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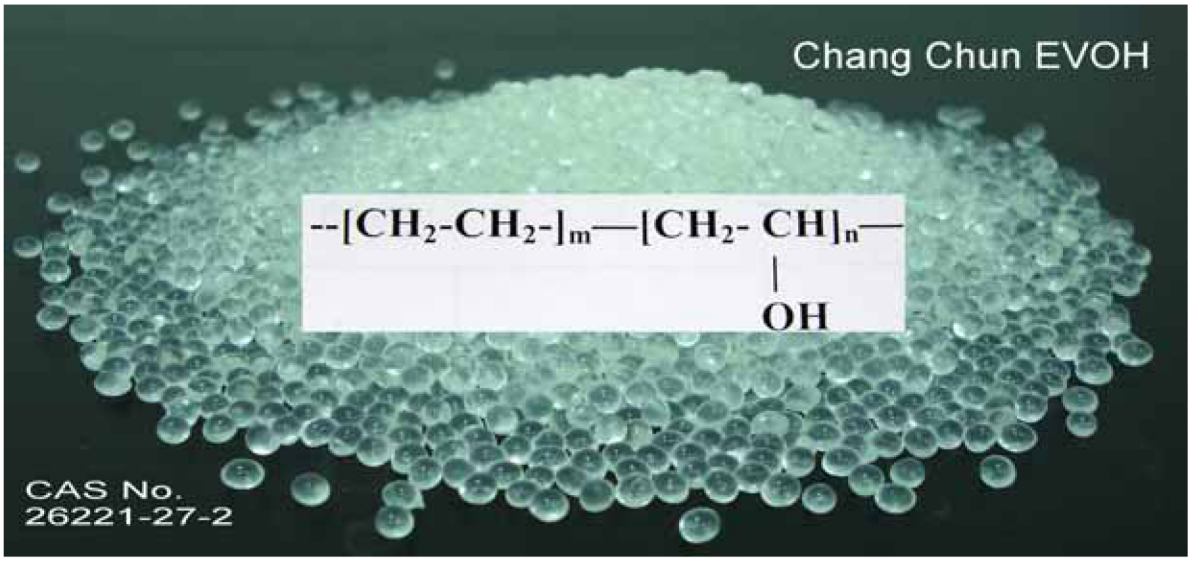
EVOH, Ethylene-Vinyl Alcohol Copolymer

EVASIN EV-3201V

Unmodified random Co-Polymer of [Ethylene–Vinyl alcohol], designed for thermo-plastic processing into Sheets and Foils with high Oxygen and Aroma Barrier Effect



DATA SHEET (EVASIN EV-3201V)

Item	Unit	Method	EV-3201V
Mechanical Properties			
Tensile strength (yield)	**Kg/cm^2**	**ASTM D638**	**741**
Tensile Strength (break)	**Kg/cm^2**	**ASTM D638**	**631**
Tensile modulus	**Kg/cm^2**	**ASTM D638**	**3.65E+04**
Elongation (yield)	**%**	**ASTM D638**	**5.6**
Elongation (break)	**%**	**ASTM D638**	**180**
Bending strength	**Kg/cm^2**	**ASTM D790**	**1263**
Bending modulus	**Kg/cm^2**	**ASTM D790**	**4.41E+04**
Izod impact strength	**Kg cm/cm**	**ASTM D256**	**3.1**
Shore Surface hardness	**M**	**ASTM D2240D**	**84**
Density	**g/cm^3**	**ASTM D792**	**1.18**

Thermal Properties and Melt Characteristics			
Melting point	℃	**DSC**	**184.86**
Heat Deflection Temperature	℃	**HDT.ASTM D-648**	**94.4**
Vicat softening point	℃	**HDT.JIS-K6742**	**173.8**
Crystallization point	℃	**DSC**	**163**
Glass transition point	℃	**DMA**	**73.9**
Melt flow index	**g/10min**	**(2160g, 190℃)**	**1.727**
	g/10min	**(2160g, 210℃)**	**3.6762**
Melt Viscosity	**Poise**	**190℃,γ =50sec^{-1}**	**4.57E+04**
	Poise	**190℃,γ =100sec^{-1}**	**3.73E+04**
	Poise	**190℃,γ =200sec^{-1}**	**2.88E+04**
	Poise	**210℃,γ =50sec^{-1}**	**2.68E+04**
	Poise	**210℃,γ =100sec^{-1}**	**2.21E+04**
	Poise	**210℃,γ =200sec^{-1}**	**1.75E+04**
	Poise	**230℃,γ =50sec^{-1}**	**1.56E+04**
	Poise	**230℃,γ =100sec^{-1}**	**1.33E+04**
	Poise	**230℃,γ =200sec^{-1}**	**1.09E+04**
Coefficient of linear	**1/℃**	**above Tg**	**5.6E-05**
Expansion	**1/℃**	**below Tg**	**4.6E-05**
Gas Barrier Properties			
O_2 - Transmission Rate	**cc.20μm/(m^2•24h•atm)***	**ASTM D3985**	**0.6**
Water Vapor Transmission Rate	**cc.20μm/(m^2•24h•atm)****	**ASTM E96**	**275**

* at 25℃ / 0%RH ** at 40°C / 90% RH

Specification of EVASIN EV-3201V

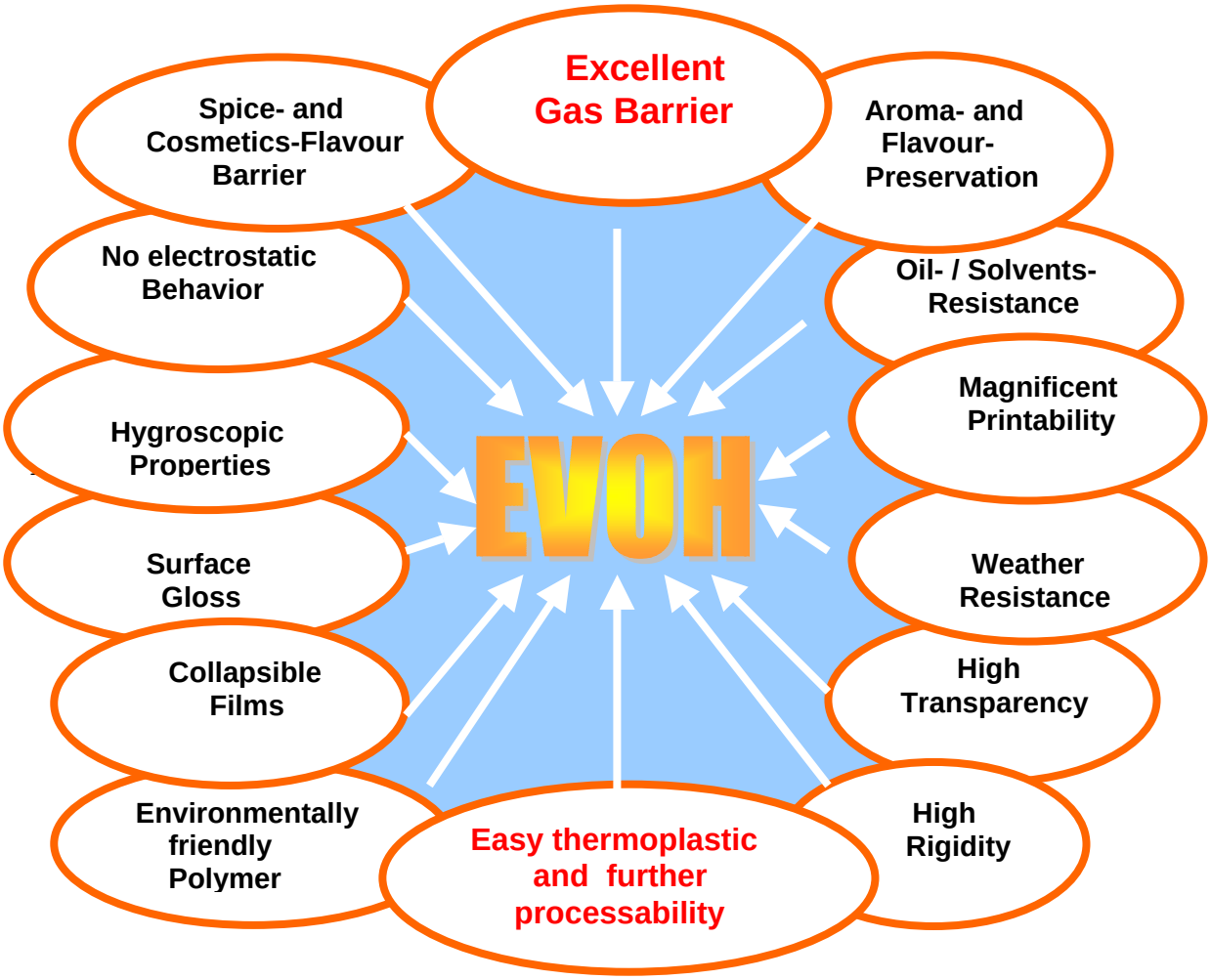
Properties	Unit	EVASIN EV-3201V
Moisture content	Wt%	max. 0.3
Melt flow (190℃, 2.16kg Load)	g/10 min	1-2
Melt point	°C	180-186

FDA status

EVASIN EV-3201V contains no heavy metals or other harmful substances, and meets FDA 21, C.F.R. Section 177.1360 standard

General Properties

In comparison to mostly used, well known thermoplastic polymers, EVOH – an environmentally friendly compound - combines distinguished and unique properties, as clearly outlined in the following graph: It is extrudable and thermo-processable; foils show high transparency, gloss and good printability. They are rigid but collapsible and also water- and weather resistant. No other polymer reaches its excellent properties concerning gas barrier, flavor barrier, aroma and spice preservation, oil and solvents resistance and hygroscopic behavior.



EVOH - Oxygen Gas Barrier Properties vs. Ethylene Content

Ethylene mol%	27-29	32	38	44	47
O_2-Barrier *	~ 0.4	~ 0.6	~ 1.6	~ 4.0	~ 5.5

* cc.20µm/(m^2•24h•atm) at 25°C / 0%RH

Becomes more like PVOH Better barrier, but less flexibility and more difficult to process.	⟷	**Becomes more like PE** Easier to process and more flexible, but slightly reduced barrier

EVASIN EV-3201V is transferred into foils, sheets or bottles for their excellent barrier effect against gases and organic liquids. The ethylene content of the polymer molecule influences this effect quite obviously, as seen from the figures in the table above.

Ethylene contents more than 30 mol% are necessary to receive adequate water-resistance and insolubility on one side as well as sufficient thermo plasticity for the demanded thermo-processability on the other side. Higher levels of ethylene – up to 38 mol% - facilitate workability and do not influence the desired barrier effect too much.

44 mol% show even easier processability, but there is already a slightly increased oxygen transmission in comparison to **EVASIN EV-3201V**. But even EVOH-types with ethylene contents of 40-50 mol% still have a remarkable higher barrier effect than any other organic foil. The comparative figures may envision the situation:

Oxygen Transmission Rates (OTR)
Values for 1 Mil (~ 25.4 µm) foils, given as [$cm^3/(m^2 \cdot day)$].

EVOH	**0.4 — 1.5**
LDPE **HDPE** **Cast PP** **OPP** **OPS**	2,500 — 3,000 2,600 — 3,000 2,600 — 3,000 1,500 — 2,500 1,500 — 2,500
OPET **biax Nylon**	30 — 90 20 — 40
EVAc	17,000 — 19,000

Also, the negative influence of residual acetyl-groups in EVOH can be estimated: They act as "spacers" leading to irregular zones along the polymer chain, this way reducing the necessary polar entanglement of EVOH-molecules. The effect of this "molecular widening" is a tremendous loss of barrier effect.

Because of the molecular design, **EVASIN EV-3201V** is insoluble in water, though hydrophilic. Therefore no surface electrostatic charge is noticed. That is an ideal property for wrapping electronic parts, being sensitive to electric sparks.

Packaging and Wrapping of sensible Foodstuff

Nitrogen Gas Barrier

Sausage, already sliced in a central factory, cannot be sold in supermarkets except with a very special protection. Accordingly, the above-mentioned trays and foils are used. But in addition, the space above the goods is flushed with nitrogen before sealing. In comparison to the anyway excellent barrier values against oxygen, **EVASIN EV-3201V** shows even much increased barrier effect – more than double - against nitrogen gas. Sealed EVOH packages keep ambient oxygen off and flushed nitrogen around the wrapped goods. This way a much longer storage lifetime (called: the "…Best-use-before-time…") - can be announced for foodstuffs.

Carbon dioxide

Until recently, "bubbling" CO_2 containing drinks were sold exclusively in glass bottles. The first attempts to use simple light weight PET bottles were only successful for water and soft drinks with no or low CO_2 content and short shelf life.

Reason is the relatively high CO_2 gas transmission through all commonly known polymers. Obviously this gas dissolves much better in organics than oxygen or nitrogen. That is true also for EVOH, though here the transmission rates are much lower than in other organic foils: 4-times higher than the value for oxygen is still an exceptionally good barrier effect.

Therefore, nowadays co-extruded PET/EVOH/PET bottles win more and more market share. They now guarantee a long storage time without loss of taste and sparkling/foaming effect, substituting even aluminium cans for beer.

As those packaging can be recycled (the material sometimes being raw material for some other applications), they were looked upon as being environmentally friendly. And, by this way, the all-over energy balance against glass or Aluminium is quite favourable.

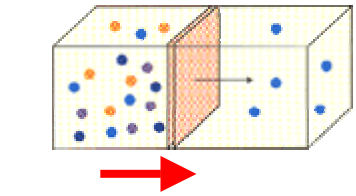
Water vapor

The OH-groups in the polymer make EVOH a hydrophilic material: Remarkable sensitivity and transmission of water and humidity is given. If this should be avoided, again, appropriate co-extruded foils and articles have to be used, with a “buried” interlayer of EVOH.

Summary

Gas Barrier Effect of EVOH

The outstanding characteristics of **EVASIN EV-3201V** - opposite to all other well known thermo-plastic processable polymers – can be visually demonstrated as a summary in the following graph:



Note:
Applications where gas-barrier effect together with water-(vapour-) resistance is obligated demand co-extruded foils and sheets.
The combination of conventional thermo-plastic polymers together with EVOH are ideal therefore.

(see chapter below)

Solubility Parameters (SP) of Polymers and Solvents

Polymer	δ ($cal^{1/2} \cdot cm^{-3/2}$)	Solvent	δ ($cal^{1/2} \cdot cm^{-3/2}$)
PTFE	6.2	n-Pentane	6.3
PE	8.0	n-Hexane	7.3
PP	7.9	n-Octane	7.6
SBR	8.1-8.5	Diisopropylketone	8.0
NR	8.1	Cyclohexane	8.2
BR	8.5	Carbon tetrachloride	8.6
PS	8.5-9.6	Toluene	8.9
PVAc	9.4	Ethyl acetate	9.1
PVC	9.6	Dioxane	9.9
PET	10.7	Acetone	10.0
EP	11.0	Pyridine	10.9
POM	11.1	Ethanol	12.7
PA	13.5	Methanol	14.5
PAN	15.4	Glycerol	16.5
EVOH	**~ 19.0**	Water	23.4

The Solubility Parameter (SP) of a polymer or solvent derives from the polarity of the (macro-) molecule and of its dependent hydrophilic/hydrophobic character.

Only molecules with very similar SP values are direct compatible to each other. That means, miscibility of polymer melts, the solubility of a polymer in a certain solvent or even the miscibility of different solvents is only possible if the SP-values of the partners are rather close together.

By comparing the parameters in the above table, it is easy to understand now, why it is necessary to use an intermediate adhesive layer, when EVOH films (SP = 19) are co-extruded e.g. with polyethylene (SP = 8.0) or polyethylene terephthalate (SP = 10.7). Such a necessary adhesive - mediating the compatibility of the different polymers - is technically called a **"Tie Layer".**

Those thermoplastic compounds could be understood as "polymer surfactants": Their chain contains polar, hydrophilic zones alternating with strongly hydrophobic sequences, ideal for the necessary interaction between the hydrophilic EVOH-layer on one side and the hydrophobic polymer layer(s), e.g. PE, PET, PP and so on, on the other side. The tie layer polymer is also generated by simultaneous extrusion.

General Application

For a co-extrusion process, two or more materials have to be extruded through a single die with two or more orifices arranged in a way, that the hot thermoplastic masses merge and weld together into a laminar structure before chilling. Each material is fed to the die from a separate extruder, but the orifices may be arranged so that each extruder supplies two or more plies of the same material. Co-extrusion can be employed in film blowing, free film extrusion and extrusion coating processes. The advantage of co-extrusion is that each ply of the laminate imparts a special desired characteristic property, such as stiffness, heat-sealability, impermeability or resistance to some environment, all of which properties would be impossible to attain with any single material.

EVOH with different kind of ethylene content can be applied in various barrier products by the fabrication process method of blown or cast co-extrusion, co-extrusion lamination, co-extrusion coating to form bottles, sheet, sheet (thermoforming), films, cast films, pipes or fibres.

The following EVOH resin processing methods are broadly adopted by extrusion companies:

- ◎ Monolayer film extrusion (blown or cast)
- ◎ Co-extruded film extrusion (blown or cast)
- ◎ Sheet co-extrusion
- ◎ Co-extrusion blow molding
- ◎ Co-extrusion coating
- ◎ Laminating
- ◎ Injection molding

For a quick adjustment of the extruder conditions the graphs in the annex may assist:

- ◎ **Melt viscosity of EVASIN EV-3201V vs. shear rate at temperatures of 190, 210, 230 and 250°C**

Typical Structures of co-extruded Substrates for Special Applications

■ **Examples**

Outside < --- > Inside

Ketchup Bottles	**PP -- Tie -- EV-3201V -- Tie -- PP**
Chemical Packaging Bottles	**PE -- Tie -- EV-3201V**
High Barrier Multilayer Pouches / Packages	**PET -- PE -- Tie -- EV-3201V – Tie -- PE**
Wine, Juice Bottles	**Paper--PE--Tie-- EV-3201V--Tie--PE**
Underfloor Heating Pipes	**EV-3201V – Tie -- PE**
Gasoline Tanks	**HDPE--Tie-- EV-3201V --Tie--HDPE**

Cerificate of Analysis and general Handling

EVASIN EV-3201V is tested lot by lot and a Certificate of Analyis (CoA) is part of each delivery to the customer. Only data of this CoA are guaranteed by Chang Chun Petrochemical Co., Ltd.

As mentioned, all EVOH–types are slightly hydrophilic polymers, therefore our bags for transport and storage are absolutely tight against water vapour from outside. Partly used bags at the customers´ site should therefore be carefully tightly closed again as soon as possible. If by accidentally wrong handling a higher water content is analysed, the beads have to be re-dried to water content <0.4 wt% before extrusion in order to avoid bubbles and fisheyes.

Note:
All data, descriptions and hints given in this leaflet are carefully evaluated in our analytical department or by reliable polymer institutes and only mean typical characteristics; they are not elements of our CoA, but should assist users for quick technical setups. Formulation, processing and final application of end-products based on EVASIN EV-3201V do not lie in our part but in the customers´ reliability only.

Furthermore, users are obliged to check for the patent situation concerning their projected end products.

Annex

EVASIN EV-3201V - Physical Data / Diagrams