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Surface Modification using Atmospheric Plasma

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Abstract

Use of atmospheric pressure partial discharges (plasma and chemical corona) is becoming ubiquitous within the metallizing, laminating and converting industry. Plasma technology advances including control of gas mixture, temperature controlled high surface area electrodes, higher frequency power supplies and better matching networks all combine to make atmospheric plasma treatment a commercially important process wherever surface functionality is a factor. This process is now used to replace the use of corona and flame treatment in promoting adhesion to flexible packaging polyolefin materials such as polypropylene, polyester and polyethylene film webs at commercial speeds. Beyond surface treatment, atmospheric plasma systems can now be used to perform a Plasma Enhanced Chemical Vapor Deposition (PECVD) process that results in clear oxide layers such as SiO_x on plastic substrates. Emerging applications include ablation or cleaning to remove unwanted residue or material, elevation of surface energy to promote adhesion of ink, lamination adhesion or wetability, sterilization, and deposition of thin functional coatings. This paper will address surface modification applications based on the use of atmospheric plasma to clean, treat, graft and coat different substrates that include, polymer films, metallized films, ITO coated films, window glass, aluminum foil and woven and non woven fabrics.

SIGMA CORE TECHNOLOGIES

- **Surface Functionalization Process and Equipment**
  - Vacuum Plasma Treatment
  - Atmospheric Plasma Treatment and Grafting
  - Nano-Polymer Coatings
  - Metal and Ceramic Coatings
- **Technology Applications Include:**
  - Ultra high Barrier Films for Packaging, Medical and Flexible Display Applications
  - Filters, Protective Fabrics, Apparel,
  - Li Batteries, Fuel Cells,
  - OLED and EL Thin Film Lights and Flexible Displays,
  - Paper, Films, Foils
  - Pigments - security and metallized,
  - Low IR Signature
  - Other

TREATMENT ENERGY DENSITY

- Plasma will generally form in the 6-10 kV range
- Corona generally requires about 8 to 20 kV
- Watt Density (Wd) Calculated the Same Way

$$Wd = \frac{PSw}{WW_m \times LS_{mpm} \times NST}$$

Where

Wd	= Watt Density (watts/m²/minute)
PS	= Power Supply (watts)
WW	= Web Width (meters)
LS	= Line Speed (m/minute)
NST	= Number of Sides Treated

SURFACE ACTIVATION

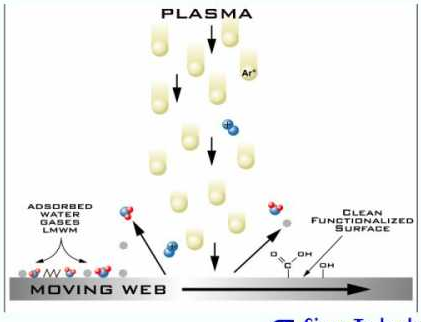
Common surface treatment processes

- **Mechanical: roughing of surface**
- **Chemical: mostly wet chemical**
- **Partial Discharge: activated gases**
  - **Corona**
  - **Flame**
  - **Plasma (ionized or neutral)**

SURFACE ACTIVATION WITH PLASMA AT ATMOSPHERIC PRESSURE

- **Surface Treatment in Atmosphere**
  - **Corona – Limitations**
    - **Intense Filament Discharge – Creation of LMW**
    - **Backside Treatment**
    - **Non Uniform**
  - **Flame - Limitations**
    - **Fixed Chemistry**
    - **Can Damage Low Gage OPP**
    - **Speed Limitations**
    - **Reduction in Film Clarity**
    - **Requires Constant Monitoring of Treatment Levels**

WHAT IS PLASMA ?



PLASMA TREATMENT

- **Sigma Introduced High Speed Plasma to the Metallizing/Converting Industry in the early 1990s**
- **Sigma is the Leading Manufacturer for Commercial Scale Plasma Treaters**

Plasma And Chemical Corona Surface Treatment

Surface Functionalization of Materials

Plasma Treater on a Foil Slitter

System for Treating Film Used to Fabricate Mercedes Windshields

Atmospheric Plasma Treater for BOPP line

Atmospheric Plasma System for Treating Carpets

2 meter Vacuum Plasma Treater

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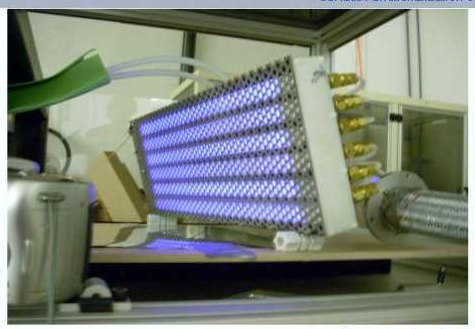
Plasma Electrode with Neutral Plasma

Surface Functionalization of Materials



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Plasma Treater Electrodes

Surface Functionalization of Materials

- Available in Water-Cooled Ceramic and Aluminum
- Al Electrodes are used for Non-conductives
- Ceramic Electrodes are Used for :
  - Treating Metallized Films and Foils
  - Treating on a Bare Metal Roll
  - Treating Thick Sheets
- Plasma Gas is Supplied Through the Electrodes
- Specialty Electrodes That can Treat Film Surfaces with No Roller – No Underlying Ground Plane or Provide Neutral Plasma
- Treater rolls may be Bare Metal or Covered with Silicone Rubber, Polyurethene or Ceramic

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Atmospheric Plasma Electronics Parts Treatment

Surface Functionalization of Materials

•97% "Superior" Parts using High O2 Atmospheric Plasma Treatment & Leading Edge WC Electrodes

vs

•80% "Good" Parts using Low O2, Old Generation Electrodes and Pwr Supply Technology

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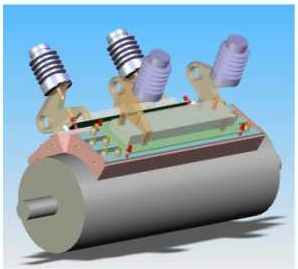
Water Cooled Aluminum Electrode System

Surface Functionalization of Materials

Ideal for for BOPP, CPP, and PE Films
- Reduces LMW Blooming to the Film surface
- Mitigates thermal load

- Maintains High Plasma Volume in Gap
- Long Electrode Life
- Extends Treater Roll Life
- Inexpensive Aluminum Extrusion Construction



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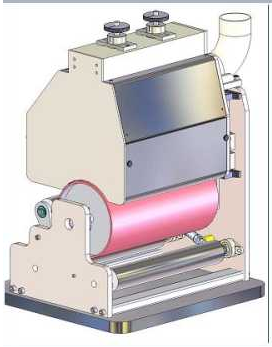
Atmospheric Plasma Controlled Atmosphere Treater

Surface Functionalization of Materials



•Innovative Electrode Design

•Precise Control of Plasma Gas Envelope

•Large Volume Plasma Rxn Region

•Improved Plasma Gas Containment

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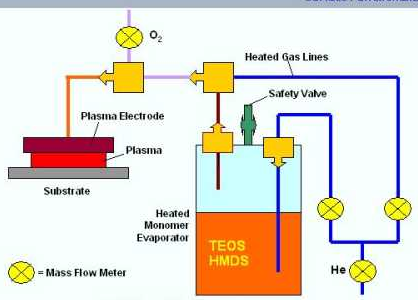
ATMOSPHERIC PLASMA CVD COATING

Surface Functionalization of Materials



TEOS:Tetra Ethyl Ortho Silicate

HMDS: Hexa Methyl Di Siloxane

ATMOSPHERIC PLASMA CVD COATING

Surface Functionalization of Materials

- **Gas Reactions**
  - He > He*
  - He* > He+ + e-
  - TMDSO + He* > TMSDO* + He
  - TMDSO* + He > TMDSO* + He*
  - TMDSO + He* > TMDSO* + He*
- **Surface Reactions**
  - $TMDSO^* + 8.5(O_2) > CO + 3CO_2 + 7H_2O + 2SiO_2$

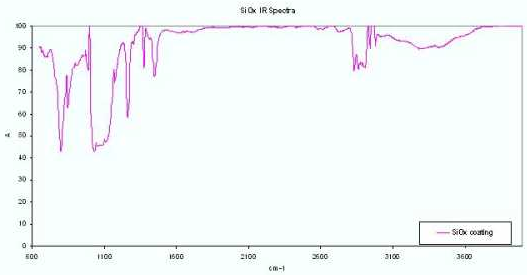
ATMOSPHERIC PLASMA CVD COATING

Surface Functionalization of Materials

Flat Plate Treater For Producing a 100A Anti-fog Ceramic Coating on Polycarbonate Sheet Material

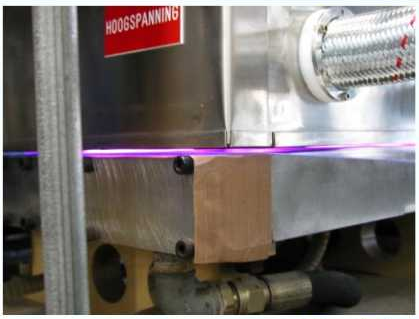
ATMOSPHERIC PLASMA CVD COATING

Surface Functionalization of Materials



ATMOSPHERIC PLASMA CVD

Surface Functionalization of Materials



SUMMARY

Surface Functionalization of Materials

- Plasma Based Surface Functionalization is an Effective Tool to Add Value to Various Large Scale Surfaces that include:
  - Flexible Webs: Films, Fabrics, Foils, Paper, Non-wovens, etc
  - Powders
  - Polymer and Glass Sheets
- Atmospheric Plasma Reactors Can be used to:
  - Treat
  - Graft
  - Coat
- Atmospheric Plasma Etching, Ashing, and CVD Based Deposition Processes will Grow Rapidly in the Near Future at the Expense of Vacuum Plasma, Corona , Flame and Liquid Chemical Treatment and Deposition Processes