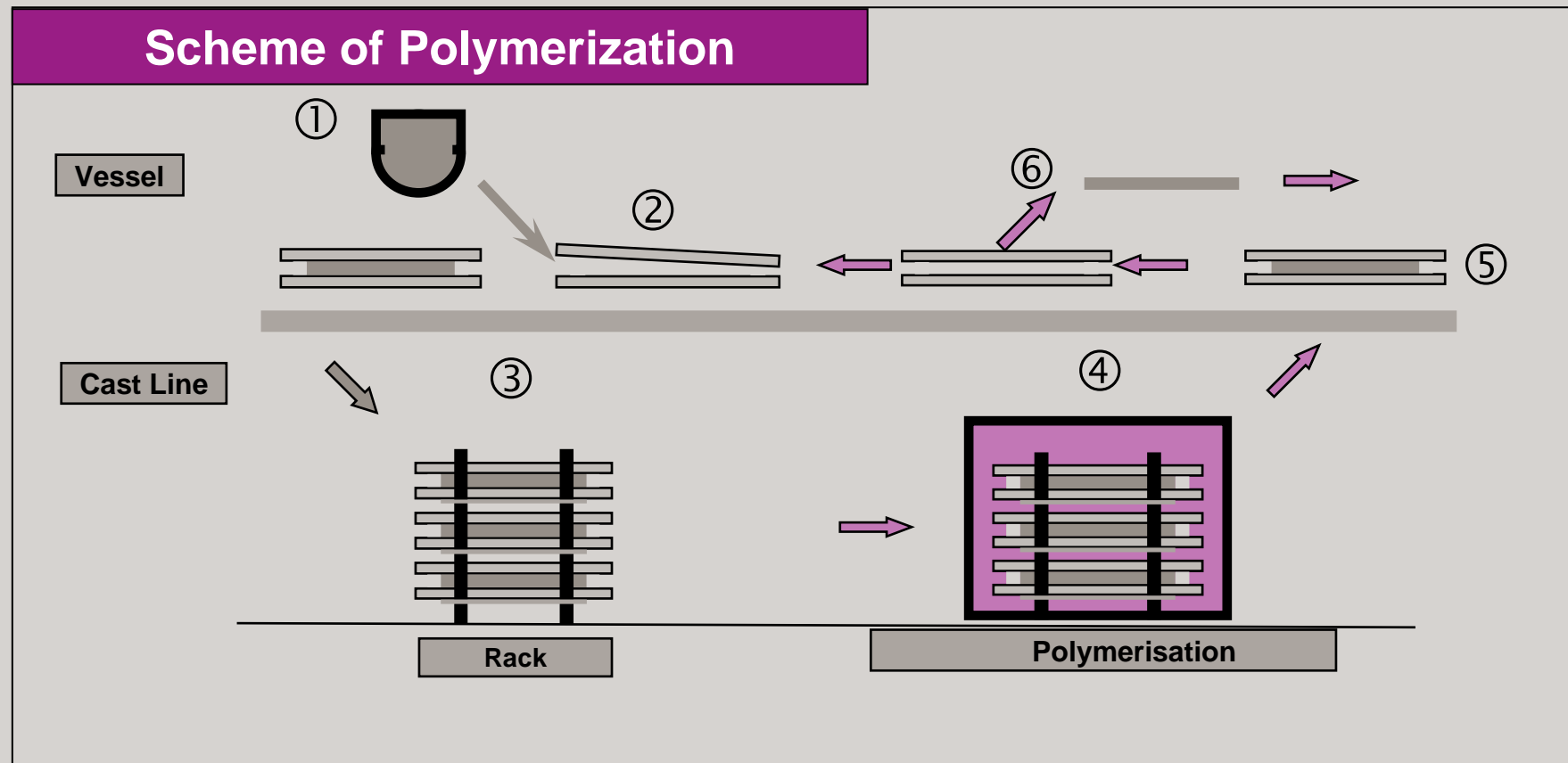
Extruded Acrylic Sheet



**Production & Technology**

# Production of Cast Aviation Grade Sheets

- In bulk polymerization liquid monomer, additives and initiator (1) are fed into the glass cell (2)
- Polymerization is carried out at a defined temperature (3+4) in order to afford a solid state (polymer product)
- At the end of the polymerization the acrylic sheet (6) and the glass sheets are separated from each other (5)



## Properties of Cast Aviation Grade Sheets

# Properties of Cast Aviation Grade Sheets



## General Properties cast acrylic sheet:

- Crystal-clear
- Excellent transparency
- Light weight (half the density of glass)
- UV stable (no yellowing)
- Easy to polish (slight scratches during handling can be removed, maintenance of used windows by polishing)
- Smooth surface
- Surface hardness (compared to other plastics)
- Scratch resistance (compared to other plastics)



# Properties of Cast Aviation Grade Sheets

The special polymer structure of cast aviation grade sheets lead to:

- Good long-term mechanical behavior
- Chemical resistance
- Stress crack resistance
- Resistance to alternating temperature
- Long-term weather resistance

Cast aviation grade sheets show excellent optical properties:

- High surface quality (very limited impurities)
- Minimum optical distortion
- Minimum optical deviation





**Product Portfolio**

# Product Portfolio



## Cast Aviation Grade:

**Thickness:** 2 to 25 mm (.08" to 1.00")  
**Standard sizes:** up to 3050 mm X 2030 mm (120" X 80")

- qualified product (customer receives a certificate with product properties measured for each batch of production)
- is a cast acrylic with specially developed to meet the high optical requirements of the aviation industry
- UV-transmittance less than 1 %
- can be supplied in both clear-transparent and transparent colored grades

# Product Portfolio



## Cast Aviation Grade, cross linked

**Thickness:** 2 to 100 mm (.08" to 4.00")  
**Standard sizes:** up to 3050 mm X 2030 mm (120" X 80")

- qualified product (customer receives a certificate with product properties measured for each batch of production)
- is a cast acrylic specially developed to meet the high demands by the aviation industry, but is **additionally cross-linked**
- UV-transmittance less than 1 %
- offers higher resistance to media that cause stress cracking and a higher heat deflection temperature
- is classified as a material with “improved moisture absorption resistance“ with less than 2.2 % water absorption after long-term exposure
- is also excellently suited for stretching, which makes it possible to improve its properties even further over the un-stretched state
- can be supplied in both clear-transparent and transparent colored grades

# Product Portfolio



## Colored cast aviation grade sheets:

Blue, green, grey and brown tints are available with various light transmission rates

Light transmission	Typical application
> 70%	Windshields, pilot windows
Between 70 % and 50 %	Passenger cabin windows
< 50%	Sun shades



**Approvals & Specifications**

# Approvals & Specifications

## Properties to be specified:

- ***Optical Properties***  
Surface defects, scratches, inclusions, lints, optical distortion
- ***Thickness tolerances***
- ***Mechanical Properties***  
Tensile stress, Tensile strain, Modulus of elasticity, Impact strength
- ***Thermal Properties***  
Vicat softening temperature, Coefficient of linear thermal expansion

**Application**

**Processing**

# Approvals & Specifications

## Specifications by countries:

	Germany	France	U.K.	AECMA	U.S.	Russia
<b>PLEXIGLAS® GS 245</b>	meets WL 5.1412	meets AIR9106/A Type I	type approved to DTD 5592 A	meets prEN 4364	meets MIL-PRF-5425	meets or exceeds GOST 10667-90
<b>PLEXIGLAS® GS 249</b>	meets WL 5.1415	meets AIR9106/A Type II	type approved to DTD 5592 A	meets prEN 4365	qualified to MIL-PRF-8184 Type I; Class II	meets or exceeds GOST 10667-90
<b>correctly stretched PLEXIGLAS® GS 249</b>	meets or exceeds WL 5.1416	meets AIR9106/A Type III		meets prEN 4366	meets or exceeds MIL-PRF-25690	

**Note:** Evonik Industries' Business Unit Performance Polymers is a worldwide manufacturer of PMMA products sold under the **PLEXIGLAS®** trademark on the European, Asian, African and Australian Continent and under the trademark **ACRYLITE®** in the Americas.

# Approvals & Specifications



## Specifications by countries:

	U.S.	Germany	France	Great Britain	AECMA	Russia
<b>ACRYLITE® GMU</b>	meets AMS-LP-391 ASTM-D-4802	Cast aviation grade sheets according to European specifications can also be provided				
<b>ACRYLITE® GMS</b>	Qualified to MIL-P-5425					
<b>ACRYLITE® GS 249</b>	Qualified to MIL-P-8184 Type II, Class2					

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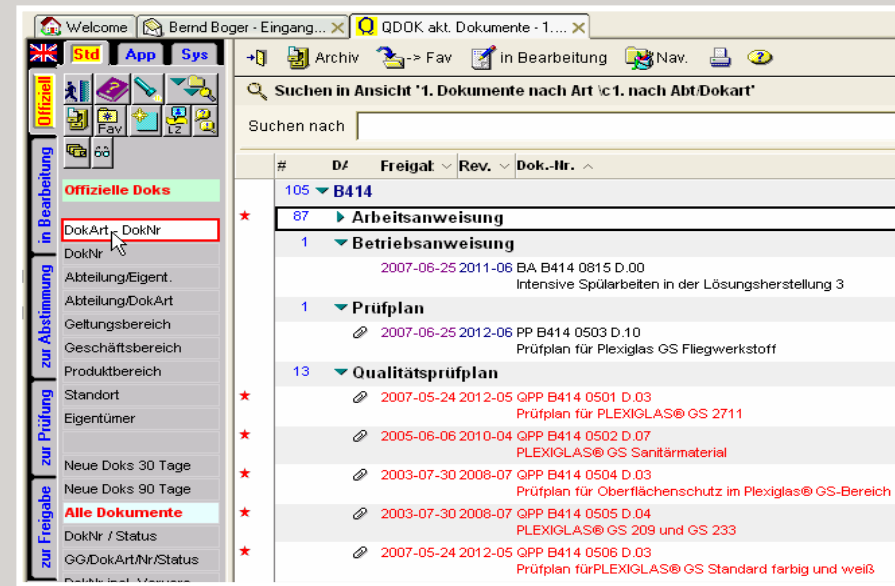
**Quality Management**

# Quality Management



## Quality Documents

- All internal *Quality Documents* are stored and distributed over a database
- Manual of Quality Management
- Process descriptions
- Work instructions
- Test plans
- Quality plans
- Internal Product Specifications
- Customer Specifications
- Job Safety Analysis
- Access to database is provided world-wide to all production sites and sales departments



# Quality Management



## Certificate of Analysis (COA) created in SAP

Evonik RÖHM GmbH, D-64275 Darmstadt

**Inspection certificate 3.1  
EN 10204**

**Business Unit Performance Polymers**

Purchase order item/date  
12186 / 2008/12/08

Delivery item/date  
33197449 000001 / 2009/01/28

Order item/date  
22788150 000001 / 2008/12/08

PLEXIGLAS® GS farblos 245P0 GT  
Platte 3050 \* 2030 \* 3,00 mm  
besäumt  
alte Sorte: 245P0  
WL 5.1412.0 DIN 65321 AECMA prEN 4364

Batch : 56149182  
Quantity : 20 EA

Your material no. : 905.25.0014

**Results of quality inspection**

Property	Test method	Unit	Value	Specification min.	max.
Vicat softening temperature	DIN 53460 / B50	°C	116	105	
Visible light transmission	DIN 5036, Part 3	%	92	91	
UV-transmission(240-360nm)	DIN 5036, Part 1,3	%	0		5
Optical deviation	EN 2155-7	Min of Arc<	10		10

We hereby confirm that the properties of the delivered materials agree with the values and comply with the standards mentioned above.  
Statement of the above data does not release the buyer from his legal obligation to examine the material upon receipt. These data cannot be construed as a legally binding warranty or guaranty of certain product properties or of the suitability of the product for a specific application.

Date: 2009/01/19

**Evonik Röhm GmbH**  
H.-J. Neske (Quality Manager Inspection)

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Sitz der Gesellschaft: Darmstadt  
 Handelsregister-Nr.: HRB 03142  
 USt-IdNr.: DE24676304  
 Steuernummer: 112 5708 0510

Geschäftsführer:  
 Oliver Reiche, Sprecher  
 Dr. Rainer Pölz  
 Dr. Rüdiger Wöhrle-Hering

Deutsche Bank AG Darmstadt, Kto.-Nr. 230 304  
 BIC: 25120310 SWIFT Code: 25120310  
 IBAN: DE15 09 00 00 00 00 00 00 00

Evonik Röhm GmbH  
 Kassenkonto  
 D-64275 Darmstadt

Deutsche Bank AG Darmstadt, Kto.-Nr. 230 370 00  
 BIC: 25120310 SWIFT Code: 25120310  
 IBAN: DE34 09 00 00 00 00 00 00 00

Vorstand der Aufsichtsrats:  
 Ralf Wothmann

Telefon: + 49 (0) 61 51 71 8-01  
 Telefax: + 49 (0) 61 51 71 8-02  
 Internet: www.evonik.com

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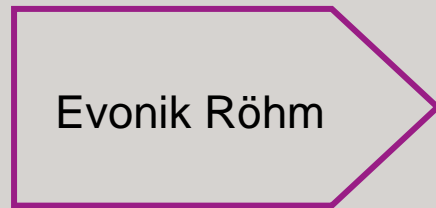
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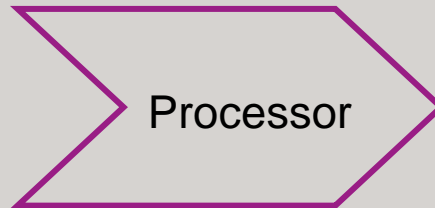
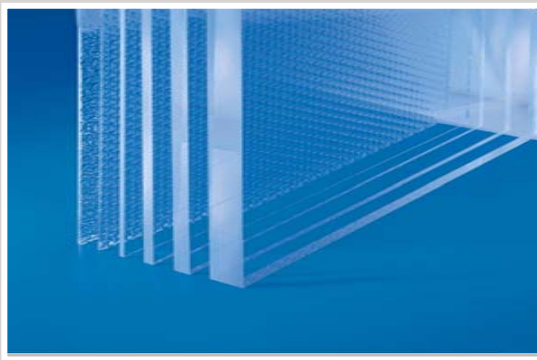
# Supply Chain



## Reliable Supply Chain of Cast Aviation Grade Sheets:



Flat sheet



Forming



Installation of Glazing



# Application in Aviation Industry – References



Aircraft



Helicopter



## Aviation Industry

Military Jets



General Aviation



# Application in Aviation Industry – References



## Civil Aircrafts:

Airbus Industries: **A300, A310, A318, A319, A320, A321, A330, A340**

Dassault: **Falcon Series**

Bombardier: **Business Jets**

Raytheon **Business Jets**

AIR: **ATR 42, ATR 72**

Avro **RJ 70, RJ 85, RJ 100 (Bae 146)**

Fairchild-Dornier (HAL): **228, 328**

Casa: **C212, CN 235, CN 295**



# Application in Aviation Industry – References



## Military Jets:

Panavia: **Tornado**

Dassault: **Mirage F1, 3, 2000 etc., Rafale, Alpha Jet**

Eurofighter GmbH: **Eurofighter Typhoon**

Saab: **350E Draken, JA 37 Viggen, JAS 39 Gripen**

British Aerospace Systems: **Harrier, Hawk**

Aero Vodochody: **L 39, L 139, L 159**

Sepecat (HAL): **Jaguar**

HAL: **MiG 21, MiG 27**



# Application in Aviation Industry – References



## Helicopter:

Eurocopter France: **Complete model range**

Eurocopter Germany: **EC 135, EC 145, Tiger**

Agusta: **A 109 all variants**

Bell/Agusta: **AB 139**

British Aerospace Systems: **Harrier, Hawk**

NH-Industries: **NH 90**

HAL: **Cheetah, Chetak, ALH**

Westland/Agusta: **EH 101**





# Application in Aviation Industry – References



## General Aviation:

Most European manufacturers

- Pilatus
- Diamond
- Cessna
- Piper

