MODIFYING SURFACE FEATURES
Extrusion Coating and Lamination

Rory A. Wolf, *Enercon Industries Corporation*
Amelia Sparavigna*, Dipartimento di Fisica, Politecnico di Torino*

Abstract
Extrusion coating, lamination and film lamination give rise to complex manufacturing techniques which allow a converter to make high-performance packaging films. The physical properties and the related performance characteristics of composites obtained by extrusion coating and lamination can be comparable to that produced by film lamination. This is not surprising since many of the major components involved by these techniques in the production of the final composites are also the same. The paper examines how the use of ozone combined with corona discharge compares to ozone combined with atmospheric plasma relative to seal strength for these composite film constructions, and suggests a direction for future improvements in seal strength.

Introduction
In extrusion coating and lamination, the resin, melted and formed into a thin hot film, is coated onto a moving substrate such as paper, paperboard, metal foil, or a plastic film. The coated substrate then passes between a set of counter-rotating rolls, pressing the coating onto the substrate for complete contact and adhesion. A coating extrusion system is shown in Figure 1.

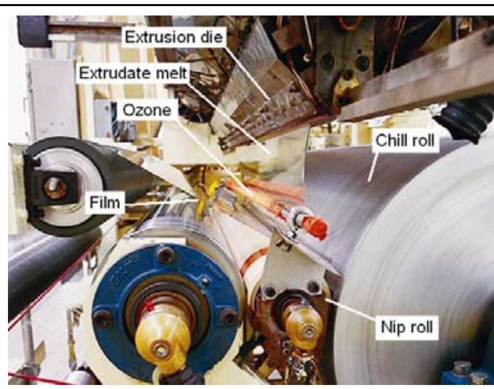


Figure 1. A coating extrusion system

Extrusion lamination, or sandwich lamination, is a process related to extrusion coating. In this case, the extrusion-coated layer is used as an adhesive layer between two substrates. A second layer is applied to the extrusion coating while it is still hot and then the sandwich is pressed together by pressure rolls (see sketch in Figure 2). In film lamination, a fabricated film is adhered to a moving substrate by application of heat and pressure. Film lamination involves several methods by which different combinations of heat and pressure are used to ensure adhesion.

Examples of common composite films are the materials for beverage pouchstocks and composites for the medical packaging industry. For example, the typical beverage pouchstock is a combination paper/PE/foil/PE, and composites used for medical packaging usually consists of PET/PE/foil/PE. These particular constructions involve four substrates and three interfaces which can utilize adhesives or primers at the interfaces. Converters can laminate the four substrates by means of three separate operations, or the layers can be combined together in extrusion laminations. The polyethylene layer can be composited in the construction by means of a coating extrusion from PE pellets, or with a lamination of PE film.

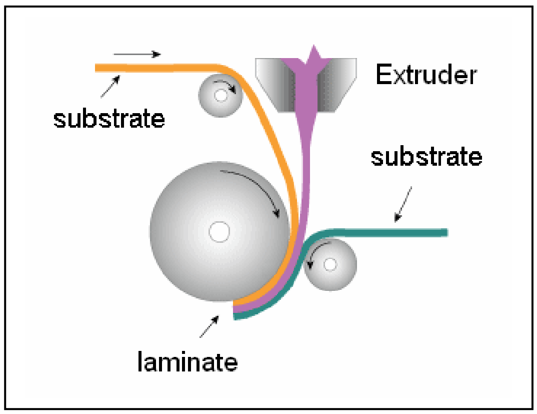


Figure 2. Sketch of the extrusion lamination

Modifying interfaces
A major factor influencing extrusion bonds is the specific adhesion that is created by the capacity of the molten polymer to conform to, or match, the chemical composition of the substrate. In the examples mentioned above, and particularly the composite polyester/PE/foil/PE used for the medical packaging industry, the actual

construction may be a polyester / interface / PE/foil/PE. At the polyester-polyethylene interface, a primer, adhesive and/or a surface modifier are necessary so that the polyester will adhere properly to the PE. Likewise, a pretreatment between the foil and PE is necessary to form a sufficient bond between those two substrates. It should also be noted that when chemical primers are used to improve extrudate adhesion, it is typical that a corona treater is required to pretreat film prior to priming and subsequent extrusion.

Application of surface modification techniques to a substrate before an extrusion coating or extrusion laminating operation requires combinations of corona, flame, ozone and atmospheric plasma equipment to optimize adhesion (Figure 3 identifies a combination of ozone and other surface treatments). In some instances a chemical primer or an adhesive layer is used to improve lamination. Previous work which details the role of primers in extrusion lamination has been outlined by many, including industry professionals such as David Bentley in his paper on primers.

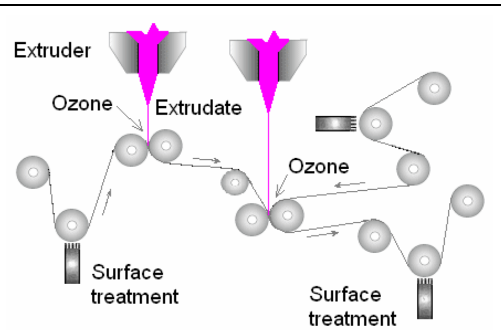


Figure 3. Typical co-extrusion line and the location of ozone and surface treatment stations

Choice of a surface modification technique

Corona discharge, particularly bare roll and universal roll designs, along with flame treatment at atmospheric pressure have both been effective for improving adhesion of various substrates on extrusion coating lines (the image in Fig.4 shows a multilayer system). More recently, variable chemistry atmospheric plasma treatment (APT) is being utilized to significantly promote covalent bonding of coatings to substrate surfaces.

Let us consider for instance coating with LPDE. To have adhesion, it is necessary to provide oxidation of this fairly nonpolar polymeric material. For molten plastic to oxidize, high temperature and exposure to air are required. Nonpolar LDPE oxidizes at high temperatures (300-330ºC) in the extrusion coating process. But excessive oxidation caused by running at low speed and high temperatures can promote odor and taste problems for the product contained in the packaging. For this reason, extrusion coaters and laminators seek to use lower process temperatures without special resins or chemical priming of the substrate. A common way to accomplish this is to blow ozone (O_3) directly onto the molten plastic, thereby oxidizing it. However, the influence of ozone on different plastics together with various surface modification techniques such as corona and atmospheric plasma has not been quantified by exhaustive experimental data and is therefore a protocol which requires research to optimize the process. .

Figure 4. A universal roll system for multilayer composite applications

Extrusion coating experiments

The analysis of a process such as extrusion coating and laminating is rather complex. As such, we are limiting this discussion to the influence of surface treatments in these coating processes, and reporting some specific results obtained comparing ozone/corona with ozone/APT treatments. In particular, two experimental runs were performed by coating low-density polyethylene onto oriented polypropylene and polyester film. Ordinary heat seal strength techniques were used to quantify the affects of the variables on heat seal strength vs. seal temperature.

Including atmospheric plasma treatment, five variables are thought to affect adhesion and heat seal strength, namely: substrate surface modification, melt temperature, line speed, air gap, and coating weight. Besides these factors, several ozone related parameters were identified that could affect adhesion and heat seal strength. These parameters were ozone flow rate, ozone concentration (power setting on ozone unit), and geometry of the applicator set-up such as horizontal distance and angle from horizontal. The levels used in this design are found in Table 1, accomplished by a combination of 1) oxidation of the extrudate, and 2) surface treatment of the substrate. The level of oxidation is a function of the melt temperature, the line speed, the air gap and the coating weight. Some combinations of these variables will yield acceptable adhesion but also produce undesirable effects such as increased taste and odor or poor heat seal strength.

Variable	Condition 1	Condition 2
Substrate Treatment	Ozone/APT	Ozone/Corona
Melt Temperature	315° C	315° C
Line Speed	90 m/min	90 m/min
Ozone Air Gap	15.24 cm	15.24 cm
Coating weight	10 g/m²	10 g/m²
Ozone	Yes	Yes
Ozone Rate	2.08 m³/min	2.08 m³/min
Ozone Concentration	0.25 kW	0.25 kW
Horizontal applicator Position	2.54 cm	2.54 cm
Applicator Angle (from Horizontal)	0°	0°
APT Gas Chemistry	95%He+ 5%C_2H_2	None
Watt Density	40W/m²/min	40W/m²/min

Table 1 - Variable levels utilized in experimental design

The Atmospheric Plasma trial runs were performed on the Enercon APT pilot line. The extrusion coating trial runs were performed on the Lyondell Equistar extrusion coating pilot line. For all extrudate runs, a LDPE (Melt Index 10, 10g/10min) was coated onto OPP and PET film. The samples were prepared and tested according to ASTM test method F88. The heat seal tests were made on a heat seal machine using a pressure P= 206.8 kPa and a dwell time T= 1 s.

Conclusions

As a result, the measurements display that the use of APT surface modification to the OPP and PET substrates increased heat seal strength by a similar amount as corona treatment of the substrate. The ozone treatment of the extrudate is the same. Figure 5 graphs the effects of substrate treatment and heat seal strength. The analysis infers that the uniformity and homogeneity of an atmospheric plasma glow discharge treatment, along with its ability to micro-etch and functionalizing the surface of films (in this case with carbon-based functionality), seems to provide a similar level of heat seal strength for OPP and PET films extruded with LPDE resin.

Since it is common knowledge that the effectiveness of melt temperature on heat seal strength is much greater at higher air gaps and lower line speeds when using ozone/corona treatments, such adjustments may also improve the heat seal strength results of atmospheric plasma. As a preliminary conclusion, it can be surmised that a further enhancement of heat seal strength of extrusion coatings to films might be obtained by optimizing the protocol of atmospheric plasma treatment combined with ozone. New trials subsequent to this paper will be attempted to document specific modifications of APT chemistry, ozone rates, melt temperature, air gap and line speed to define optimizing settings.

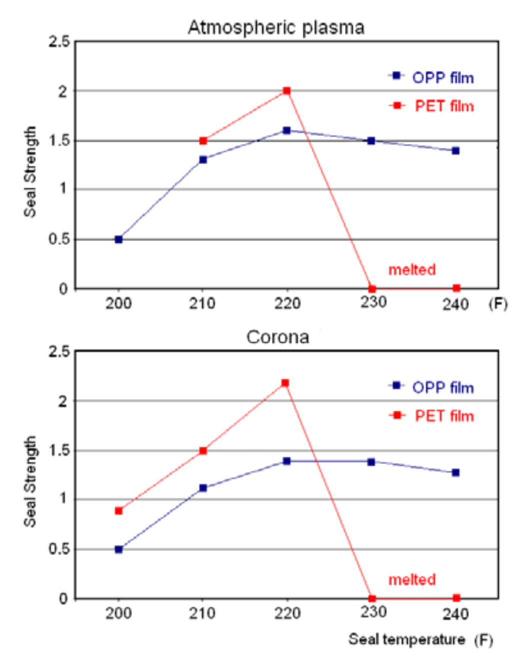


Figure 5. The seal strength (lb/in.) as a function of the temperature seal (F) for atmospheric plasma treated films and corona treated films

References

1. Tietje, A., Fifteen Years of Ozone Treatment in Extrusion Coating, 1987 Polymers, Lamination, and Coatings Conference, TAPPI PRESS, Atlanta, p. 221-224

2. Sherman P.B, The Benefits of Ozone in Extrusion Coating, 1996 Polymers, Lamination, and Coatings Conference, TAPPI PRESS, Atlanta, p. 93-99

3. Hosmer, D.W. and Lemeshow, S., *Applied Logistic Regression*, John Wiley & Sons, New York, 1989, p. 1-23

www.tappiplace.org

PLACE

POLYMERS • LAMINATIONS • ADHESIVES • COATINGS • EXTRUSIONS

2007 PLACE Conference

September 17-19
St. Louis

OPTIMIZING EXTRUSION COATING/LAMINATION SEAL STRENGTH BY SURFACE TREATMENT

Presented by:

Rory A. Wolf
Enercon Industries Corporation

Introduction

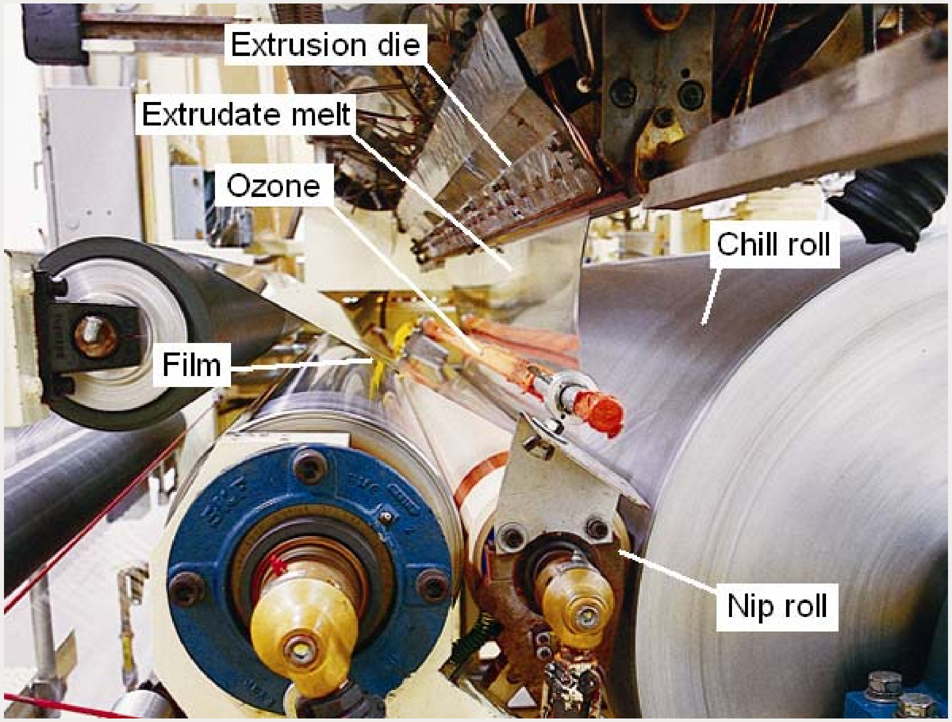
- **Extrusion coating, lamination and film lamination use complex manufacturing techniques for making high-performance packaging.**
- **Physical properties and performance characteristics of composites comparable to that produced by film lamination.**
- **Presentation examines how ozone combined with corona discharge compares to ozone combined with atmospheric plasma relative to seal strength for composite film constructions.**

www.tappiplace.org PLACE Polymers • Laminations • Adhesives • Coatings • Extrusions

Introduction

- In extrusion coating and lamination, the resin, melted and formed into a thin hot film, is coated onto a moving substrate such as paper, paperboard, metal foil, or a plastic film.
- The coated substrate then passes between a set of counter-rotating rolls, pressing the coating onto the substrate for complete contact and adhesion.

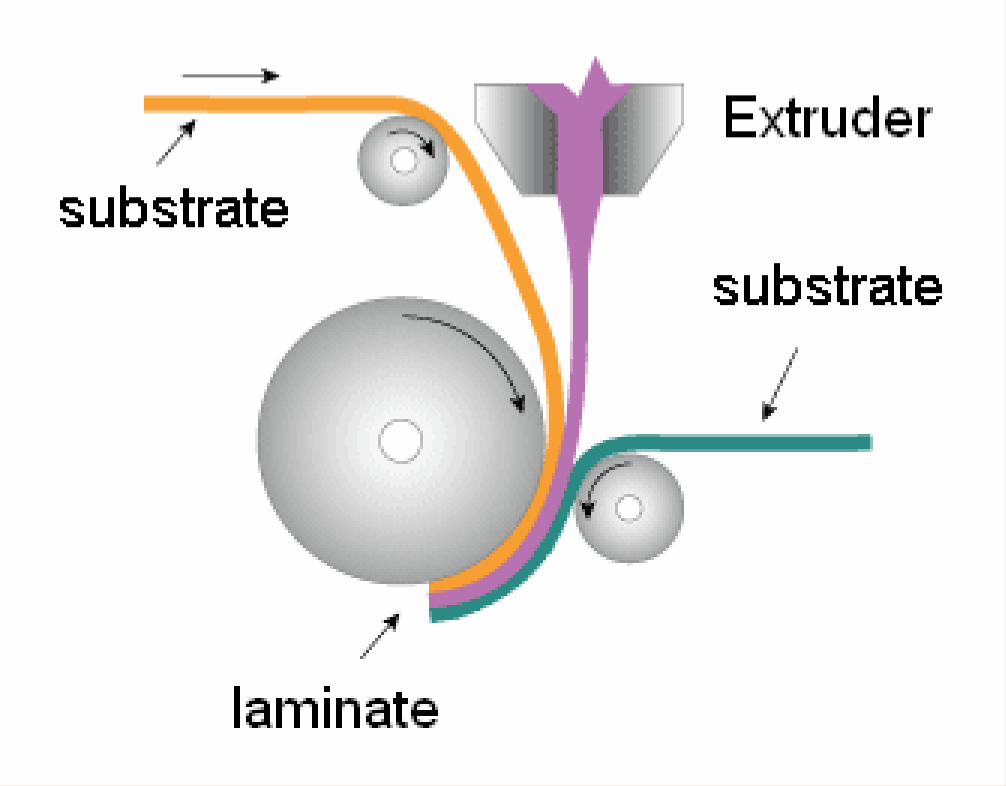
Introduction



- **Extrusion lamination, or sandwich lamination, is a process related to extrusion coating.**
- **Extrusion-coated layer is used as an adhesive layer between two substrates.**

Introduction

- Second layer is applied to the extrusion coating while it is still hot and then the sandwich is pressed together by pressure rolls.
- In film lamination, a fabricated film is adhered to a moving substrate by application of heat and pressure.



Introduction

- Examples of common composite films are the materials for beverage pouchstocks and composites for the medical packaging industry.
- Typical beverage pouchstock is a combination paper/PE/foil/PE, and composites used for medical packaging usually consists of PET/PE/foil/PE.
- These particular constructions involve four substrates and three interfaces which can utilize adhesives or primers at the interface.

Introduction

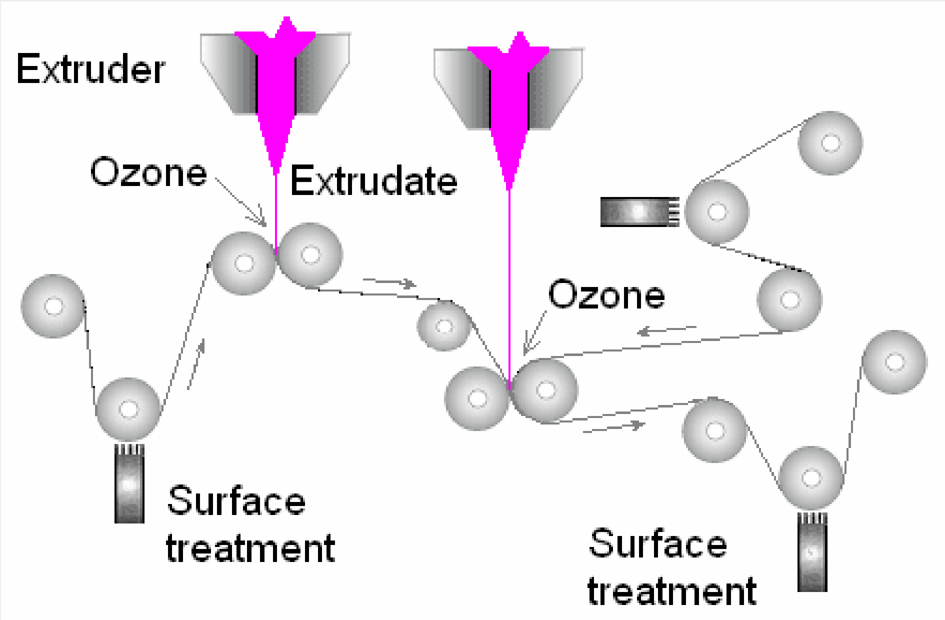
- Converters can laminate four substrates by means of three separate operations, or the layers can be combined together in extrusion laminations.
- The polyethylene layer can be composited in the construction by means of a coating extrusion from PE pellets, or with a lamination of PE film.

Interface Modification

- Major factor influencing extrusion bonds is the specific adhesion that is created by the capacity of the molten polymer to conform to, or match, the chemical composition of the substrate.
- PET/PE/foil/PE for medical packaging → PET/interface/PE/foil/PE
- At the PET-PE interface, a primer, adhesive and/or a surface modifier are necessary so that the PET will adhere properly to the PE.
- Pretreatment between the foil and PE is necessary to form a sufficient bond between those two substrates.
- When chemical primers are used to improve extrudate adhesion, corona is typically required to pretreat film prior to priming and subsequent extrusion.

Interface Modification

- Application of surface modification techniques to a substrate before an extrusion coating or extrusion laminating operation requires combinations of corona, flame, ozone and atmospheric plasma equipment to optimize adhesion.



Typical co-extrusion line, location of ozone and surface treatment stations

Choice of Surface Modification Technique

- Corona discharge, particularly bare roll and universal roll designs, along with flame treatment at atmospheric pressure are effective for improving adhesion of various substrates on extrusion coating lines.
- More recently, variable chemistry atmospheric plasma treatment (APT) is being utilized to significantly promote covalent bonding of coatings to substrate surfaces.

Experimental

- Two experimental runs were performed by coating LDPE onto OPP and PET film.
- Ordinary heat seal strength techniques were used to quantify the affects of the variables on heat seal strength vs. seal temperature.
- Including atmospheric plasma treatment, five variables are thought to affect adhesion and heat seal strength:
  - Substrate surface modification
  - Melt temperature
  - Line speed
  - Air gap
  - Coating weight

Experimental

- Several ozone-related parameters were identified that could affect adhesion and heat seal strength:
  - Ozone flow rate
  - Ozone concentration (power setting on ozone unit)
  - Geometry of the applicator set-up (horizontal distance and angle from horizontal)

- Levels accomplished by a combination of
  - Oxidation of the extrudate
  - Surface treatment of the substrate

- The level of oxidation is a function of melt temperature, line speed, air gap and coating weight.

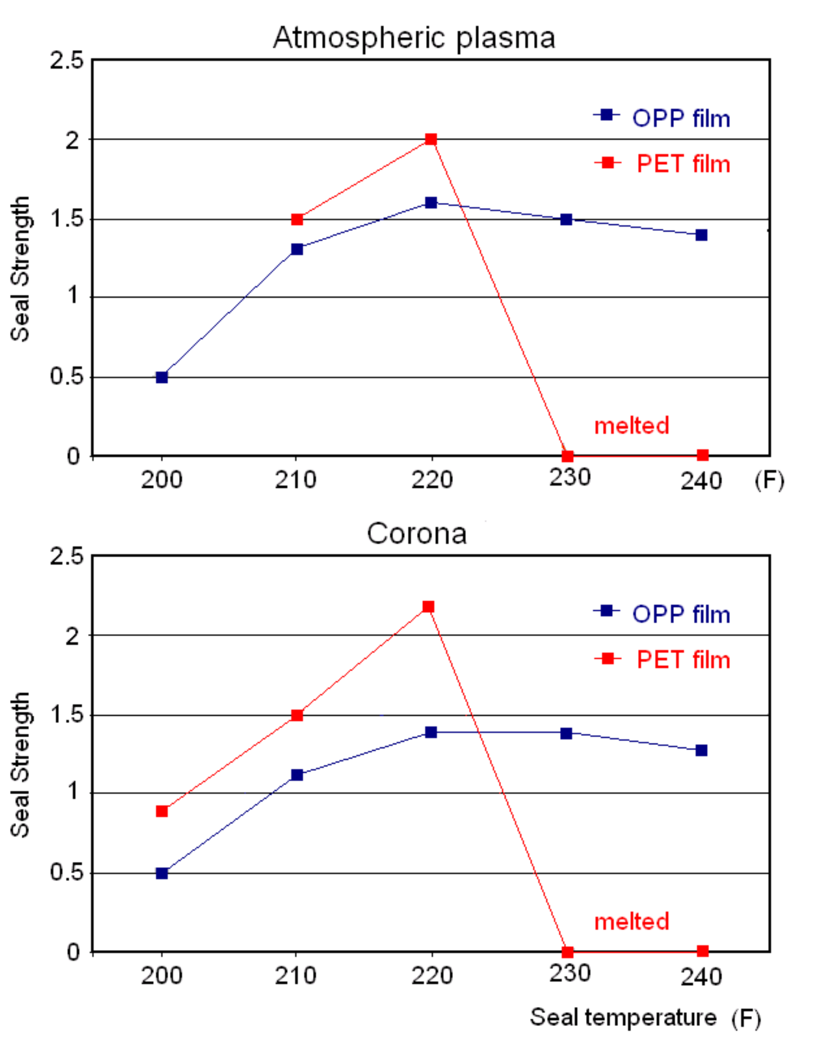
Experimental

Variable	Condition 1	Condition 2
Substrate Treatment	Ozone/APT	Ozone/Corona
Melt Temperature	315° C	315° C
Line Speed	90 m/min	90 m/min
Ozone Air Gap	15.24 cm	15.24 cm
Coating weight	10 g/m^2	10 g/m^2
Ozone	Yes	Yes
Ozone Rate	2.08 m^3/min	2.08 m^3/min
Ozone Concentration	0.25 kW	0.25 kW
Horizontal applicator Position	2.54 cm	2.54 cm
Applicator Angle (from Horizontal)	0°	0°
APT Gas Chemistry	95%He+ 5%C_2H_2	None
Watt Density	40$W/m^2/min$	40$W/m^2/min$

Experimental

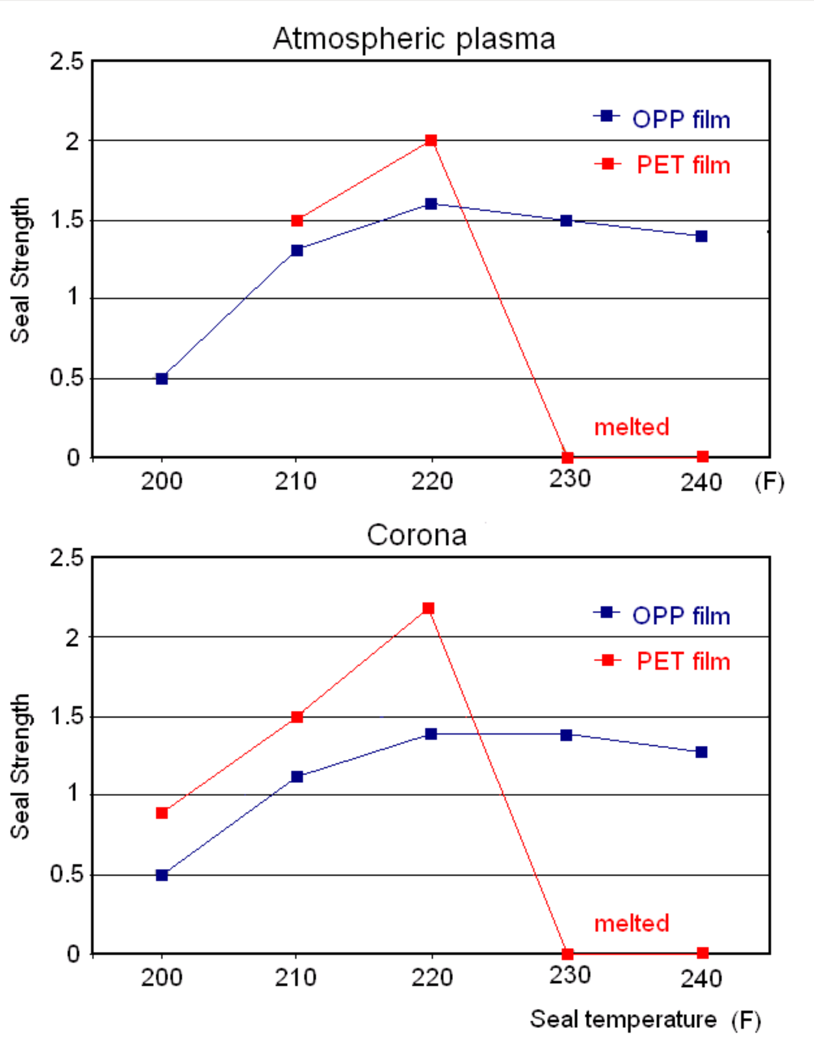
- **Atmospheric Plasma trial runs were performed on the Enercon APT pilot line.**
- **Extrusion coating trial runs were performed on the Lyondell Equistar extrusion coating pilot line.**
- **For all extrudate runs, a LDPE (Melt Index 10, 10g/10min) was coated onto OPP and PET film.**
- **Samples were prepared and tested according to ASTM test method F88.**
- **Heat seal tests were made on a heat seal machine using a pressure P= 206.8 kPa and a dwell time T= 1 s.**

Experimental



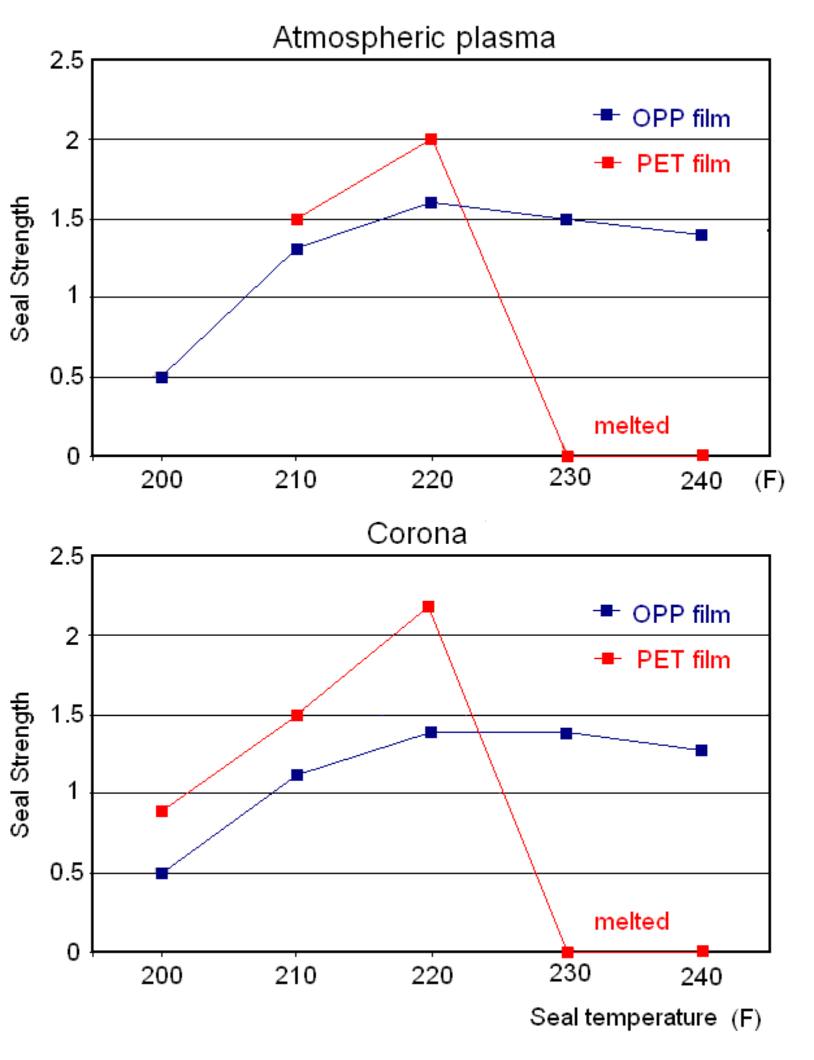
Seal strength (lb/in.) as a function of the seal temperature (F) for atmospheric plasma treated films and corona treated films.

Conclusions

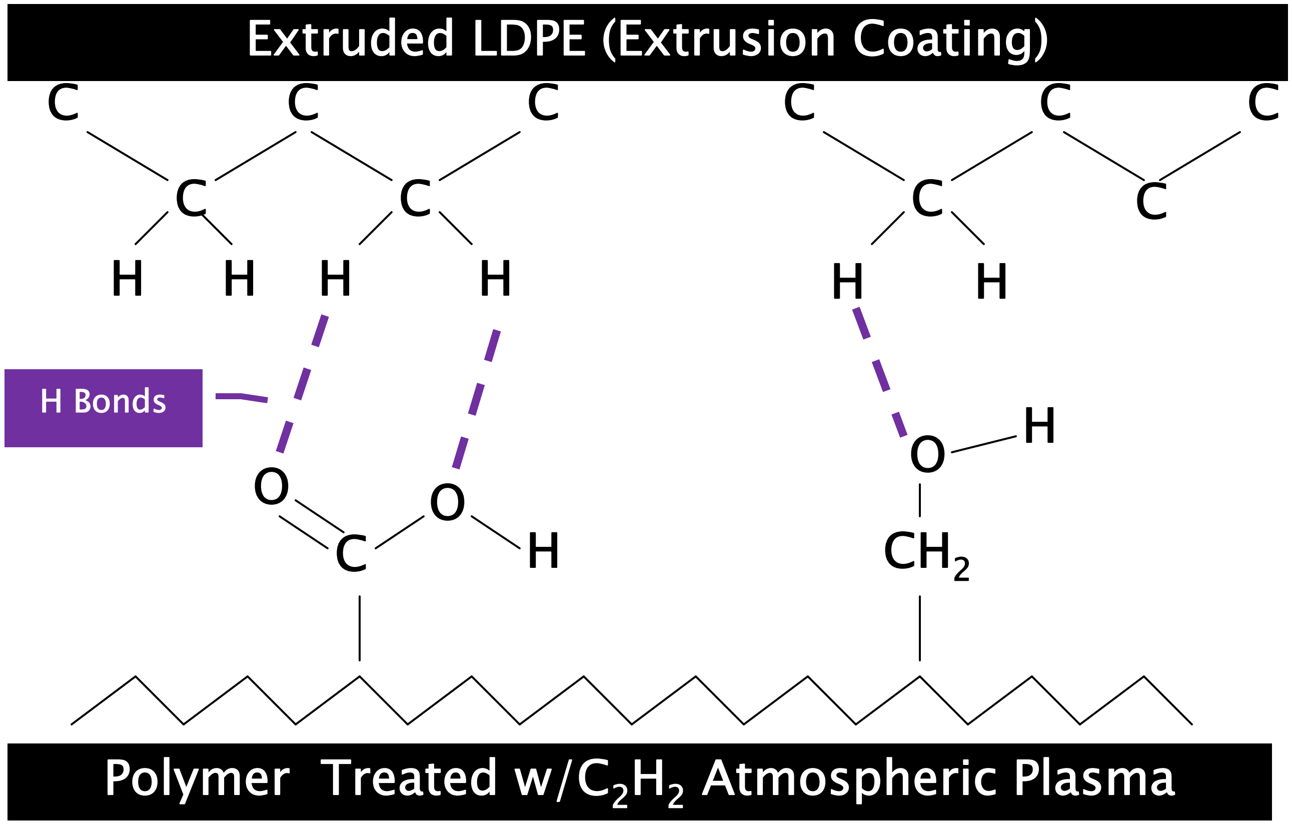


- Measurements display that the use of APT surface modification to the OPP and PET substrates increased heat seal strength by a similar amount as corona treatment of the substrate.
- Ozone treatment of the extrudate is the same.

Conclusions



- **Since effectiveness of melt temperature on heat seal strength is much greater at higher air gaps and lower line speeds when using ozone/corona treatments, similar adjustments may also improve the heat seal strength results of atmospheric plasma.**


Extruded LDPE (Extrusion Coating)
C
C
C
C
C
C
H
H
H
H
H
H
H Bonds
O
C
O
H
O
H
CH2
Polymer Treated w/C2H2 Atmospheric Plasma

www.tappiplace.org PLACE Polymers • Laminations • Adhesives • Coatings • Extrusions

Conclusions

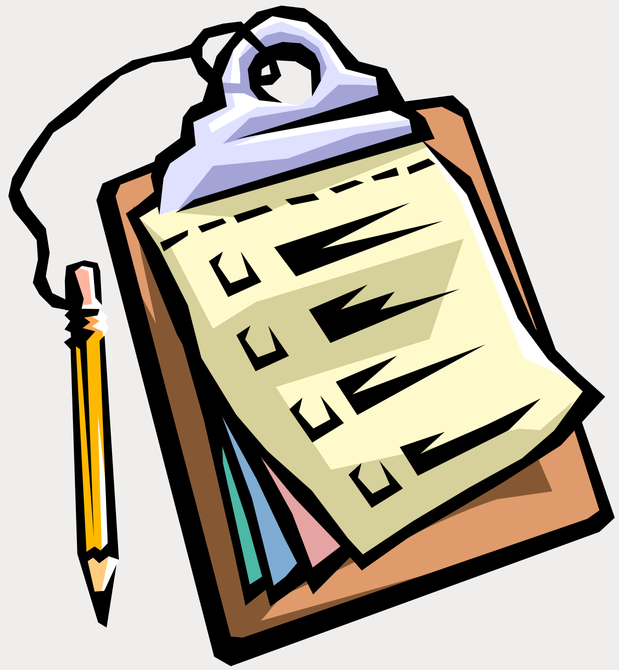
- **Preliminarily, further enhancement of heat seal strength of extrusion coatings to films might be obtained by optimizing the chemistries of atmospheric plasma treatment combined with ozone.**
- **New trials subsequent to this paper will be attempted to document specific modifications of APT chemistry, ozone rates, melt temperature, air gap and line speed to define optimizing settings.**

www.tappiplace.org
PLACE
POLYMERS • LAMINATIONS • ADHESIVES • COATINGS • EXTRUSIONS

Thank You!

PRESENTED BY:

Rory A. Wolf
rwolf@enerconmail.com
Enercon Industries Corporation



Please remember to turn in your evaluation sheet...