OTR (Oxygen Transmission Rate) Information

OTR (oxygen transmission rate) is the steady state rate at which oxygen gas permeates through a film at specified conditions of temperature and relative humidity. Value are expressed in cc/100 in2/24 hr in US standard units and cc/m2/24 hr in metric (or SI) units. Standard test conditions are 73°F (23°C) and 0% RH.

Relevance to package performance

The air we breathe is about 21% oxygen and 79% nitrogen, with very small concentrations of other gases like carbon dioxide and argon. Essential to human and animal life, oxygen gas is also a reactive compound that is a key player in food spoilage. Most of the chemical and biological reactions that create rancid oils, molds, and flavor changes require oxygen in order to occur. So, it is not surprising that food packaging (and some non-food packaging for products where atmospheric oxygen causes harm) has progressed and found ways to reduce oxygen exposure and extend the shelf life of oxygen-sensitive products.
There are two methods for reducing product exposure to oxygen via flexible packaging.

1. **MAP (modified atmosphere packaging)** is a process for replacing the air in the headspace of a package with another gas before the final seal is made. This is also called gas flushing. The most common replacement gases are nitrogen or nitrogen/carbon dioxide mixtures. The shelf lives of potato chips, dried fruits, nuts, and shredded cheese are commonly extended by this packaging method.

2. **Vacuum packaging** is where the atmosphere is drawn out and eliminated, rather than being replaced by another gas. This vacuum forces the flexible material to conform to the product shape. Meats (fresh and processed) and cheeses are commonly packaged this way.

Once air has been replaced or eliminated from the package, there must be an adequate oxygen barrier and seal integrity to keep a low oxygen concentration inside the pack. Otherwise, the driving force created by the oxygen partial pressure differences (21% outside the bag and 0-2% inside the bag) will cause an ingress of oxygen and destroy the benefit of removing it in the first place. OTR values are used to compare the relative oxygen barrier capabilities of packaging films. An industry rule-of-thumb is that a material is considered a "high oxygen barrier" if its OTR is less than 1 cc/100 in2/24 hr (15.5 cc/m2/24 hr).

Table 10 shows OTR values for common polymer packaging films. Note that the table is divided into two sections. The first contains normalized (1 mil) values for common materials. The second section displays the OTRs for coated or metallized films where the total film thickness is unimportant, because the barrier is primarily coming from the additional layer.

Film Type	**OTR @ 73°F (23°C), 0% RH**

	(cc/100 in2/24 hr)	(cc/m2/24 hr)
The following OTRs are bulk material properties displayed at 1 mil. You may divide by the gauge (in mil) in order to approximate OTR at a different thickness.		
EVOH* (ethylene vinyl alcohol)	.005 -.12	.08 - .19
Biax Nylon-6	1.2 - 2.5	18.6 - 39
OPET (oriented polyester)	2 - 6	31 - 93
OPP	100 - 160	1550 - 2500
Cast PP	150 - 200	2300 - 3100
HDPE (high density polyethylene)	150 - 200	2300 - 3100
OPS (oriented polystyrene)	280 - 400	4350 -6200
LDPE (low density polyethylene)	450 - 500	7000 - 8500
The following OTRs are enhanced by coating or metallizing. Therefore, these are not bulk film properties, and total film thickness has little impact on the OTR value.		
Metallized OPET	.01 - .11	.16 - 1.7
PVOH-coated OPP (AOH)	.02	.31
Metallized biax Nylon-6	.05	.78
PVdC-coated OPET	.30 - .50	4.7 - 7.8
High Barrier PVdC-coated OPP	.30 - .60	4.7 - 9.3
PVdC-coated biax Nylon-6	.35 - .50	4.7 - 7.8
Metallized OPP	1.2 - 10	19 - 160
Sealable PVdC-coated OPP	1.5 - 3.5	23 - 54

Table 10: OTR values for common films

*The range of possible values is especially wide for EVOH because the value is dependent on the ethylene content of the particular grade. EVOH is typically a buried layer, either via coextrusion or lamination.

What affects the OTR of films

Good oxygen barrier is achieved by combining functional layers to create a film with the required barrier, as well as those other properties necessary to produce a serviceable package. For example, EVOH has exceptional OTR properties, but needs moisture barrier and mechanical properties provided by layers that are coextruded or laminated around it.

OTR is most affected by the following factors.

1. **Thickness of barrier layer:** Generally, the thicker the oxygen barrier-providing layer, the better the barrier. But there are process and cost limitations that restrict the thicknesses that can be realistically produced or successfully utilized.

2. **Copolymer ratio, plasticizer content, and polymerization process:** All PVdCs (or EVOHs or PVOHs) are not created equal. Properties are compromised during polymer and product development, so that total performance in target applications is optimized. There can be substantial differences in OTR values depending on the selections made. For example, both ASB-X and AXT are PVdC-coated and sealable, but their OTRs are 4.5 cc/100 in2/24 hr and .40 cc/1 00 in2/24 hr, respectively. ASB-X has the poorer OTR, but a broader seal range than AXT.

3. **Base film surface compatibility:** The physical and chemical characteristics of the base film surface have a major effect on the OTR after metallization, and to a lesser degree, after coating. This is evidenced by Met PET's exceptional barrier, as well as the difference in OTRs between various metallized OPP products (refer to Table 10).

ExxonMobil only measures and controls OTR for those films that are modified through coating, coextrusion, or metallization, and guarantee a maximum OTR value in the product specification. This includes AXT, HBS-2, AOH, MET-HB, and MU842.

Test principles

ExxonMobil uses MOCON OX-TRAN@ instruments for measuring OTR. The instrument design and the way we operate the instrument are consistent with the ASTM D 3985 standard. ExxonMobil standardizes its reporting to test conditions of 73°F (23°C) and 0% RH.

Conceptually, a test cell looks like Figure 4. Dry nitrogen gas is swept through a chamber, where the test film acts as the membrane separating this stream from an oxygen stream on the other side. The partial pressure difference creates a driving force for oxygen molecules to diffuse through the film to the low pressure side. The film barrier determines the rate of oxygen permeation, and this is continuously measured by a MOCON® patented coulometric sensor in the outgoing ,stream of the nitrogen side.

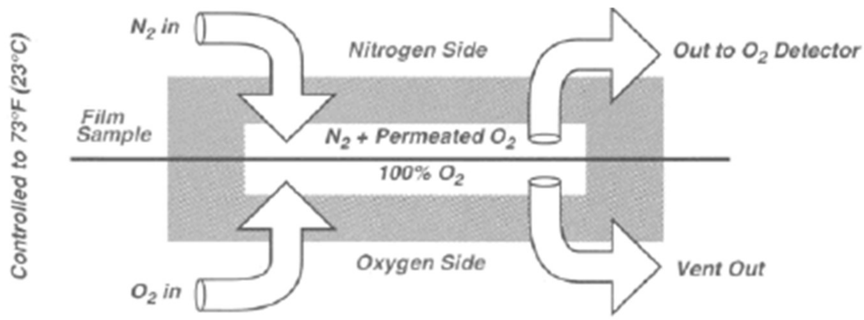

Figure 4: Cross-section of an OTR test cell

The test is complete when equilibrium, or steady state, is achieved; that is, it is complete when the sensor detects a constant amount of oxygen in the nitrogen carrier stream. The rate of oxygen permeating through the sample is not changing. This rate is the sample OTR and is recorded in units of cc/100 in2/24 hr or cc/m2/24 hr at 73°F (23°C), 0% RH.

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