Functional Web Coating: from Food Packaging to Technical Applications

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Introduction

A review of Fraunhofer IVV research projects about functional web coating for food packaging and technical applications is presented. The scientific-industrial projects focus on analysis and optimization of R2R vacuum web coating and lacquering processes used for the enhancement of thermo-oxidative and hydrolytic stability, improvement of the gas barrier, adhesion, corrosion resistance and electrical insulation properties of plastic films.

Effects of oxygen plasma surface treatment on BOPP film

An adhesion mechanism between untreated and pre-treated biaxially oriented polypropylene (BOPP) film and evaporated aluminium was investigated to gain a better understanding of process. A special BOPP homopolymer film was modified by inline low-pressure oxygen plasma prior to metallisation in an industrial roll-to-roll vacuum web coater. The pre-treated and metallised film was investigated regarding its aluminium adhesion and barrier properties. An overview of X-ray photoelectron spectroscopy (XPS), contact angle/surface energy measurement and atomic force microscopy (AFM) tests showed the following evidences [Struller et al. 2010]:

- The plasma treatment induced a change on the BOPP film surface by incorporation of oxygen containing polar functional groups, resulting in an increase of the measured aluminium adhesion.
- A weak boundary layer consisting of low-molecular weight oxidized material and thus a decline of aluminium adhesion resulted by higher plasma intensities overtreatment lead.
- AFM indicated a slight change in surface topography due to plasma treatment and confirmed the existence of low molecular weight material on treated BOPP.
- A considerable improvement of oxygen barrier on increasing plasma intensity was observed, whereas water vapour barrier was only slightly enhanced. This confirmed that moisture permeation through polymer films coated with a metal layer is controlled by different mechanisms than oxygen permeation.

Functional Coatings on PET Insulation Films

Plastic films play a supporting role as insulation materials in electrical machinery such as electric motors, generators and transformers. The highly demanding requirements regarding operating voltage, temperature limits, adhesion of the laminate and resistance to media mean that it is necessary to optimize the film properties for electrical engineering applications. The thermo-oxidative and hydrolytic resistance of PET is limited, so the practical use of these films is limited to temperature class B applications (maximum continuous use temperature = 130° C). Electrical machines operating at higher temperatures require the more expensive insulation materials such as polyethylene-naphthalate PEN or polyimide (PI) films. An important economic aspect is the cost differences between the PET and these more stable insulation films. PEN is up to 4-6 times and PI is up to 10-20 times more expensive in comparison to PET. Suitable layer systems with functional coating on standard insulating films (PET) have been investigated in order to replace highly-priced special insulating films.

The idea of functional coating application on top of a polymeric substrate originally comes from the applications used for food packaging [Moosheimer, Langowski et al. 1999]. Deposited diffusion barrier coatings that prevent the access of oxygen and moisture to the PET film could bring a marked improvement in long-term stability of PET films. And this could move the operation limit of the insulation film to higher temperatures. Some improvement trials on insulation polymer material by organic-inorganic hybrid coating have been already described by [Marini et al, 2008].

PET films were coated in roll-to-roll processes with one inorganic oxide layer and combinations of inorganic and hybrid-polymer layers. The effects of accelerated aging on lifetime, barrier performance against oxygen and water vapour and electrical properties of the coated films were investigated. Reduction of oligomeric structures on the surface of high temperature loaded PET films was demonstrated with a two coating layers.

Overview

A first overview of tests carried out on the functional coatings of PET substrates for insulation films showed the following evidences:

- 50 micron PET films were coated with thin barrier layers with a thickness of 1-2 microns
- The barrier properties against oxygen were in the order of 10-2 $cm^3/(m^2\ d\ bar)$ and in the order of 10-2 $g/(m^2 d)$ for water vapour.
- The breakdown voltage was not changed negatively compared to the uncoated reference PET foil.
- Basic correlations were found between film topography, temperature stability and the resulting film properties with a focus on the mechanical and barrier properties.
- A good aging stability of the coated films was demonstrated for short-term thermal storage for two weeks at 160 ° C
- A significant reduction in the growth of crystalline structures on PET surface (100 hours at 190 °C) could be reached by the application of barrier layers.

Examples of practical applications will be also presented.

References

[Struller et al. 2010]: Carolin Struller, Effects of oxygen plasma surface treatmet on biaxially oriented polypropylene film, A diploma thesis, TUM 2010

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