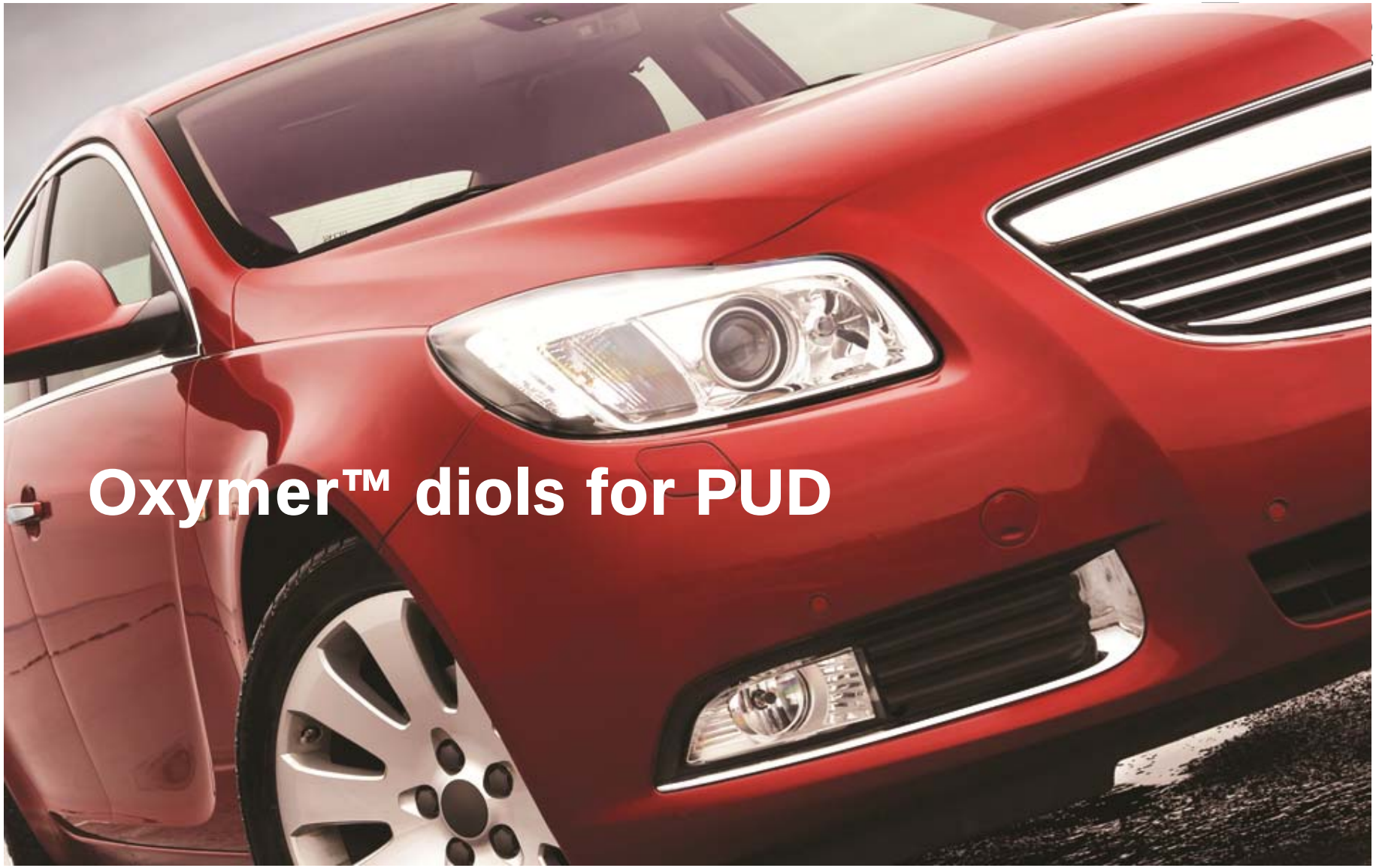

Oxymer™ diols for PUD

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Outline

- High performance diols for polyurethane dispersions
  - Oxymer™ Polycarbonate polyols
- Experimental
  - Polyurethane dispersions
- Results
  - Coating performance
- Conclusion

Oxymer™ – polycarbonate diols

Polycarbonates offer

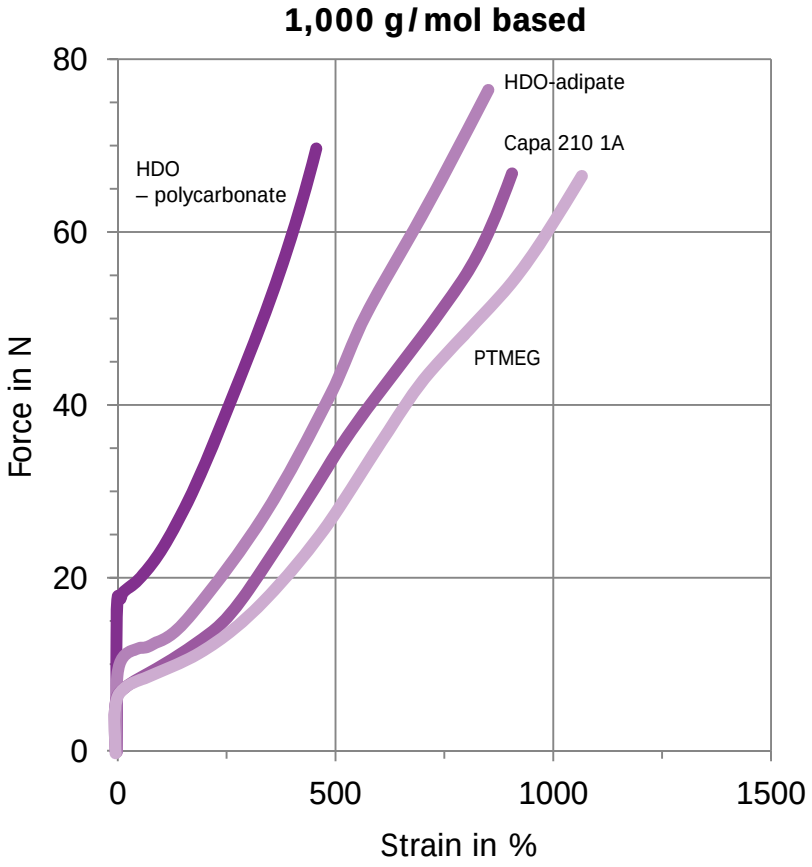
- High chemical resistance
- Very good hydrolysis and UV resistance
- Excellent outdoor durability
- Overall high performance

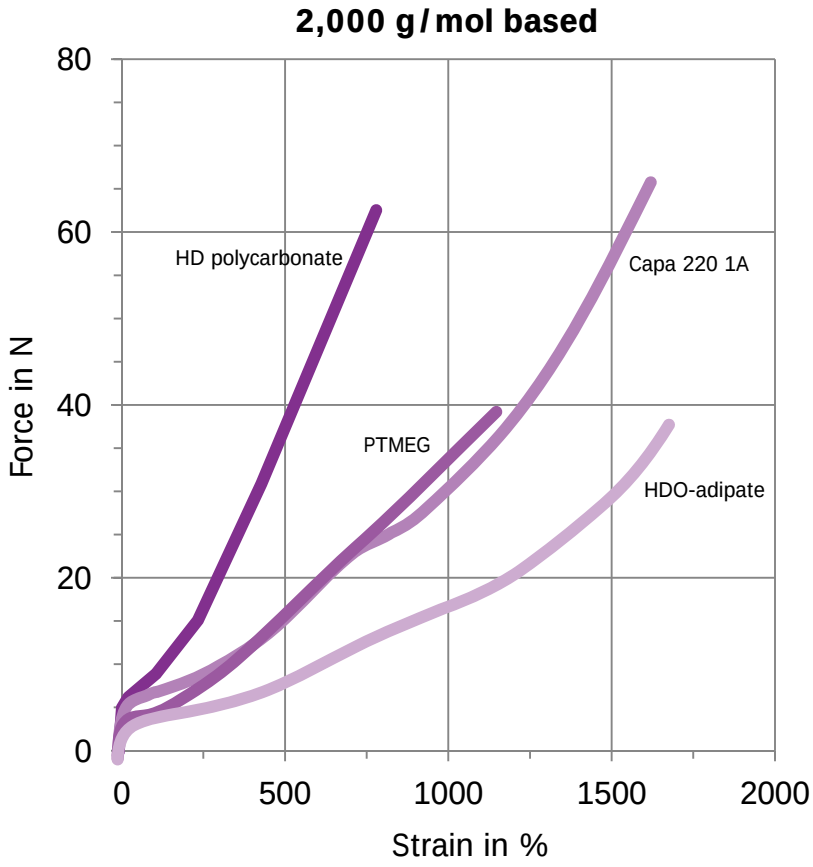
Perstorp's range of polycarbonate polyols includes Oxymer™ M112 and C112

- Oxymer™ polycarbonate diol are based on rigid carbonate-linkage and branched aliphatic 1,3-diols
- Oxymer™ no crystallinity, high hydrophobicity and low surface energy

Tensile properties – flexibility

The polycaprolactones are very suitable for applications with high demands on flexibility





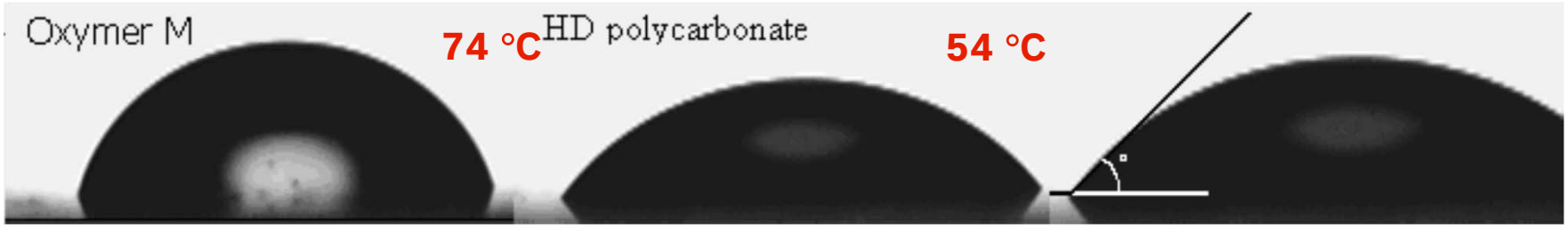
The characteristics of Oxymer™ M112

Oxymer™ M is a rigid hydrophobic diol

- Low surface energy due to hydrophobic side-branches
- Excellent acid and alkali resistance
- High hardness
- Very good outdoor durability and hydrolytical stability
- Recommended for rigid substrates, e.g. metal

Waterdrop contact angle (θ) on polyurethane coating with

Oxymer™ M112 and 1,6-Hexanediol polycarbonate as macrodiol



The characteristics of Oxymer™ C112

Oxymer™ C is the more flexible diol in the range

- Very good outdoor durability
- Excellent hydrolytic stability
- Improved flexibility and abrasion resistance compared to Oxymer™ M
- Improved wetting and adhesive properties (substrate dependant)
- Very good alkali and acid resistance
- Suitable for plastic and wood substrate

A winning formula for performance

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Materials and PUD preparation

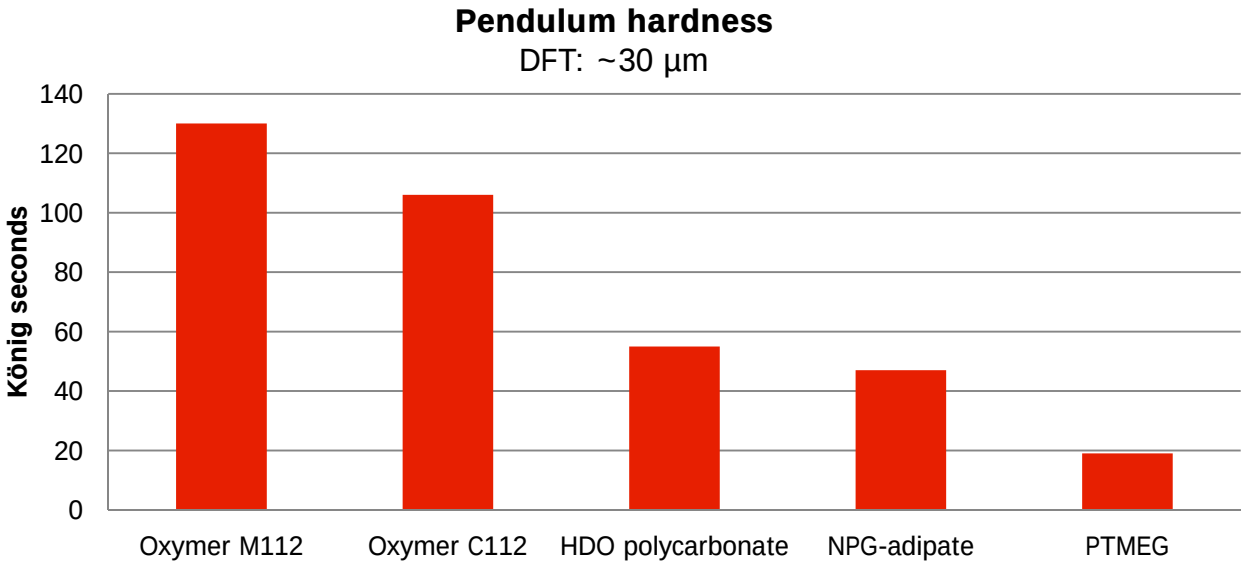
Oxymer™ – liquid polycarbonate diols based on substituted aliphatic diols

Oligomer	Physical state (RT)	T_m/T_g (°C)	Viscosity (Pas) 75°, 60^{-1}s
Oxymer™ M112	Clear viscous liquid	-23	1.1 (75 °C)
Oxymer™ C112	Clear viscous liquid	-33	1.5 (75 °C)
HDO-PCD	Solid	-61	0.4 (75 °C)
PTMEG	Solid	ND	0.1 (75 °C)
NPG-Adipate	Solid	-55	0.4 (75 °C)

Oxymer™ M112 and C112 were evaluated in physically drying PUDs prepared using the pre-polymer mixing process

Oxymer™ increases coating hardness

Including Oxymer™ in your formulation will increase the coatings hardness.

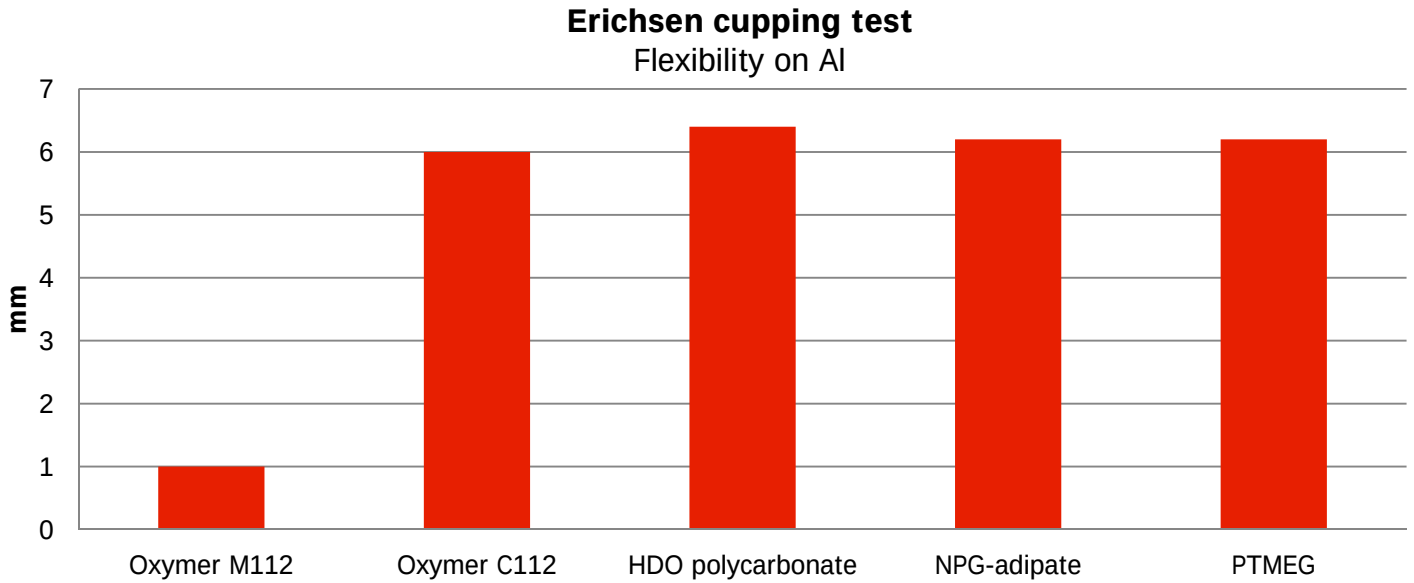


Oxymer™ M112 is the more rigid diol

Flexibility of physically dried polyurethane dispersion measured as Erichsen flexibility on force dried films (25 µm ± 5 µm or 24 h at 80 °C) on aluminum panels.

Oxymer™ C maintains flexibility

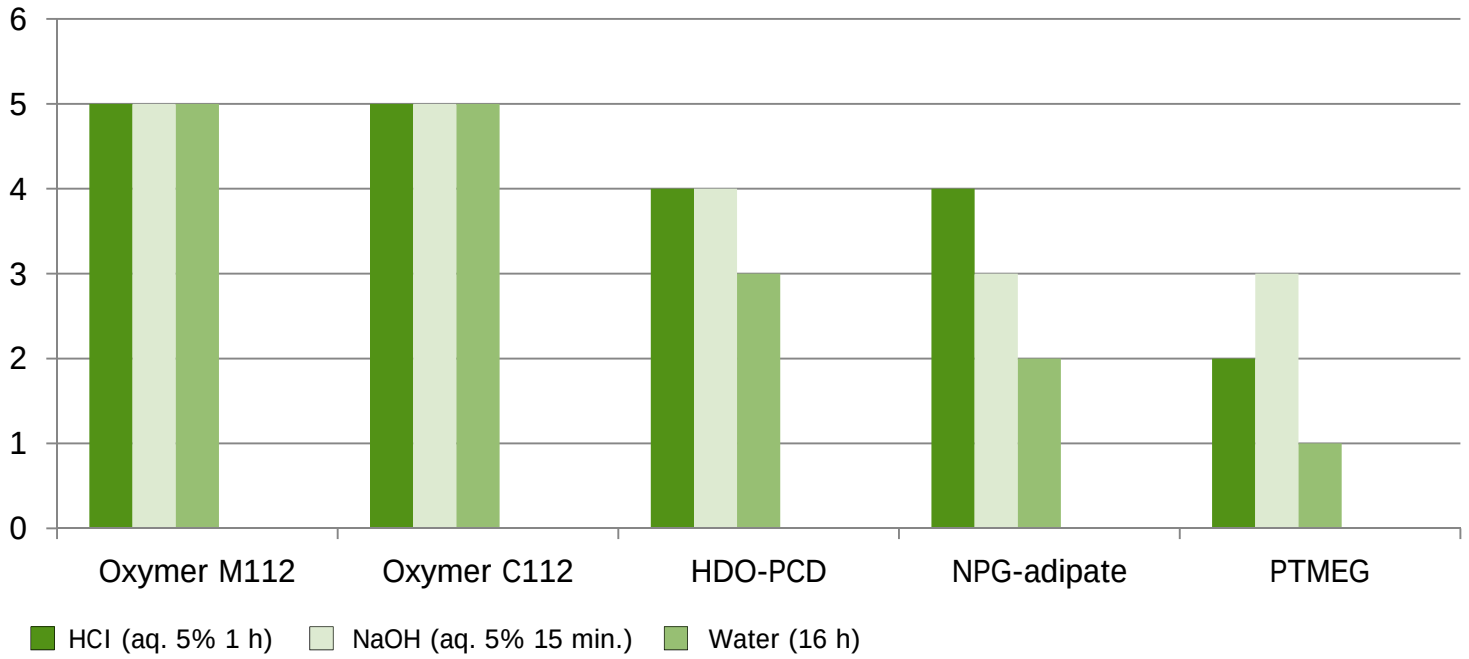
Oxymer™ C112 manages to combine coating hardness with flexibility

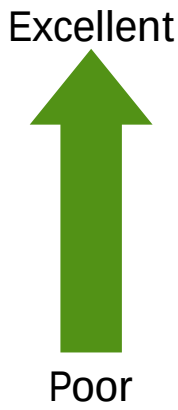


Evaluated on Aluminum plates using Erichsen cupping test
Forced dried samples 24 h at 80 °C. Dry film thickness
25 μm ± 5 μm on Al.

Polyurethanes with Oxymer™ have improved resistance to acid and base

Oxymer™ display excellent resistance towards both alkali and acidic media



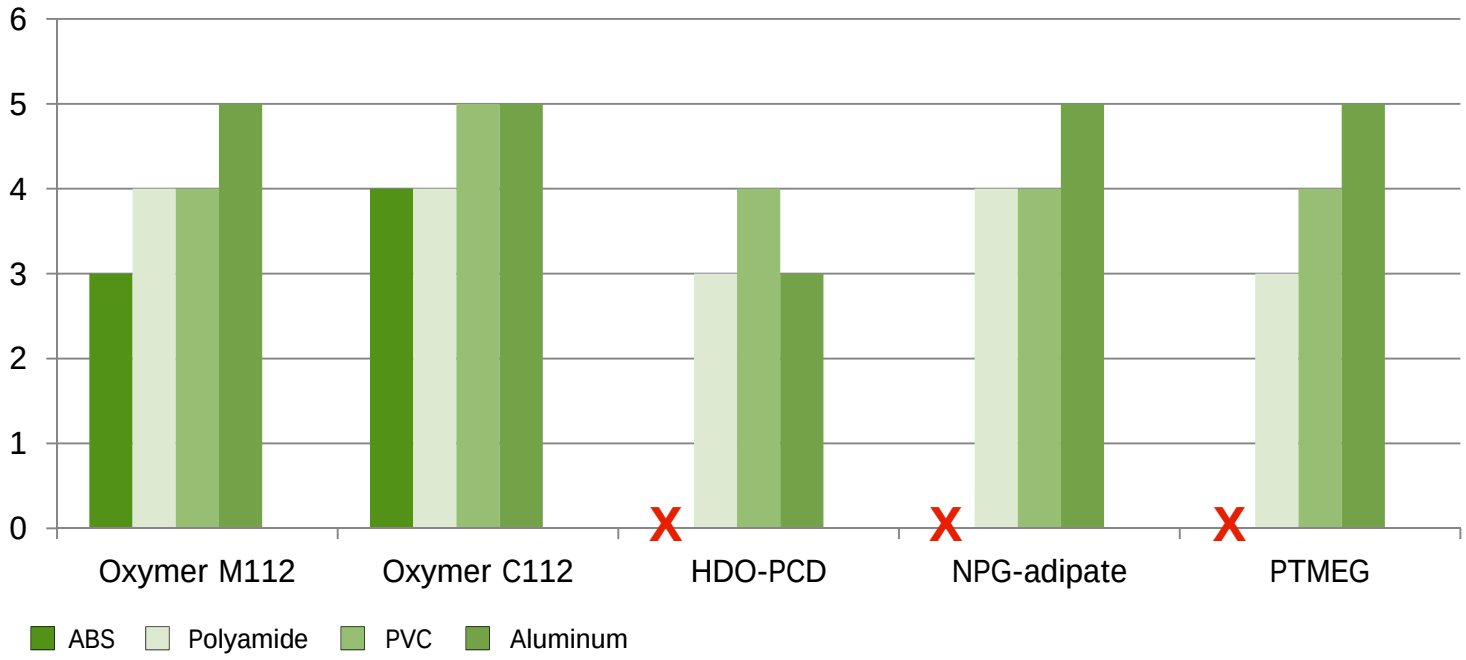


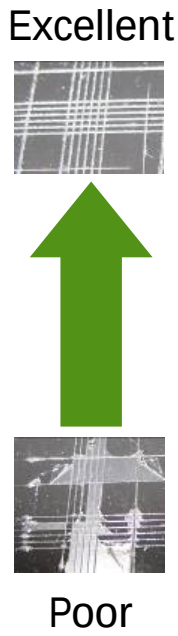
Evaluated by chemical spot tests. 5-1, where 5 = no visible change;
1 = distinct mark with altered surface Forced dried samples 24 h at 80 °C.
Dry film thickness 30 μm ± 5 μm on glass panels.

Oxymer™ offers improved wetting and adhesion to plastics

Oxymer™ has low surface tension → Improved wetting and adhesion

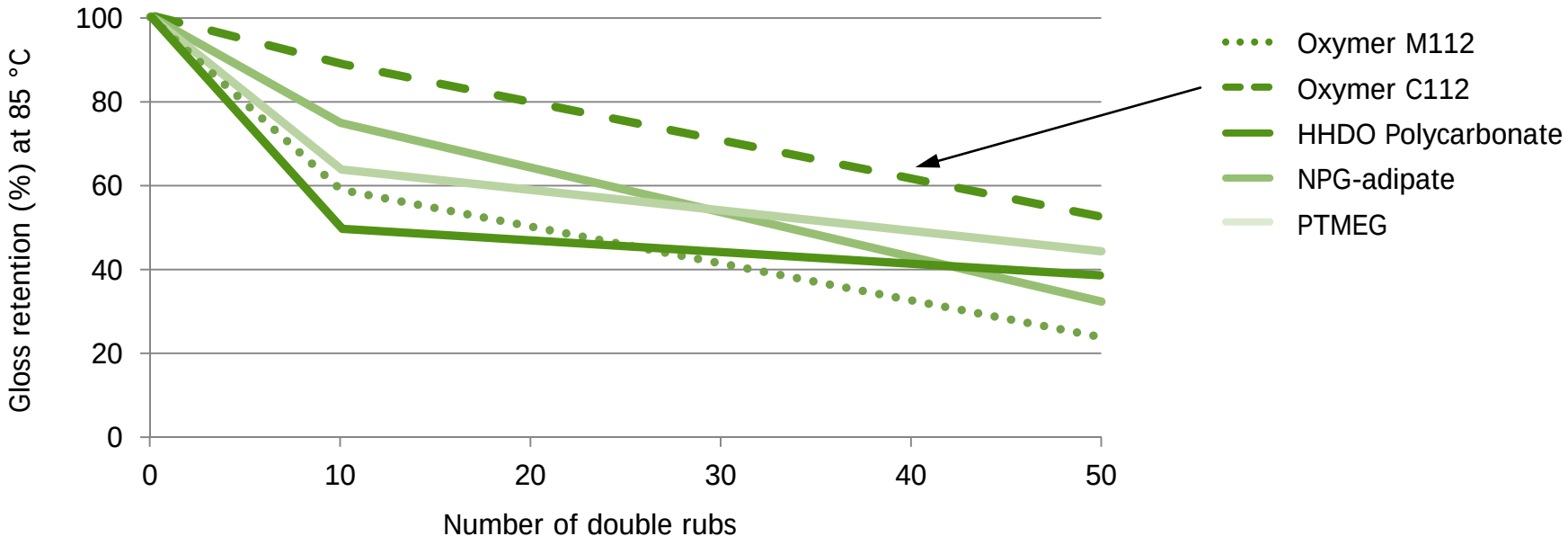
Oxymer™ display improved adhesion to both plastic and metal substrates





Oxymer™ C improves abrasion resistance

The combination of hardness and flexibility of Oxymer™ C112 results in good abrasion resistance



Abrasion resistance evaluated using Scotch Brite gloss retention test – 1,000 g/mol macrodiols Forced dried samples 24 h at 80 °C. Dry film thickness 25 μm ± 5 μm on black glass panels.

UV-PUD with Oxymer™

Macrodiol	50.09
Bis-MPA	6.71
Di-propylene glycol di-methyl ether	40.00
DBTL 100%	2 drops
IPDI	33.34
Di-TMP tetra acrylate (Ebecryl 140)	25.00
4-metoxyphenol	0.025
TEA	4.30
Water	245.06
Ethylene diamine	2.70
Summa	**407.70**

NCO/OH	1.5
Extender NH/NCO	0.9
Neutralization, %	85
Solid content, %	30

The UV-PUDs were mixed with Irgacure500 (1.5% w/w).

UV-PUD, hardness

Thin coatings

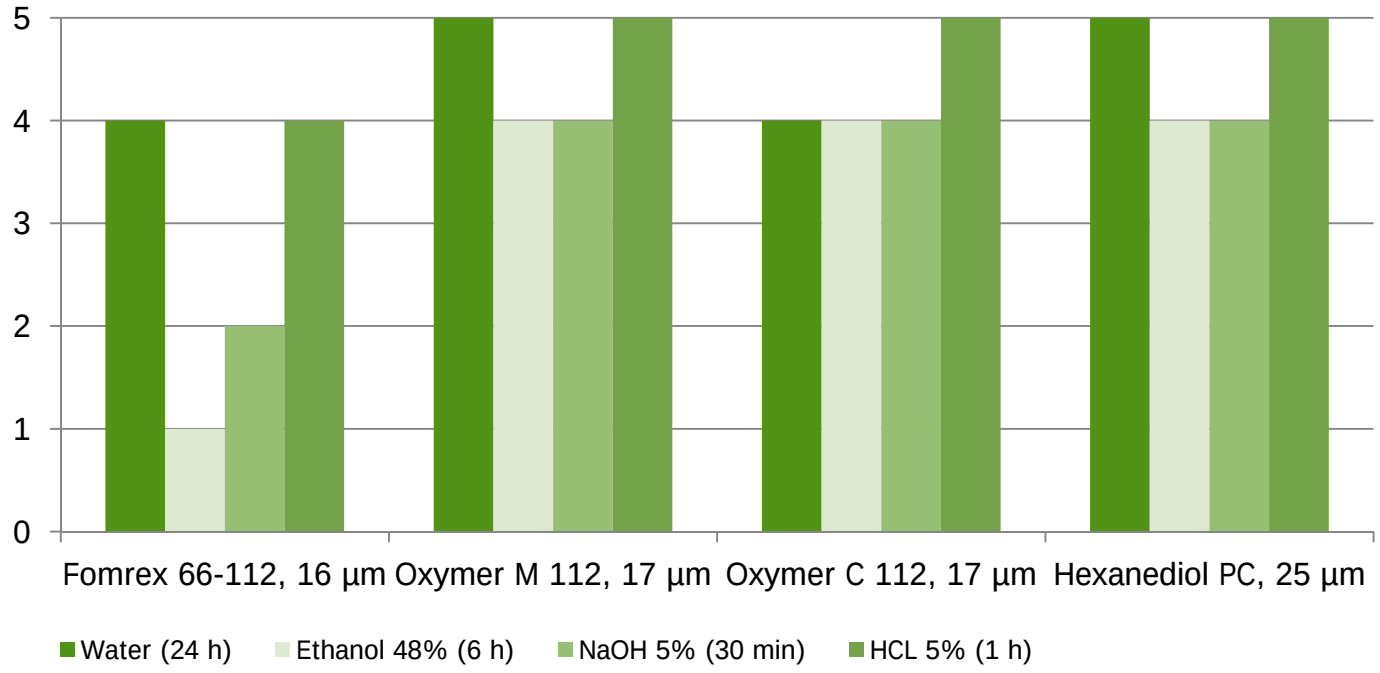
Sample	Thickness	Pendulum hardness	Pencil hardness
Fomrez 66-112	22	110	H/2H
Oxymer M 112	20	201	6H/7H
Oxymer C 112	25	180	6H/7H
Hexanediol polycarbonate	25	154	3H/4H

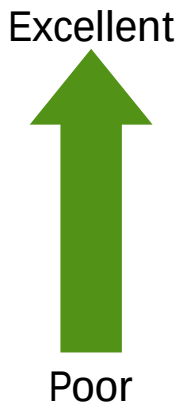
Thicker coatings

Sample	Thickness	Pendulum hardness	Pencil hardness
Fomrez 66-112	44	87	2H/3H
Oxymer M 112	42	153	6H/7H
Oxymer C 112	42	138	5H/6H
Hexanediol polycarbonate	42	118	6H/7H

Applied on glass panels, force dried at 80 °C for 30 minutes.
Evaluated 1 week after curing.

UV-PUD, chemical resistance





Note: Varying thickness of coatings

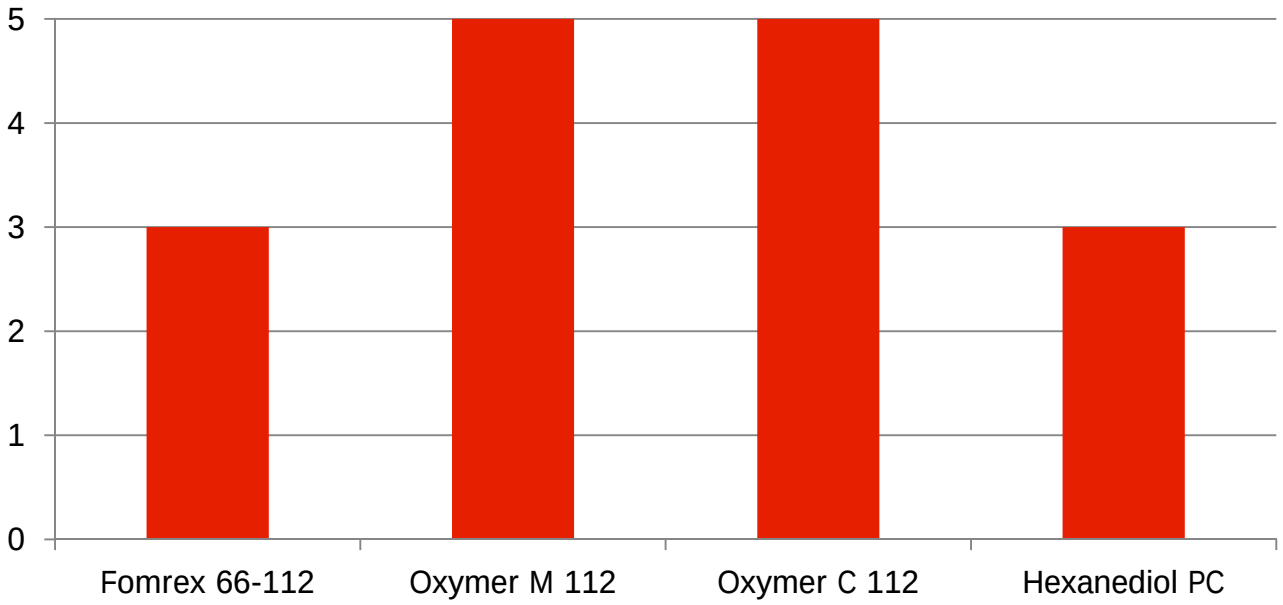
Applied on glass panels, force dried at 80 °C for 30 minutes.
Chemical spot test 1 week after curing, evaluation 24 hours after testing.

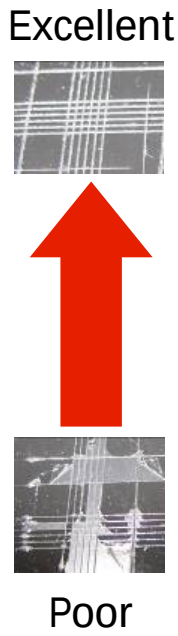
UV-PUD, MEK and flexibility

Sample	MEK	Erichsen flexibility
Fomrez 66-112	40	> 6.0
Oxymer M112	160	> 6.0
Oxymer C112	130	> 6.0
Hexanediol polycarbonate	30	> 6.0

Thickness ~20 µm.
Applied on Aluminium panels, force dried at 80 °C for 30 minutes.
Evaluated 1 week after curing.

UV-PUD, cross cut adhesion





Thickness ~20 µm.
Applied on Aluminium panels, force dried at 80 °C for 30 minutes.
Evaluated 1 week after curing.

Conclusion

The Oxymer™ products are excellent starting diols for PUDs

- **Oxymer™** polycarbonate diols improves the **resistance against hydrolysis**, has very good **outdoor resistance**, high **hardness** and good **adhesion**
- **Oxymer™ C112** has good **flexibility** and increases the **abrasion** resistance
- **Oxymer™ M112** , the most **hydrophobic** carbonate diol, gives the highest **resistance towards chemicals and solvents (polar**) and offers advantages when applying to **plastic coatings**

Putting the care into chemicals

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PUD formulation

PUDs prepared according to prepolymer mixing

General PUD formation	1,000 g/mol
Macrodiol	16.7
Bis-MPA	2.2
IPDI	10.4
NMP	10.0
DBTL	0.005

Triethyl amine (TEA)	1.4
Water	58.6
Ethylene diamine	0.6
Total	**100.0**

Theoretical data	1,000 g/mol
Bis-MPA/macrodiol molar ratio	1.0
NCO/OH ratio	1.4
NH/NCO ratio	0.8
TEA/COOH ratio	0.85
Non volatile content, % m/m	30

Macrodiols (1,000 g/mol)

- Oxymer™ M112
- Oxymer™ C112
- HD polycarbonate (hexane diol polycarbonate)
- Polyester (neopentyl glycol-adipic acid)
- Polyether (poly(tetramethylene ether)