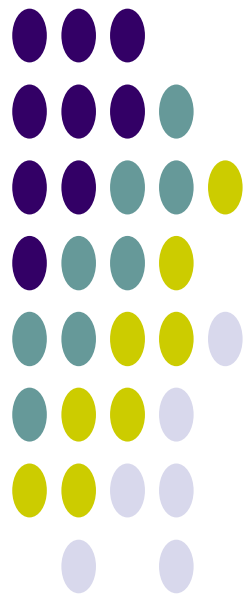


A stylized globe showing the continents of Asia and Australia in white against a blue background, located in the top left corner of the page.

KUREDUX[®]

Polyglycolic Acid (PGA) Resin

For Packaging &
Industrial Applications



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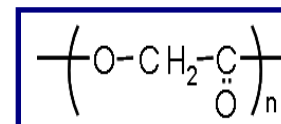
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Kuredux® - Polyglycolic Acid -

Polyglycolic acid (PGA) possesses several distinguished attributes that make it a very useful polymer for today's plastics world. Kureha Corporation's proprietary polymerization technology has resulted in the world's first industrial scale PGA manufacturing facility, allowing the introduction and first commercial widespread use of Kuredux® as a new polymer offering to industry.



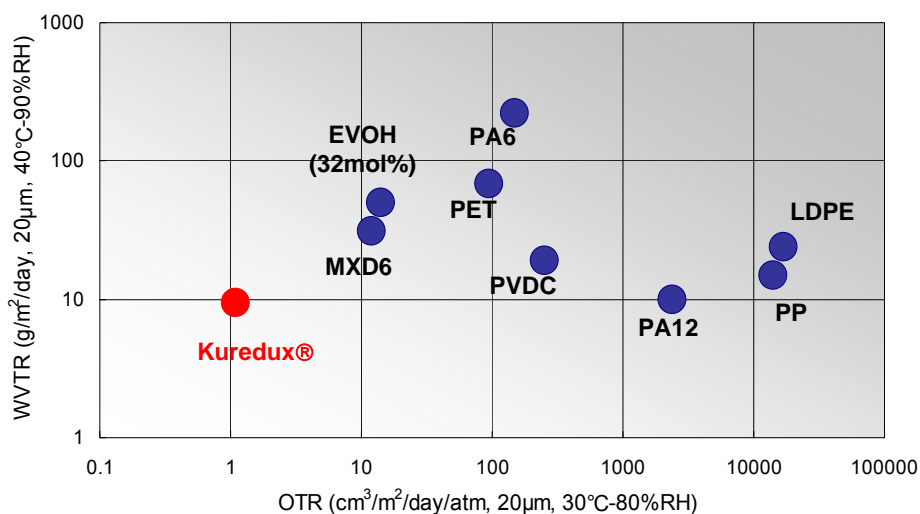
Kuredux® has been specially formulated to deliver outstanding performance and value in a range of packaging and industrial application areas.

Excellent Barrier Properties

Kuredux® has high gas barrier properties (O₂, N₂, CO₂ and moisture vapor) making it an ideal solution to:

- ▶ Insure optimal shelf life of perishable foods
- ▶ Extend the functional shelf life of carbonated beverages
- ▶ Maintain gas environments in modified atmosphere packaging (MAP)

Kuredux® barrier properties are not impacted by high relative humidity conditions -- as are other common barrier materials, like EVOH and polyamide -- making it especially effective for food and beverage packaging in bottle, formed container and flexible film formats.



WVTR and OTR

<Test protocols>

OTR: ISO14663-2

WVTR: ISO15106-2

High Aroma & Flavor Retention

Kuredux® is a desirable packaging material where aroma/flavor is an important part of product quality. Kuredux® demonstrates a high retention rate for commonly used flavor groups such as D-limonene, L-menthol and vanillin.

Aroma Retention Performance

Tested at 30 °C -80%RH

	Thickness (µm)	D-Limonene	L-Menthol	Vanillin
Kuredux®	15	A	A+	A+
EVOH	16	A	A	C
PVDC	10	C	C	C

<Results of lab sensory evaluation>

A+: No failure after 2 weeks

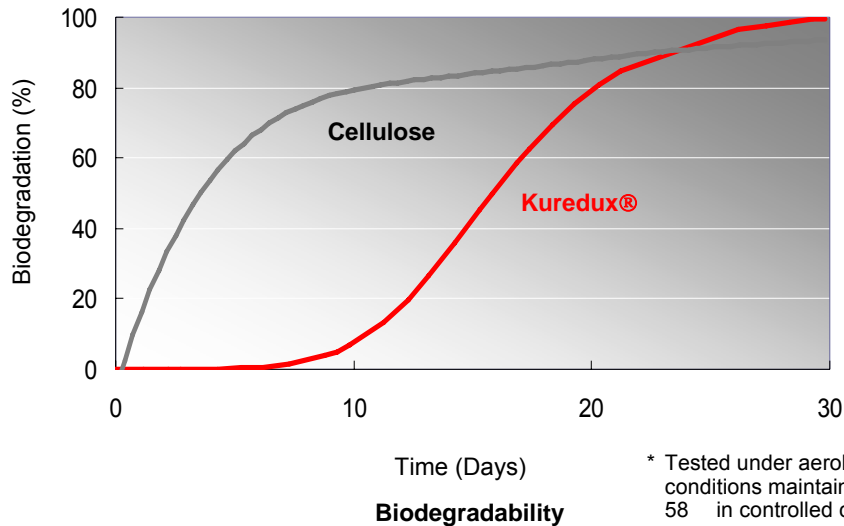
A : Failure after 2 weeks

B : Failure after 1 week

C : Failure within 3 days

Compostability / Biodegradability

Kuredux® is a fully compostable material, satisfying the test protocols for ISO 14855 as well as ASTM D6400 and EN13432. Kuredux® is certified industrially compostable by Vincotte (EU), the Biodegradable Products Institute (US) and JBPA/GreenPla (Japan). The inclusion of Kuredux® into PLA, PHA or other bio-resin constructions can enhance performance properties while maintaining compostability.



* Tested under aerobic conditions maintained at 58 in controlled compost

<Tests based on ISO14855 protocols>

PET Recycling Compatible

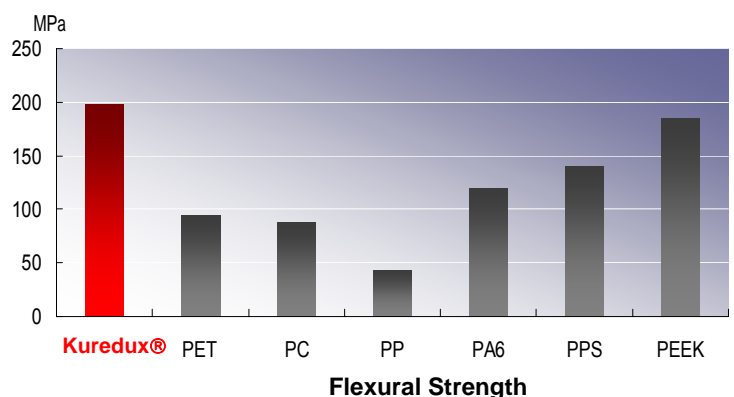
Testing has demonstrated that the inclusion of PGA as a barrier layer in multilayer PET bottles and/or rigid packaging has no material effect on PET recycle processing or resultant rPET quality. Kuredux® rapidly hydrolyzes in alkali wash water conditions ensuring that – unlike other barrier polymer alternatives – it can be chemically separated during the washing of PET flake.

Processability

Kuredux® can be readily extruded or molded by itself or in combination with PET, PP, PE, PLA and other common polymers on conventional processing equipment. Unique material combinations for bottles, sheet, film and fibers are possible via multilayer coextrusion and polymer blending.

High Strength and Modulus

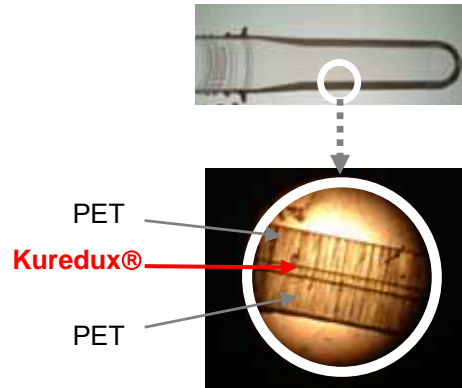
Kuredux® exhibits high mechanical strength and modulus. Flexural strength properties of Kuredux® exceed those of PET, PA, PPS and other polymers.



<Tests based on ISO178 protocols>

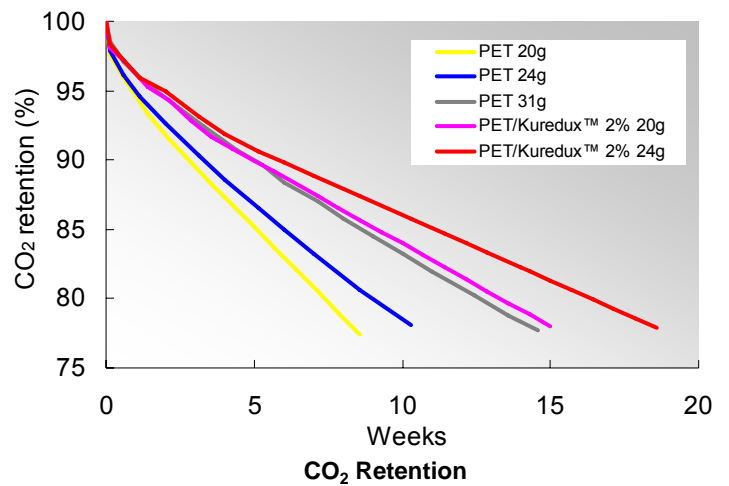
Barrier Bottles

Multilayer PET bottles manufactured with Kuredux® demonstrate significant improvements in CO₂, O₂, moisture and aroma barrier properties. Kuredux® barrier bottles can present innovative and valuable opportunities for source and cost reductions as well as improved product quality.



Shelf life extension for improved product quality, broader product distribution and a better overall consumer experience

- Incorporating as little as 2wt% Kuredux® can significantly extend the measured shelf life of carbonated beverages versus traditional PET bottles.
- Barrier bottles with Kuredux® keep carbonation in and unwanted oxygen out of bottles, allowing perceived freshness and better quality products for your consumers.



Light weighting PET bottles for real source reduction and corporate sustainability goals

- Kuredux's outstanding gas barrier property – nearly 100 times better than PET – makes possible dramatic bottle weight reductions and savings.
- A 2wt% Kuredux® containing bottle allows for a 35% reduction in bottle weight and PET savings, without sacrificing any performance in product shelf life.

Shelf Life Extension

500ml bottles	Weeks to lose 20% of CO ₂
PET 31g	13
PET 24g	9
PET 20g	7.5
PET/Kuredux®(2wt%) ML 24g	16.5
PET/Kuredux® (2wt%) ML 20g	13

Above data are results of quantitative spectrographic tests measured at 22 °C -50%RH (outside) and 22 °C -100%RH (inside).

New small sized/single serving bottle presentations

- Small size PET bottles (<400ml) pose a very difficult shelf life problem, limiting the use and availability. Kuredux® allows for commercially viable shelf life for small bottles and new product possibilities.
- New small bottle presentations can be positioned as high convenience, lower calorie per serving, or lower price point offerings to expand product range and target new consumers.

Glass-to-PET bottle conversion for cost efficiencies

- High barrier Kuredux® bottles can extend shelf life to allow glass replacement in beverage and food applications.
- Lighter weight barrier one-way PET bottles have lower shipping costs and breakage rates, resulting in more convenience and distribution/logistics cost savings versus glass bottles.

Applications of Kuredux® for Barrier PET Bottles include:

- ⊕ Carbonated soft drinks
- ⊕ Juices
- ⊕ Beer, Wine
- ⊕ Vitamin fortified water, Isotonics
- ⊕ Condiments
- ⊕ Cosmetics, Health & Beauty products
- ⊕ Household cleansers and products

Sustainable & Responsible Use of Multilayer Barrier Containers

- Kuredux® has been proven compatible with industrial PET recycling processes. Kuredux® is easily dissolved in the alkaline wash water stages of rPET processing, assuring a simple and complete chemical separation of PGA from the valued rPET flake.
- Kuredux® bottles satisfy the new polymer ingredient and bottle-to-bottle recycling test protocols for PET developed by the Association of Postconsumer Plastics Recyclers (US).
- For other environmentally friendly bottle or container solutions, Kuredux® can also be combined with polylactic acid (PLA) or other renewably sourced polymers. Kuredux's superior gas barrier performance can compensate for the limited properties associated with many of these alternative, but increasingly attractive, bio-resin materials.



PLA/Kuredux® ML bottle
for cooking oil

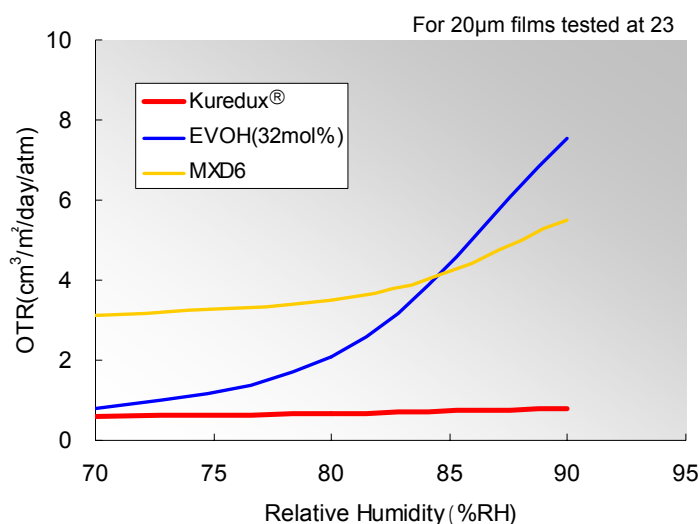
Barrier Sheet, Film & Other Packaging Materials

Kuredux® can serve as a core material for value-added packaging materials. Outstanding barrier, processability and mechanical properties enable Kuredux's inclusion in a variety of protective packaging applications.



Barrier Properties

- Kuredux® possesses excellent gas barrier properties, inhibiting oxygen ingress that can lead to spoilage and rancidity of perishable foods and/or containing CO₂ and nitrogen for gas flushed/MAP applications. Kuredux® also exhibits excellent aroma barrier.
- Kuredux® barrier properties are largely insensitive to relative humidity levels, making it extremely effective for a broad range of food packaging and environmental/storage conditions.



Humidity Sensitivity of OTR

<Tests based on ISO14663-2 protocols>

Processing/Converting

Kuredux® can be easily extruded or coextruded with a wide variety of polymers to create multilayer barrier sheet and film constructions. Subsequent conversion of Kuredux® via thermoforming, printing, lamination and other downstream processing to final end-products has been demonstrated under standard operating conditions.

Mechanical Properties

Kuredux® is a strong, tough, stiff material that imparts excellent barrier integrity and abuse resistance to rigid, semi-rigid and flexible packages materials.

Mechanical Properties of Oriented Films

*Calculated by 0.1-1.0% elongation

	Tensile Modulus (GPa) MD / TD	Tensile Strength (MPa) MD / TD	Tensile Elongation (%) MD / TD
Kuredux®	7.0* / 5.5*	380 / 250	40 / 80
EVOH (32mol%)	4.0 / 3.7	210 / 200	100 / 110
PET	3.9 / 4.0	230 / 240	100 / 90
PA6	1.5 / 1.0	206 / 290	105 / 65

<Tests based on ISO527-3 protocols>

Compostability

Kuredux's unique combination of barrier properties and compostability provide an attractive opportunity for introducing high performance eco-friendly packaging concepts. Inclusion of Kuredux® into PLA or other bio-resin structures can enhance performance significantly while retaining sustainability and environmental claims for products.

		Test Method	Unit	Kuredux®	
Specific Gravity		ISO1183-1	-	1.50 ~1.60	
Mechanical Properties					
Injection Molding	Tensile Strength	ISO527-1,2	MPa	117	
	Tensile Elongation	ISO527-1,2	%	13	
	Flexural Modulus	ISO178	GPa	7.6	
	Flexural Strength	ISO178	MPa	195	
	Charpy Impact Strength	ISO179	kJ/m ²	2.2	
	Izod Impact Strength	ISO180 Notched	J/m	29.2	
	Rockwell Hardness	ISO2039-2 M-scale	-	111	
Oriented Film (20µm) *Stretch ratio: MD5.0, TD3.5	Tensile Modulus	ISO527-3	MD	7.0	
			TD	5.5	
	Tensile Strength	ISO527-3	MD	380	
			TD	250	
	Tensile Elongation	ISO527-3	MD	40	
			TD	80	
Thermal Properties					
Crystal Melt Temperature		ISO11357 (DSC) Initial Temperature: -50°C Final Temperature: 280°C Heating rate: 20°C /min Purge Gas: N ₂ 50ml/min	°C	220	
Glass Transition Temperature			°C	40 (oriented film: 50)	
Coefficient of Linear Thermal Expansion		ISO11359	1/K	5.4 × 10 ⁻⁵	
Heat Deflection Temperature		ISO75 (1.82MPa)	°C	168	
Thermal Conductivity		ISO8302	W/m·K	0.35	
Barrier Properties					
Oxygen Transmission Rate		ISO14663-2	23°C-80%RH	cm ³ /m ² /day/atm (20 µ m)	0.7
Carbon Dioxide Transmission Rate		ISO15105-2	23°C-80%RH	cm ³ /m ² /day/atm (20 µ m)	2.6
Water Vapor Transmission Rate		ISO15106-2	40°C-90%RH	g/m ² /day (20 µ m)	10
Electrical Properties					
Surface Resistance		IEC 60093	/sq	10 ¹⁴	
Volume Resistance		IEC 60093	· cm	10 ¹⁴	
Dielectric Constant 1MHz		IEC 60250	-	4.2	
Dielectric Loss Tangent 1MHz		OEC 60250	-	0.012	

- The figures presented in this bulletin are the results of lab measurements and not secured values.

- Kuredux® is not intended for use in biomedical applications. For biomedical applications, contact your Kureha representative for information on Kuresurge® PGA.



The Pursuit of Excellence

All information and data contained in this bulletin are based upon tests and data believed to be reliable. However, Kureha Corporation assumes no liability for absolute accuracy and completeness of presented information.

Please contact your Kureha representative for further information on Kuredux® and its usage and suitability for your products.