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Atmospheric Plasma & Flame Medical Primer

digital book series

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Table of Contents

Introduction

Atmospheric plasma and flame surface treatment is playing a key role in the design and development of medical devices. Plasma improves the condition of the surface prior to **applying inks, coatings & adhesives**.

In-line atmospheric plasma treating systems are ideal for medical devices because of their ability to **improve adhesion** properties on a wide variety of surfaces of all shapes and sizes.

Benefits of in-line surface treatment include **stronger bonds**, faster line speeds, and improved product quality.

This ebook covers the basics of **plasma surface treatment** and the technologies available for medical applications.

Chapter 1

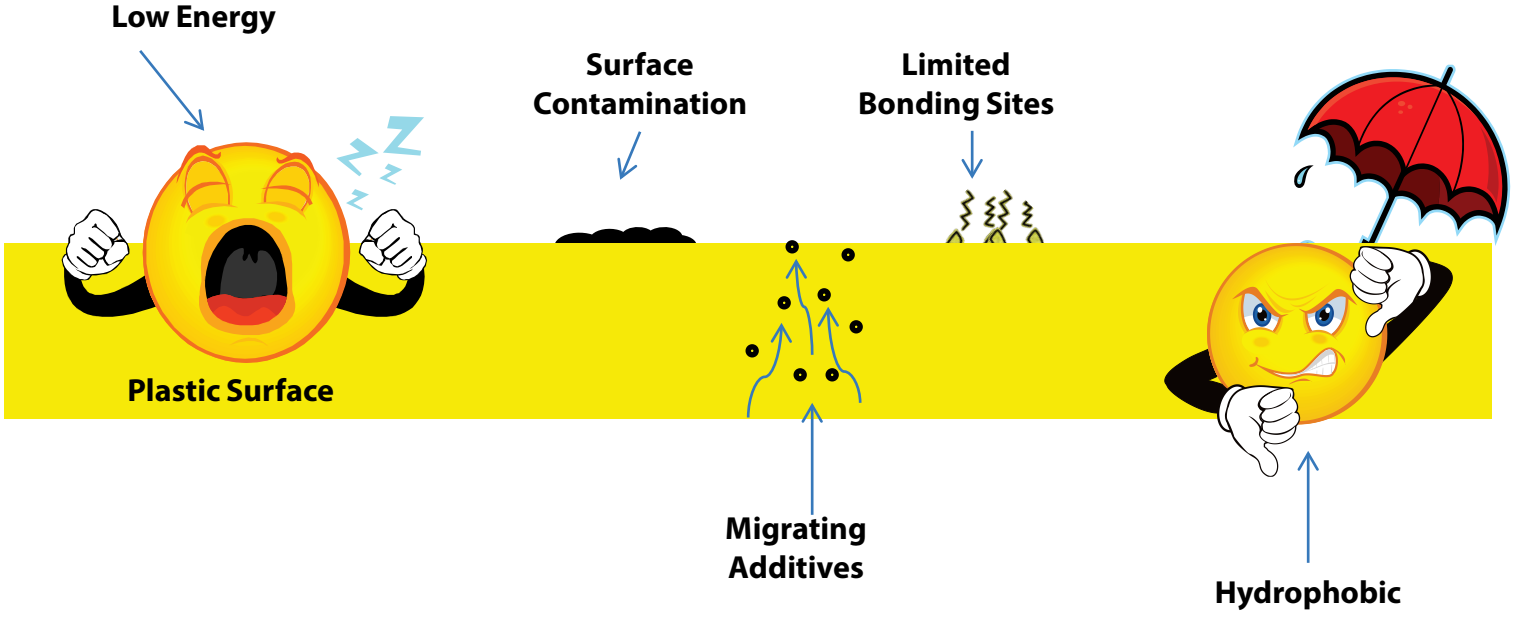
Why inks, coatings & adhesives need help bonding to surfaces

Controlling surface variables is key to for successful adhesion

Factors Affecting Adhesion Dynamics

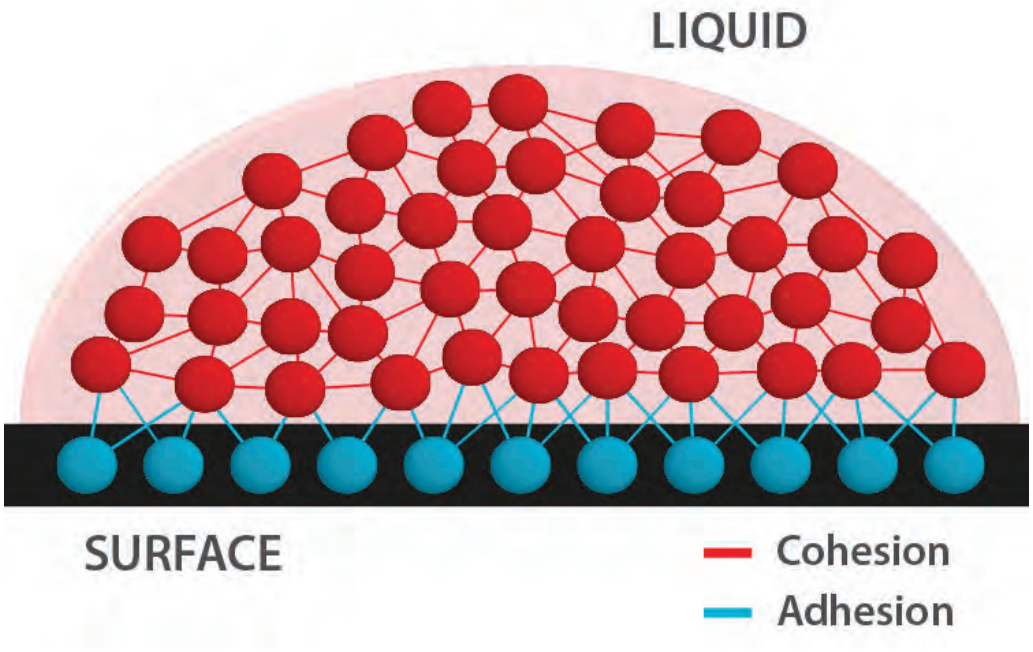
- Material type
- Performance-aiding additive load
- Adhesive chemistry
- Bond stress
- Surface contaminants
- Surface roughness
- Surface chemistry

Common adhesion impediments found on plastic surfaces



Plastics are generally composed of non polar long-chain molecules with non porous and hydrophobic surfaces. They have low surface energy with few available bonding sites due to low levels of charged ions on the surface. Additionally any type of surface contamination negatively effects adhesion. This includes material additives & release agents which can migrate to the surface

How the Forces of Cohesion & Adhesion Affect Wetting Out



Low energy, lack of bonding sites, and surface contamination have a negative impact on molecular attraction, causing liquids to fail to wet the surface.

In simple terms:

When you observe a liquid beading up on a surface you are witnessing **the forces of cohesion** (the property of the liquid's like molecules to remain attracted) being stronger than the **forces of adhesion** (the property of unlike molecules to attract.)

Examples of poor adhesion

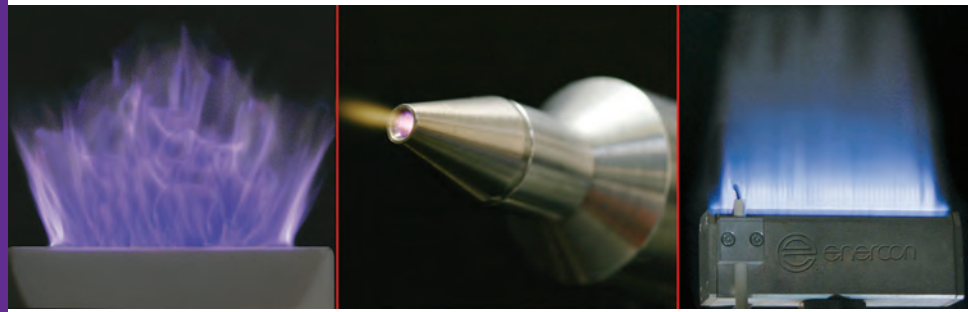
Poor adhesion resulting from surface issues appear in a variety of ways:

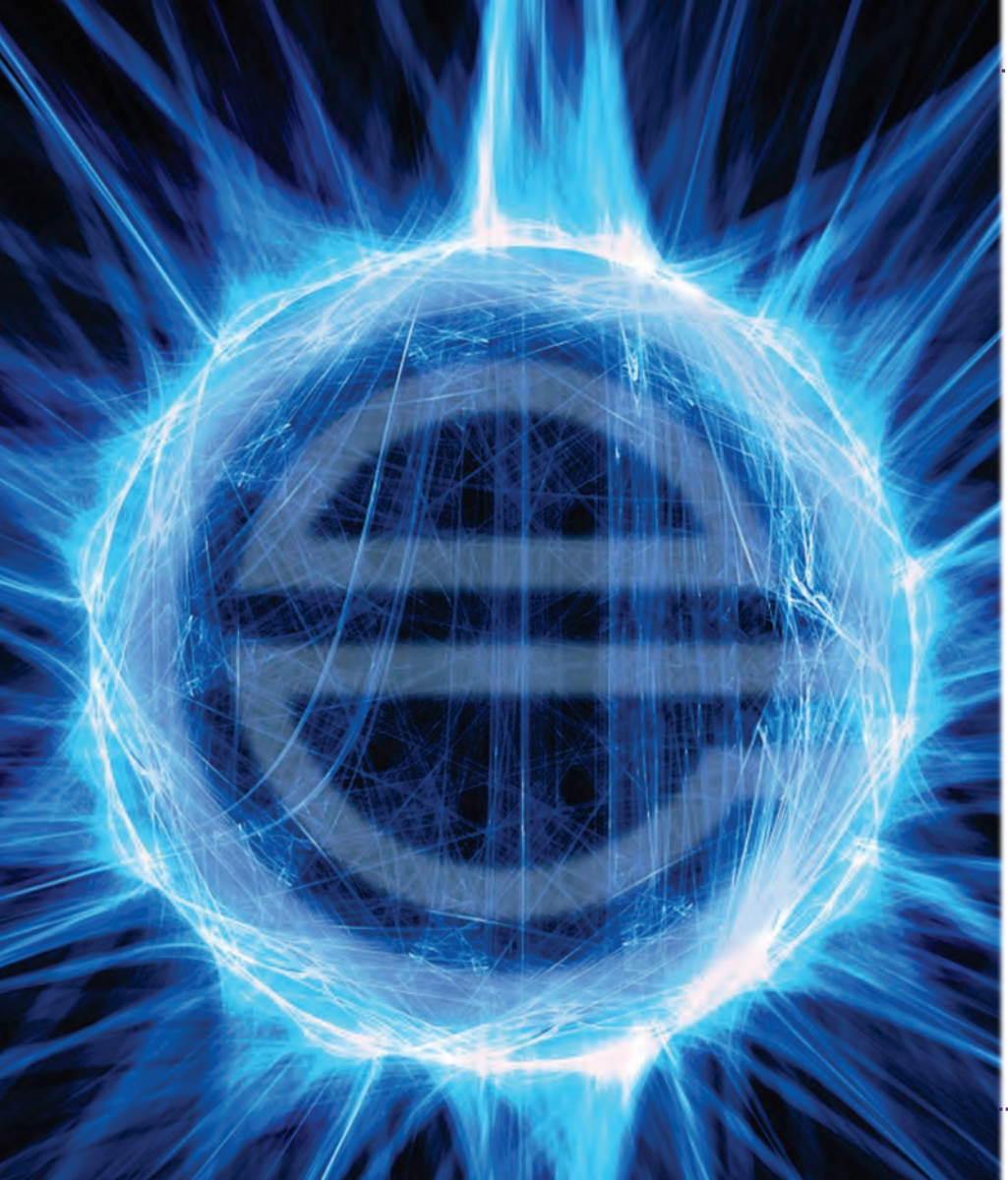
- **Inconsistent ink adhesion**
- **Adhesive failures**
- **Failure of coatings to wet out**
- **Bond strength failures**

Chapter 2

How atmospheric plasma treatment improves adhesion

Atmospheric plasma discharges clean, etch and functionalize surfaces to improve adhesion.





What is atmospheric plasma?

plasma : n ; "Fourth state of matter",
(Solid, Liquid, Gas, Plasma.)

Mixture of charged ions & energetic electrons generally in equilibrium.

Atmospheric plasma surface treaters generate plasma to impart adhesion promotion onto a wide range of surfaces.

Adhesion promoting surface effects

Cleans Surfaces

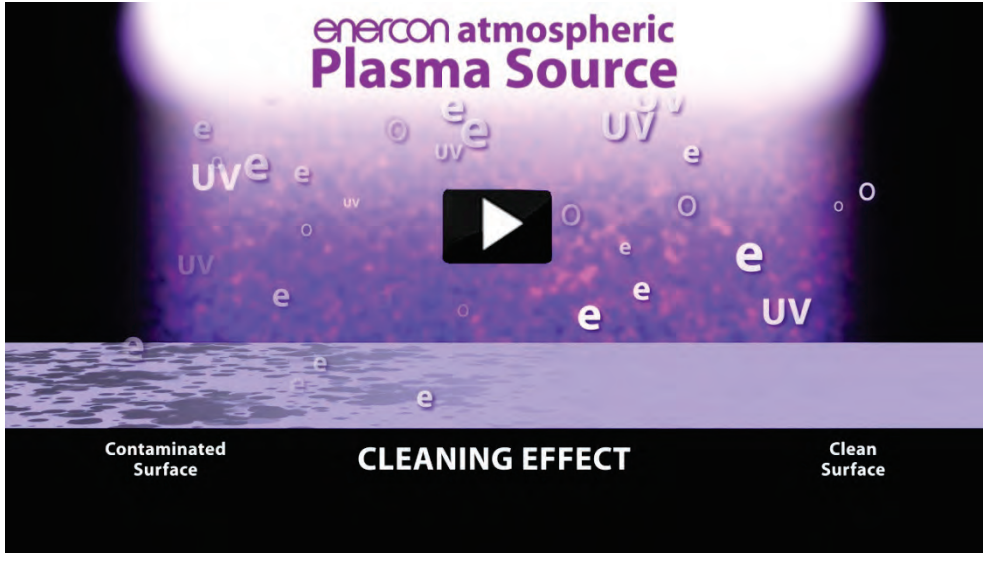
Etches Surfaces

Functionalizes Surfaces

Atmospheric plasma is highly effective at **cleaning, etching & functionalizing** a variety of surfaces.

The following pages will provide insights into how atmospheric plasma achieves these effects and how they help promote adhesion.

Plasma Cleaning



Click the image above to see an animation of plasma cleaning.

Plasma treatment **removes organic and inorganic impurities & contaminants** from the surface.

Plasma species react with the surface and decompose, volatilize & vaporize low molecular weight contaminants to expose a clean, fresh surface to promote adhesion.

Cleans Surfaces

Plasma Etching

Click the image above to see an animation of plasma etching.

Micro etching of a polymer surface is accomplished as charged ions, neutral atoms and radicals, in both the plasma forming gas and the reactive process gas, bombard the surface.

Increasing surface area creates more bonding sites which promotes adhesion success.

Etches Surfaces

Plasma Functionalizing and Activation

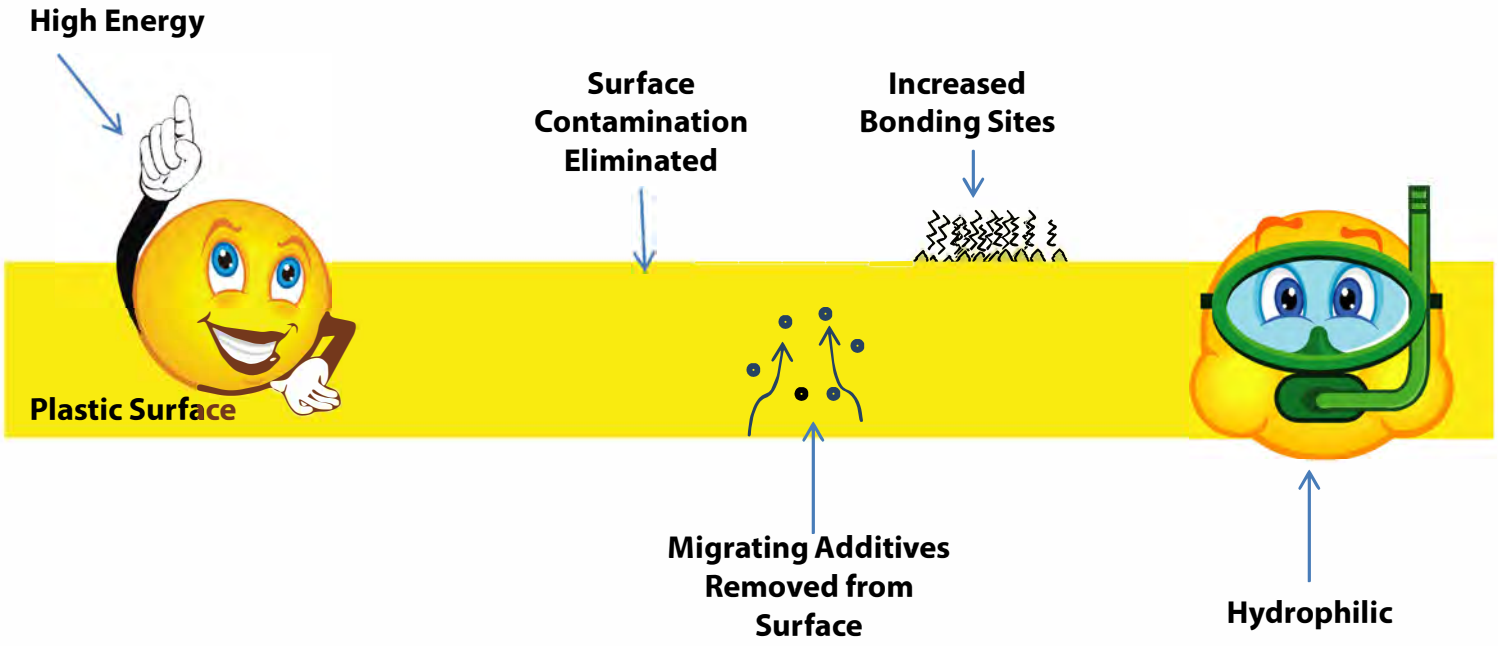
Plasma activation or functionalization is the concurrent process of using radicals & small amounts of UV radiation to break up surface polymer bands to create cross linking of surface molecules.

This process **increases polar groups** which directly contributes to the surface's adhesion properties.

Click the image above to see an animation of plasma functionalizing.

Functionalizes Surfaces

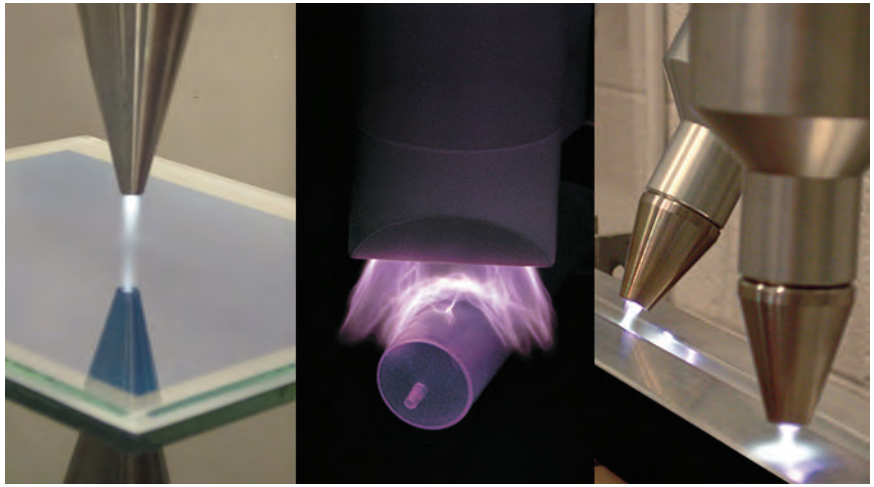
The Transformation of a Surface Prepared for Adhesion

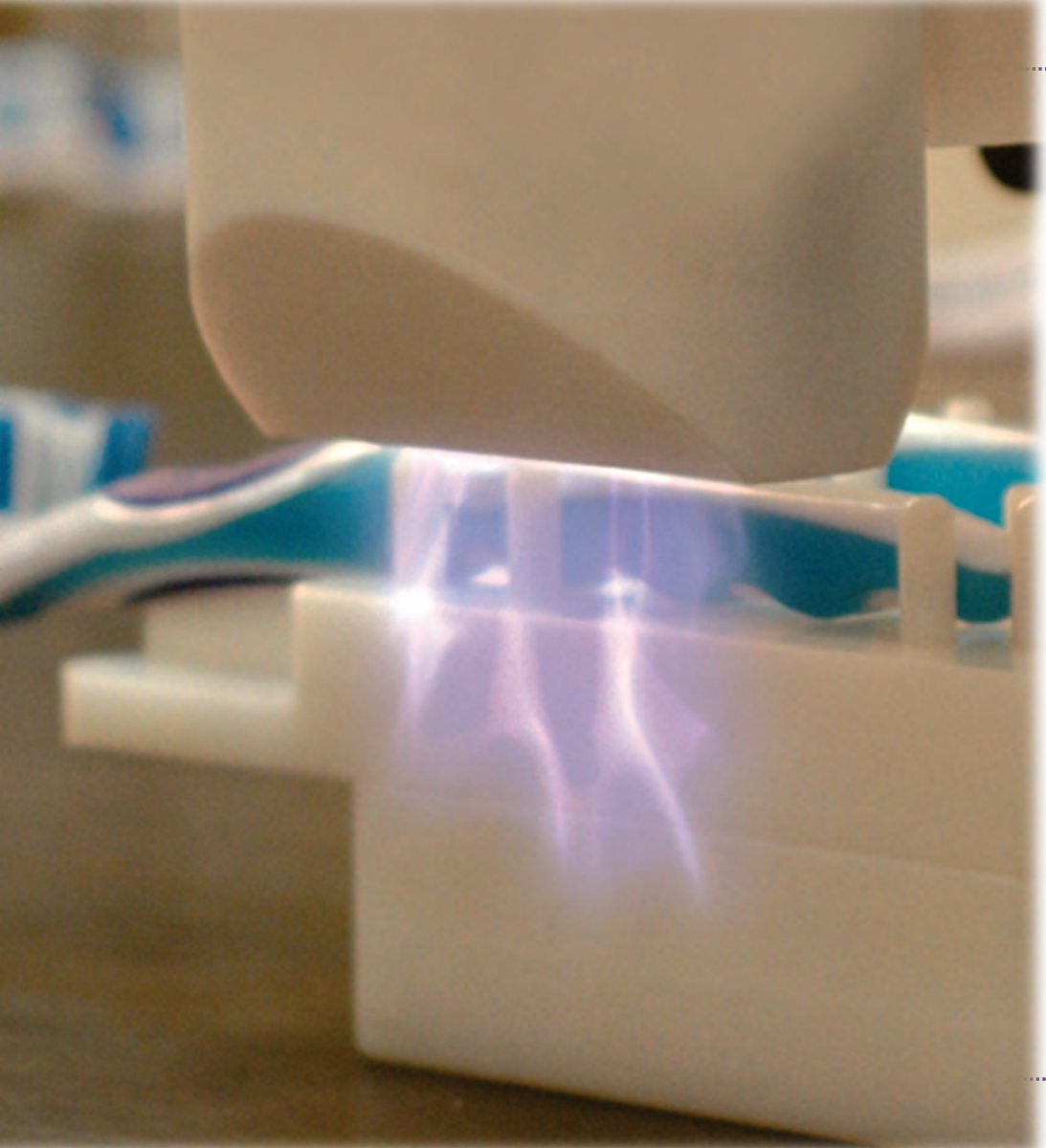


Chapter 3

What type of surfaces can be treated?

Atmospheric Plasma Treatment effectively treats glass, plastics and metals





Polymers for Biomedical Devices

Plastics, polymers, and resins are widely used for in vivo and in vitro medical applications. However they are nonporous making them non-receptive to bonding with inks, adhesives and coatings.

Atmospheric plasma aids in cleaning & decontaminating medical devices by increasing the hydrophilic nature of the surface, increasing adhesion.

Tech Paper: Atmospheric Surface Modification Of Polymers For Biomedical Device Adhesion

Surface Treatment Plastics

Atmospheric plasma surface treatment is effective at treating a wide variety of plastics and polymers for medical applications. Below is a list of common materials and applications:

	ABS	PA	PBT	PC	PE	PET	PMMA	PP	PS	PUR	PVC	TPU
Angioplasty Balloons		●				●						
Catheters/Housing			●									
Filter Casings	●			●			●					
Microplates								●				
Needle Hubs	●			●	●		●	●				
Optical Lenses				●			●					
Petri Dishes									●			
Syringes			●					●				
Tubes, Valves, Connectors	●			●						●	●	●
Vials								●				

Other Common Polymers:

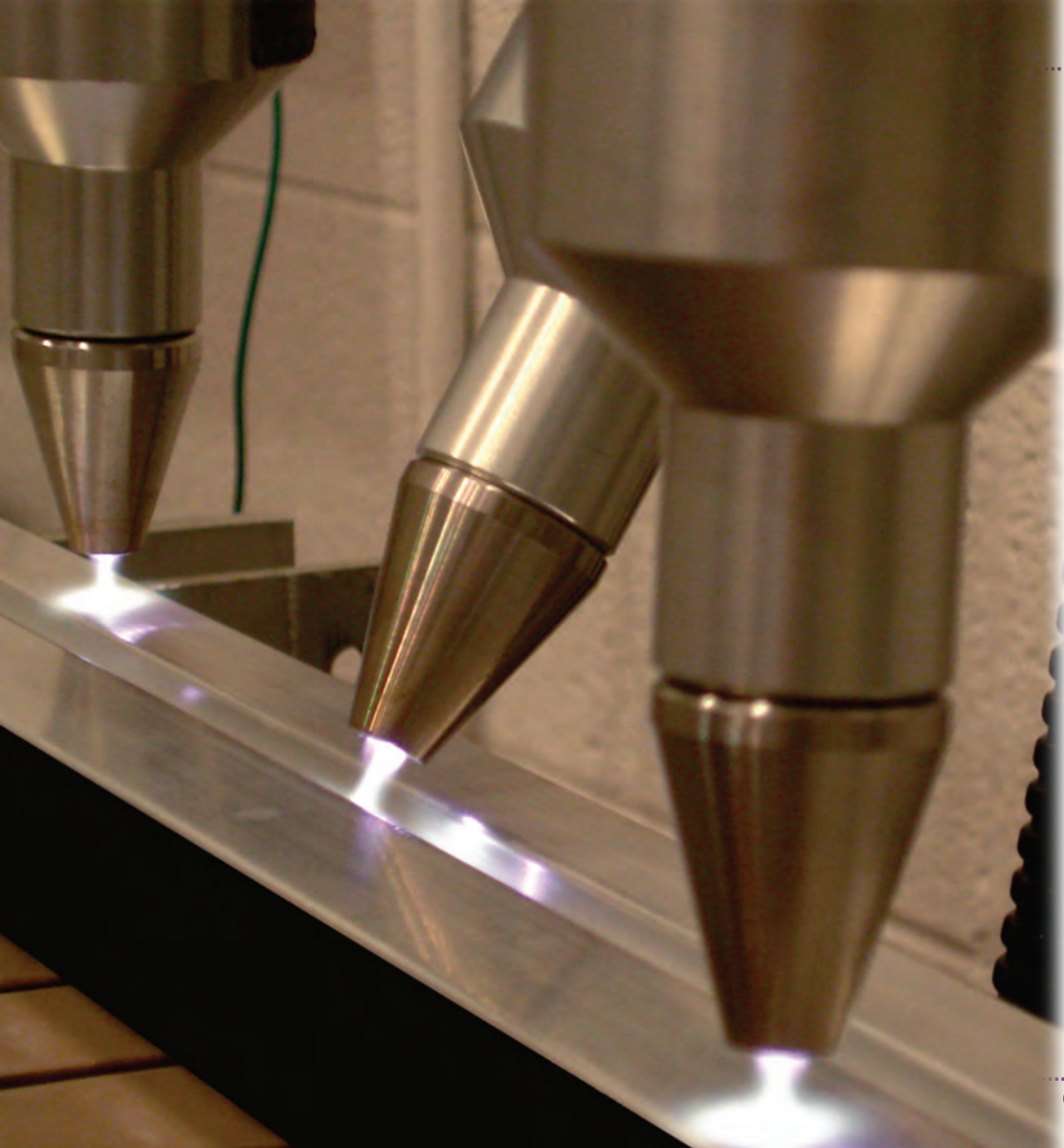
ASA, EPDM, EVA, HDPE, LDPE, PU, PBT, Silicones

Surface Treatment Glass

Atmospheric plasma surface treatment is effective at **treating glass for the purposes of cleaning and sterilization.**

In some cases flame treatment may be used to treat glass as well.

Is Plasma right for you?
Ask an application expert
Click or call 1-262 255-6070



Surface Treatment Metals

Atmospheric plasma surface treatment is effective at treating metals for **cleaning and removing contaminates.**

For large areas flame treatment is often used to treat metals as well.

(note: not all atmospheric plasma treaters are suitable for treating metal, please consult with your treater supplier to verify the capabilities of your system.)

Chapter 4

Common Medical Applications

Surface treatment is used on a variety of medical device applications

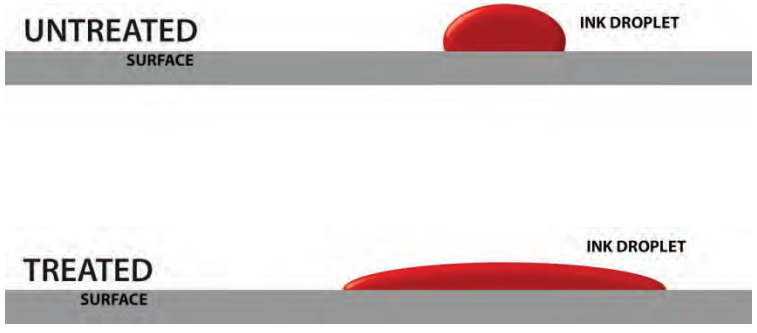
Atmospheric Plasma Medical Application : Inks

Accurate and long lasting ink adhesion is critical for medical device manufacturing.

Plasma and flame surface treatment is effective at improving adhesion for solvent, water based and UV/EB printing processes.

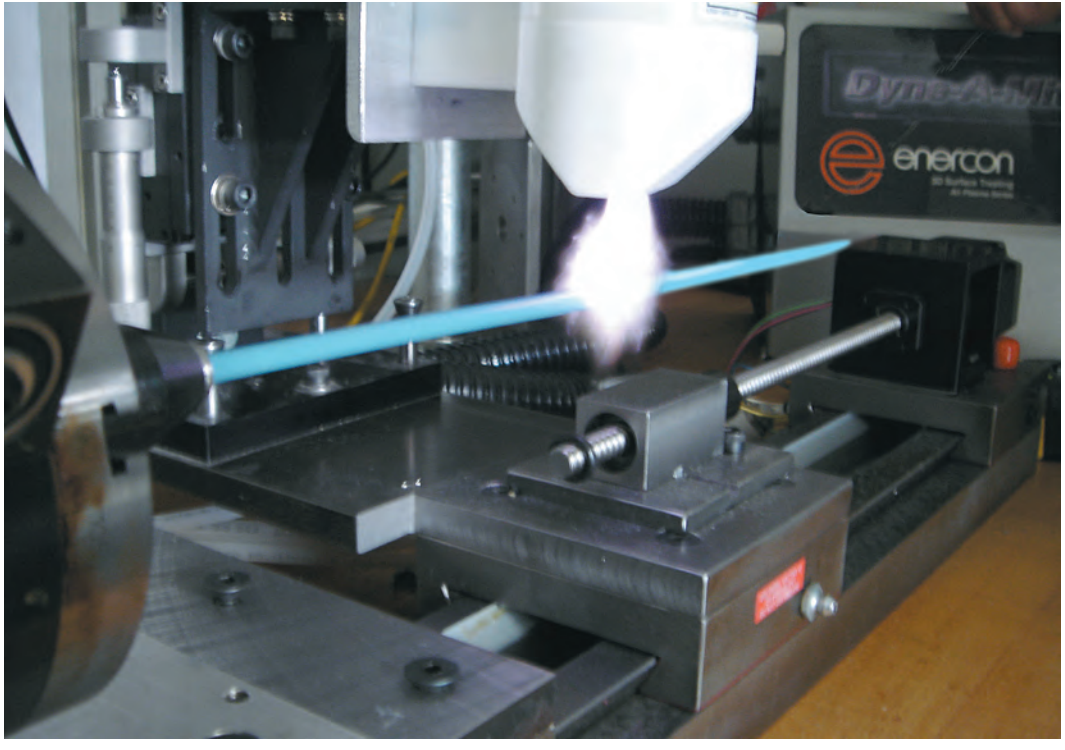
Pretreatment eliminates surface contamination and the addition of surface roughness can further **enhance ink wettablility and bond strength**.

Medical device manufacturers using plasma surface treatment benefit from increased production speed, enhanced print quality, lower applied cost, reduced energy and space requirements.



Tech Paper Available:
Energy Curing Substrates & Inks

Atmospheric Plasma Medical Applications



"For medical printing applications it's imperative to follow the defined protocols. Enercon's experience with medical device applications ensured the project went very smoothly."

Ron Kohl
President
K-Kolor, Custom Wire Technologies

Click here to see a story on this application on our website

Atmospheric Plasma Medical Application : Adhesives

Hard-to-bond plastics, such as polyolefins often used for catheters, syringes, and tubings require assembly using cyanoacrylate adhesives.

Release agents and other contaminations exposed to the molded and formed medical parts during production can hinder the performance of adhesives.

Plasma and flame treatment alter the first few atomic layers of the polymer to **render surfaces wettable so that adhesive bonding can be achieved.**

When tested on a balloon catheter using chemical surface activation or mechanical surface roughening techniques, bond failures were noted after eight repetitive inflations. With plasma treatment up to 40 repetitions were achievable.

Lap-shear bond strengths (psi), without and with plasma treatment

Medical Polymer	Without	With
Polypropylene	370	1,380
Polyethylene (Low Density)	370	1,450
Polyethylene (High Density)	315	3,125
Nylon	850	4,000
Polystyrene	570	4,000
Polycarbonate (Lexan)	410	928
Tefzel	410	3,200

Tech Papers Available:
Joining of Medical Plastics
UV/ LED Adhesive Bonding Solutions

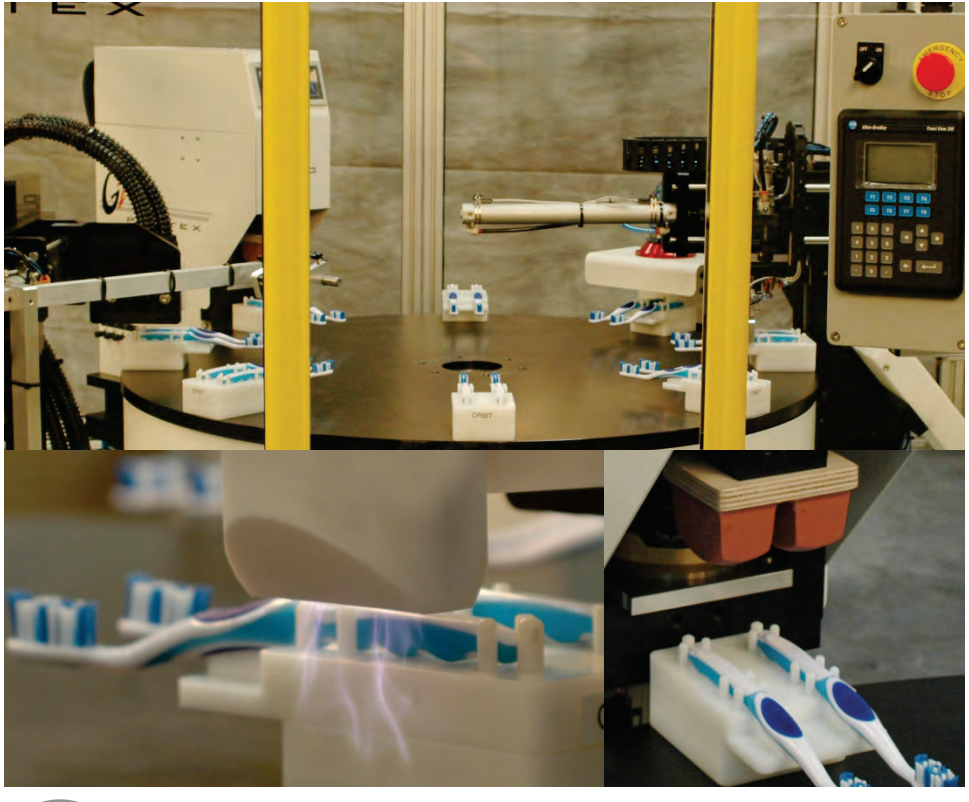
Atmospheric Plasma Medical Application Spotlight: Needle Hubs

Atmospheric plasma is used to promote adhesion on needle hubs used in the medical industry. It effectively treats the inside of polypropylene hubs prior to bonding with needles.

Polypropylenes are often selected for their good mechanical properties, but they are a difficult-to-bond substrate since they are have low surface polarity, an intermediate level of crystallinity, and no inherent surface roughness to which an adhesive can secure itself.

Enercon's plasma treater bombards the polypropylene with high velocity discharge of ions **cleaning the surface of contaminants and micro-roughening the surface to create more bonding sites** resulting in more bonding sites for the adhesive.

Atmospheric Plasma Medical Applications



"We enjoy working with Enercon because they are a single source supplier of multiple atmospheric plasma technologies. Enercon is able to match the best and most cost-effective solution for each application."

Robert Bowden
Vice President
Printex

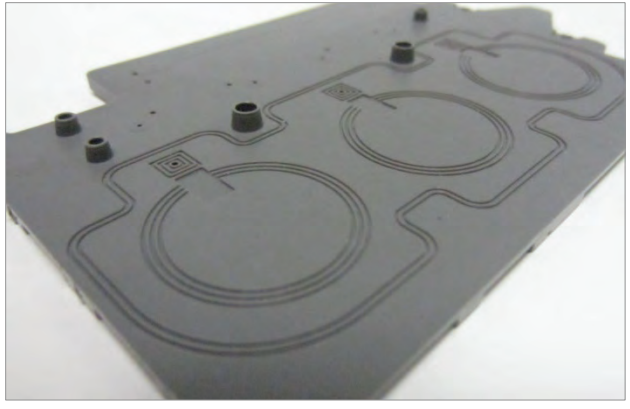
Click here to see a story on this application on our website

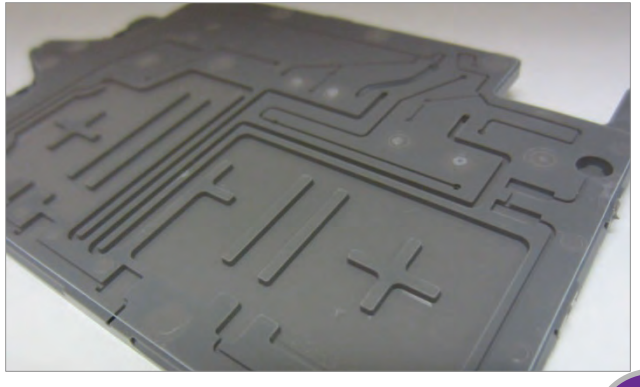
Atmospheric Plasma Medical Application Spotlight: Lab-on-a-Chip

A Lab-on-A-Chip (LOC) is a single use Point-of-Care testing cartridge that allows various fluids to flow and combine with a specific test material.

Most LOC cartridges utilize multiple micro channels to guide the fluid path; however, flowability can be a concern depending on the surface energy of a material.

Currently, plasma and flame treatment are both being used to clean, functionalize, and increase the flowability of fluids on these microchip-sized wafers. Common materials include glass as well as various medical plastics.





Atmospheric Plasma Medical Applications

Click the image above to open a photo gallery

Common Medical Applications

- Angioplasty Balloons
- Artificial Cartilage
- Blood filtration membranes
- Catheters
- Clamps
- Dental
- Diabetic Test Strips
- Filter Casing
- Implants
- IV & IV Bags
- Medical Films
- Medical Gowns
- Microplates
- Needle hubs
- Optical lens
- Prosthesis
- Petri Dishes
- Stent
- Syringes
- Test Tubes
- Tubes
- Valves
- Vascular Devices
- Vials

Chapter 5

How can I tell if surface treatment changed the surface?

There are number of methods to determine the effectiveness of surface treatment.

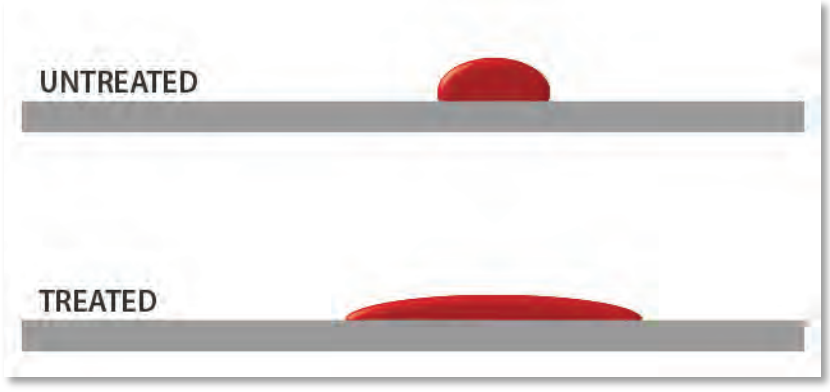
Determining the Effects of surface treatment

In most cases a surface that has been plasma treated will show no change to the human eye.

We'll review a number of different test methods designed to determine the effectiveness of surface treatment.

Its important to remember **the most important test is the success or failure of your ultimate bonding process,** whether that be printing, painting, coating or bonding.

Visually seeing results of plasma surface treatment



Instant examples of improved adhesion from surface treating can be observed by watching an ink or adhesive droplet wet out on a surface as shown in the examples to the left.

The liquid on the untreated surfaces fails to wet out whereas the treated surface enables wetting out.

Measuring Surface Energy in Dynes

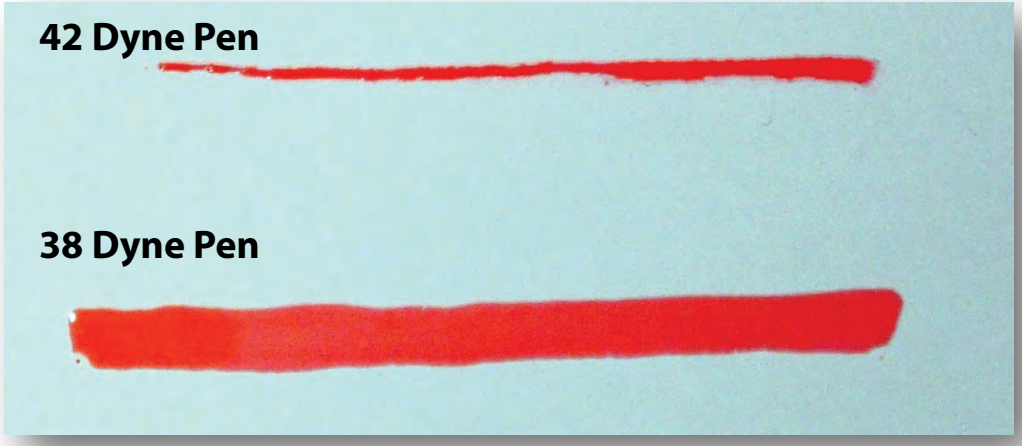
A popular way of determining the effect of surface treatment is to **measure its change in surface energy with dyne solutions.**

Dyne solutions are calibrated liquids that measure surface energy. They are available in bottles and pens.

Often your ink or adhesive supplier will recommend a specific minimum surface dyne level for adhesion success.

Click here for more information on dyne testing

Considerations regarding dyne levels



The solid line created by the 38 dyne pen indicates a surface energy of at least 38 dynes. The 42 dyne pen ' s ink did not wet out indicating a dyne level less than 42 dynes.

Dyne level readings are subjective

± 2 dynes is a safe margin of error.

Higher dyne levels and adhesion

In general higher dyne levels are better for adhesion, but once the dyne level threshold for successful adhesion is reached, there are not significant benefits to striving for even higher levels.

Dyne levels do not guarantee adhesion

Dyne level is one of many factors that contribute to adhesion, therefore it is only an indicator of your chances of success.

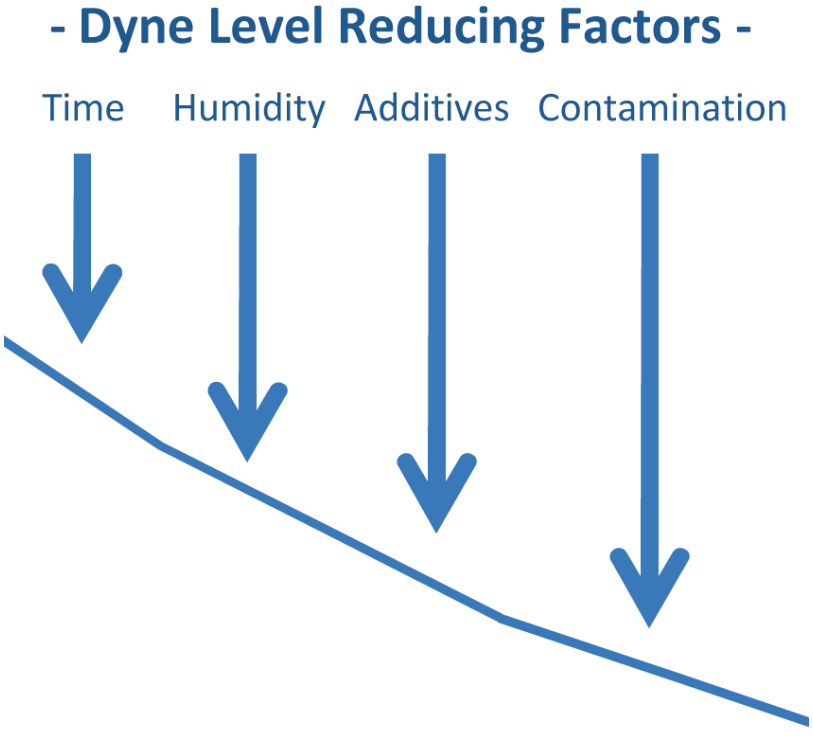
Surface Treatment Plastics Typical Starting Dynes

Material	Initial Dyne Level	Post Treatment Dyne Level
ABS	31-35	44-72
ETFE	30>	50
ETFE	30>	50
Flexible PVC	33-36	40-56
PEEK	30	>72
PET	35	44-60

Material	Initial Dyne Level	Post Treatment Dyne Level
Polycarbonate	37	56-72
Polyethylene	32-34	42-60+
Polypropylene	30-34	45-60
Polystyrene	36	52-70
PTFE	30>	50
Rigid PVC	33-36	42-60+
TPU	34	48

Several factors can impact initial and post treatment dyne level readings. The chart above is provided as a general guideline of typical results.

Considerations regarding dyne levels



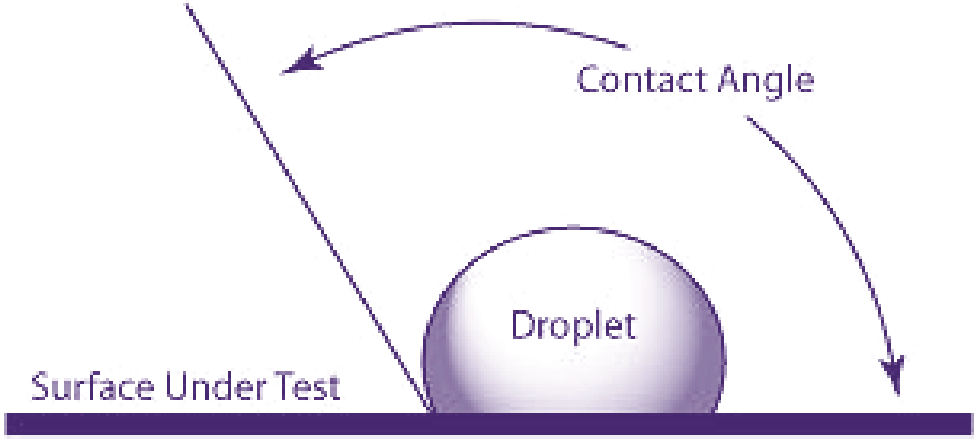
Dyne level decay rate vary based on environmental and material factors.

Treatment life may vary from hours to several months.

Special care should be taken when handling any surface after it has been treated to not contaminate the surface.

Since dyne levels decay over time it is a best practice to print, coat, paint, laminate or bond to a surface as soon as possible after treatment.

Contact Angle Measurement

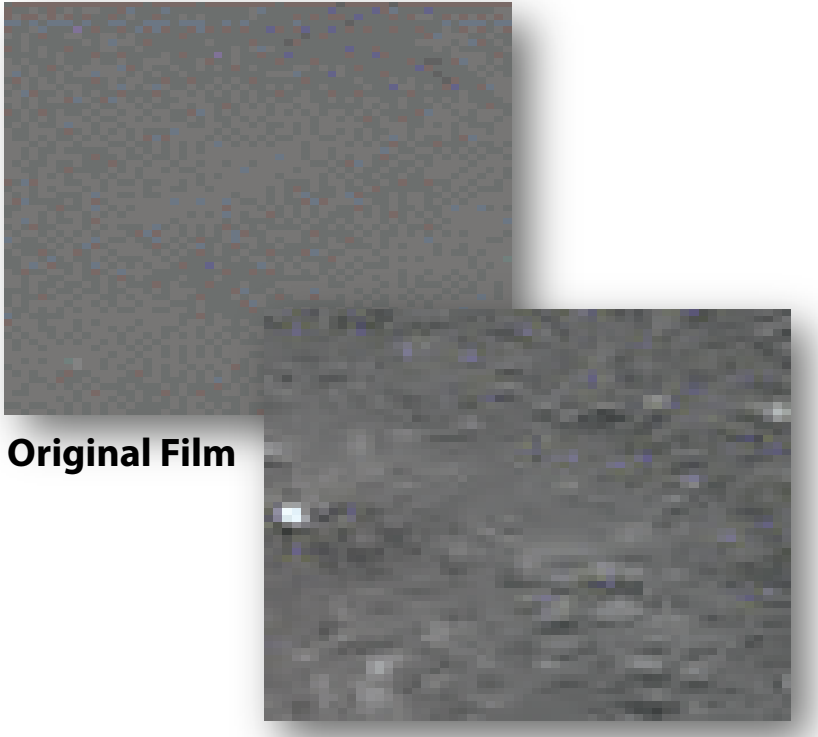


Contact angle measures the interaction of a liquid with a solid.

In general, a water droplet which "runs" to the base of the incline surface at a low incline angle indicates that the material has a low surface tension.

Water droplets which do not run at low angles indicate the material has a high surface energy.

Advanced analysis of surface treatment



Another example of how plasma treatment can affect a surface is shown to the left.

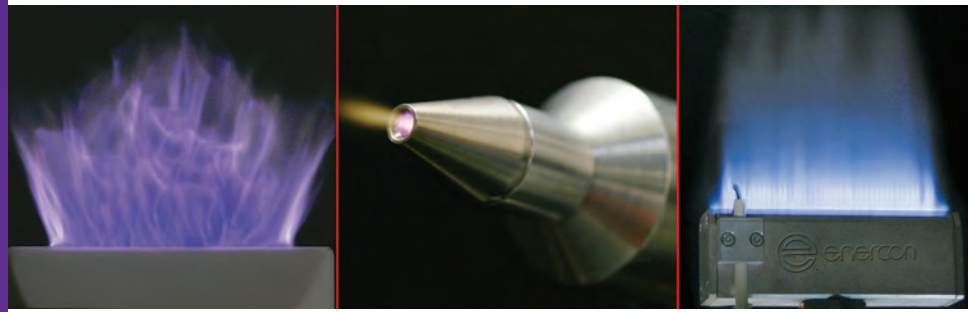
The images are of a Polyethylene film captured by a Scanning Electron Microscope (SEM) at 30,000 magnification.

The plasma treated surface has an increase in surface area & bonding sites which promotes adhesion.

Chapter 6

Atmospheric Plasma Treater Technology Comparison

Understanding the capabilities of your plasma treater is key to success.



Blown Arc Air Plasma Characteristics

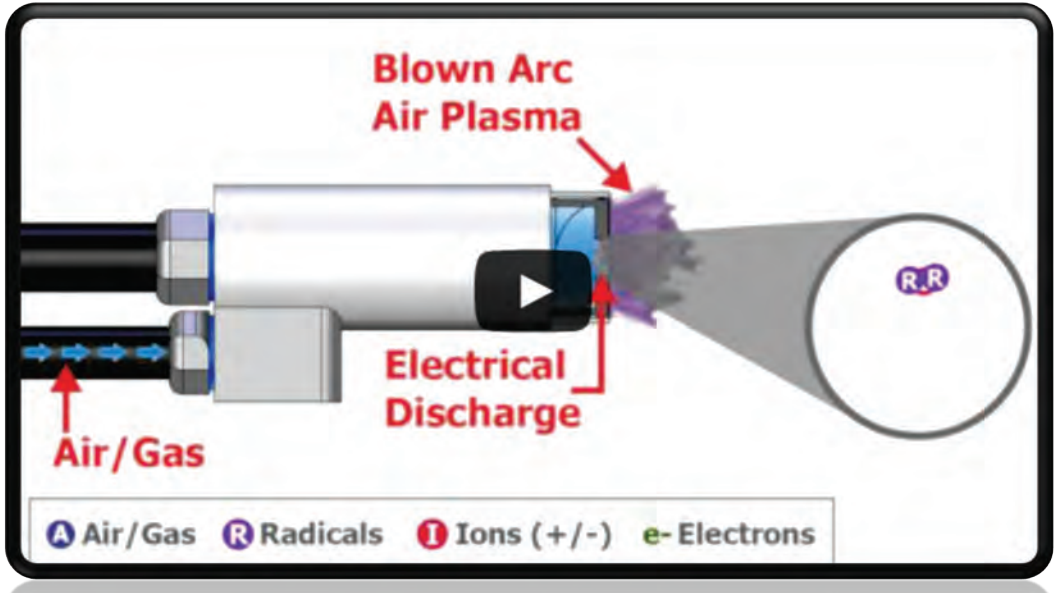
Ideal for a wide range of applications

Treats extruded, molded and formed materials

Treats non-conductive materials

Wide Treatment Pattern – 2 " or 3.5"

How Blown Arc Air Plasma Treatment Works

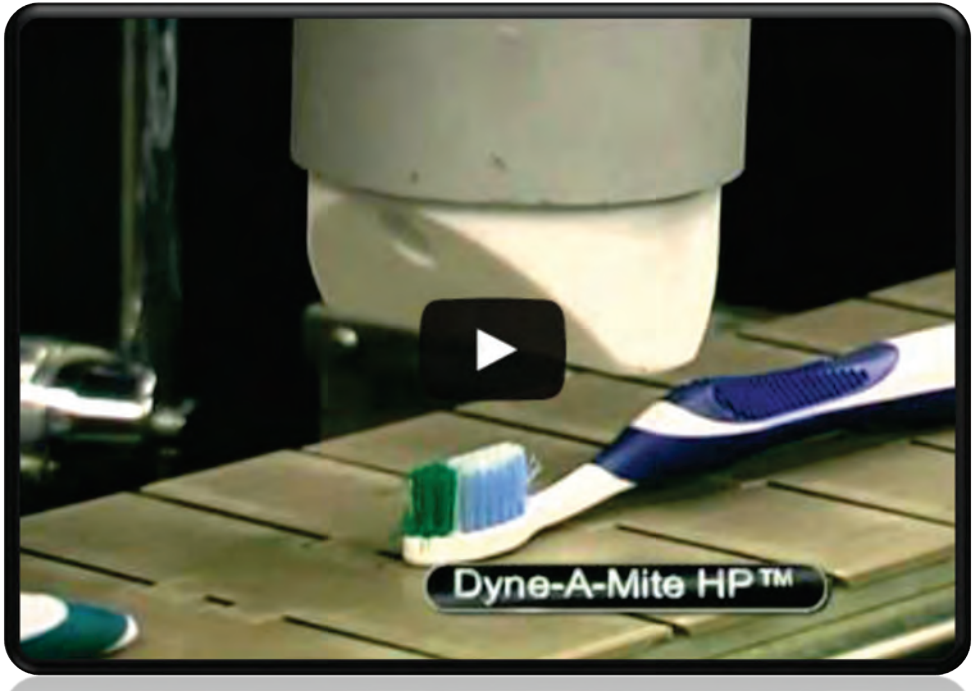


Click the image above to see an animation of how blown arc plasma treatment is created.

Blown-arc air plasma is formed by blowing air past two high voltage power electrodes and is sometimes referred to as corona treatment.

The electrical discharge positively charges the ion particles surrounding it. Through direct contact, these **particles positively charge the treated area** making the surface more receptive to any applied substance.

Blown Arc Plasma Treatment in Action

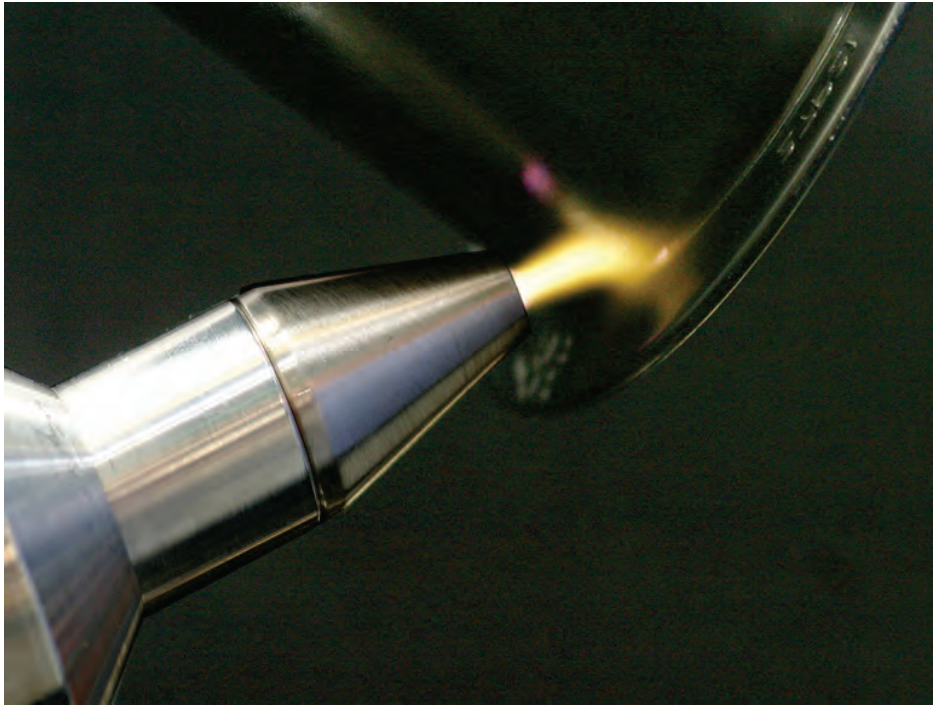


Click the image above to see Enercon's Dyne-A-Mite™ HP plasma treater in action.

The video to the left shows **a lab trial of a blown arc plasma treater** treating toothbrushes prior to pad printing.

The resulting increase in surface energy enabled successful printing.

Blown Ion Air Plasma Characteristics



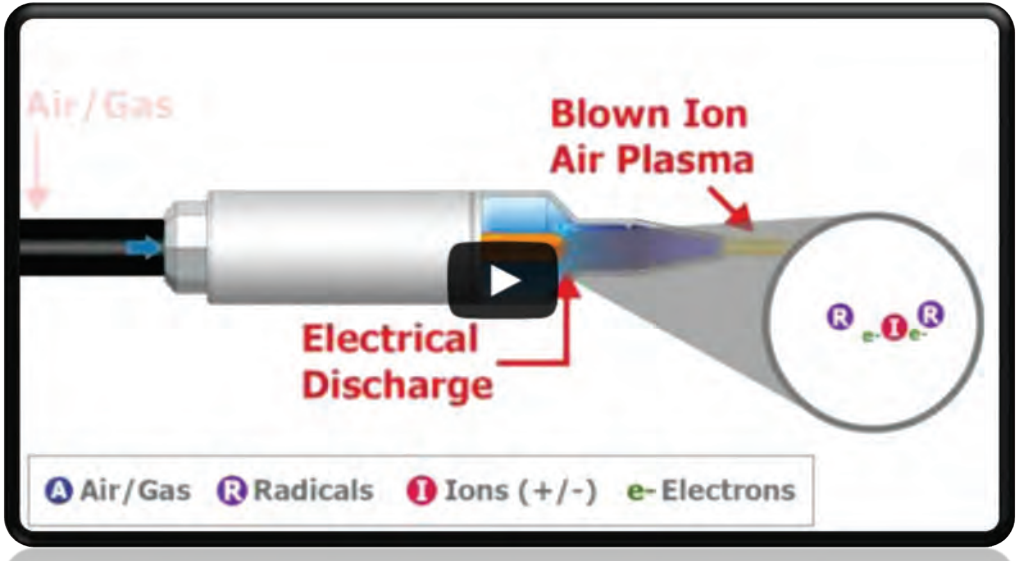
Treats conductive & non conductive materials

Most common used technology in medical industry because of focused treatment coverage: 3/8" – 5/8"

Precise pattern or spot treatment

Requires minimum dwell time (enables high speed in-line treatment)

Blown Ion Plasma Treatment



Click the image above to see an animation of how blown ion plasma treatment is created.

Blown-ion air plasma pushes pressurized air past a single electrode which discharges inside the treater head. The electrode creates positively charged ions in the surrounding air particles.

The air pressure then forces the air particles to accelerate of the tip of the head as **a high velocity stream of charged ions directed toward the object's surface**.

Blown Ion Plasma Treatment in Action

Click the image above to see a video of Enercon's Dyne-A-Mite™ IT plasma treater integrated with a robotic arm.

The video to the left demonstrates a blown ion **plasma treater integrated with an articulating robotic arm** for precise treatment patterns.

Flame Plasma Characteristics

Treats conductive & non conductive materials

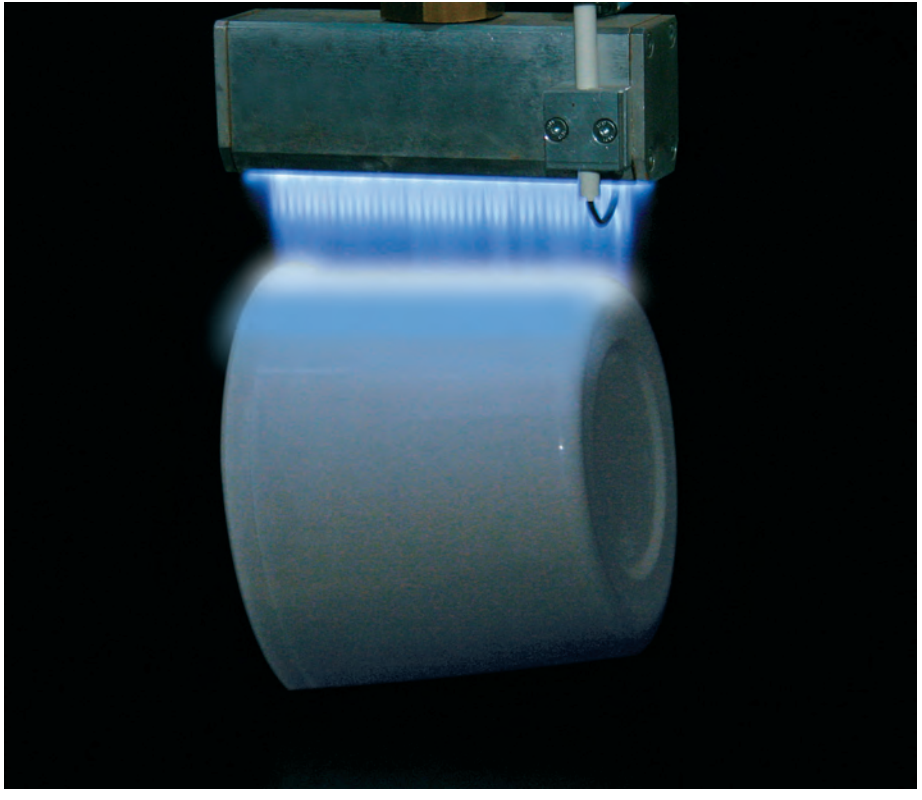
Long lasting, delicate, uniform & high treatment levels

Wide treatment pattern:
35 mm -1500 mm +

Fail safe design

High speed, in-line treatment

Flame Plasma Treatment



Flame plasma is created when flammable gas and air are combined to combust, forming an intense blue flame.

Brief **exposure to the energized particles affects the distribution and density of electrons** on the substrate's surface and polarizes the molecules through oxidation.

This method deposits functional chemical groups that promote wetting and adhesion.

Flame Plasma Treatment in Action

Click the image above to see a video of Enercon's Dyne-A-Flame™ treater.

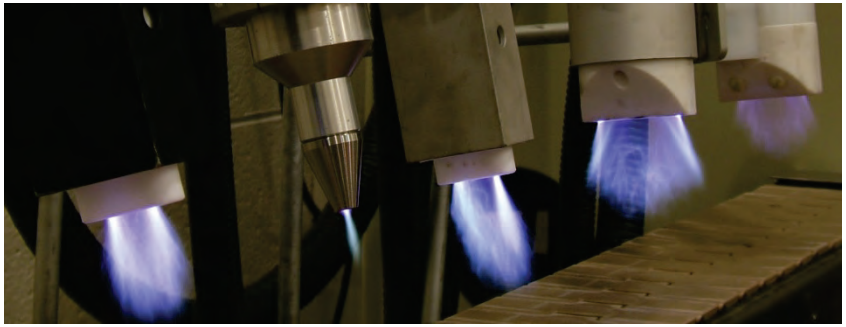
The video to the left demonstrates a atmospheric flame treater both mounted in a **stationary position and integrated with a multi-axis robot**.

Click here for more information on plasma & flame treaters

Chapter 7

Getting Started… Review, Integration, & Free Lab Trials

Putting your application to the test is the best way to find the optimal surface treating solution



Atmospheric Plasma Surface Treating Review

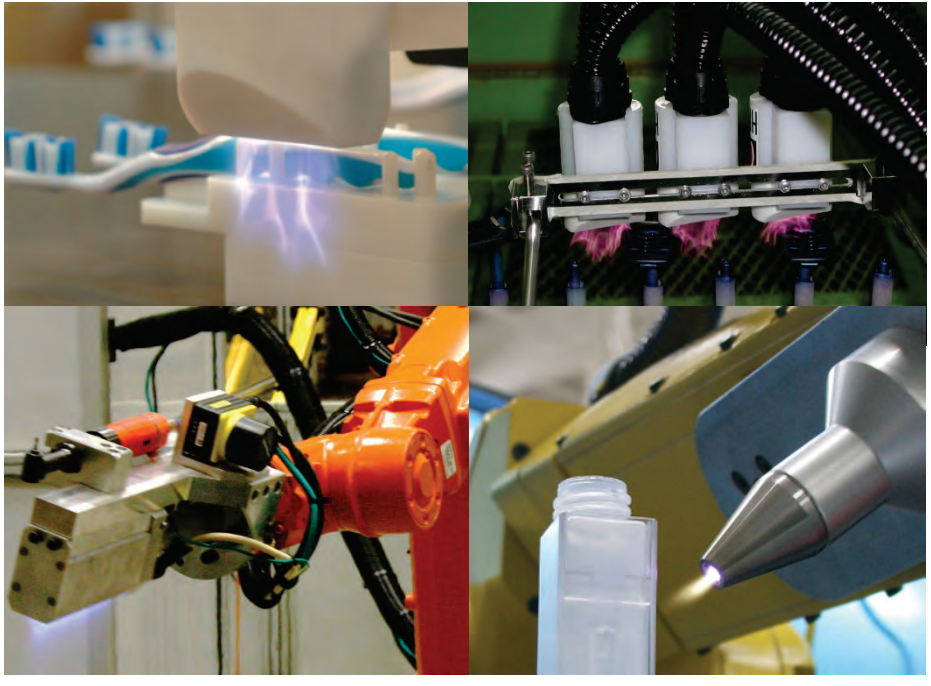
Plasma treatment is being used for a variety of medical applications to clean, etch and functionalize surfaces to improve wettability & adhesion.

Plasma treaters are effective at treating plastics, glass and metals surfaces. They are ideal for medical devices because of their ability to treat a wide variety of surfaces of all shapes and sizes.

Treatment levels decay over time so it is best practice to use treated surfaces as soon as possible.

There are many factors that contribute to adhesion dyne level is one of them.

Integrating atmospheric plasma treaters into your process



Fixed Location Treatment Head

Parts are conveyed, indexed or otherwise presented to the treatment head.

Moving Treatment Head

Head can be indexed or robotically controlled to follow precise treatment patterns.

Putting your application to the test

Enercon offers **free laboratory trials** with blown-ion, blown- arc and variable chemistry plasma systems.

We can also help you decide if **flame plasma treatment** might be better suited to meet your application requirements.

Innovative People. Ensuring your treating success.

Surface Treating. It's our passion.
And, we'd love to help you get started with your next project.

Take advantage of our reliable technology , decades of application expertise and steadfast commitment to your success.

Learn more about how our surface treating solutions can help you. Contact us today.

Contact an application expert .
Click or call 1-262 255-6070

Global perspective and Local support from a world leader

Since 1974 Enercon has brought innovative and cost-effective solutions to manufacturers.

Our team is committed to your success & will provide you the finest application expertise & product support.

We invite you to consult with us on your next project.

Enercon's global operations are supported by an international network of equipment and application expert who provide you with global perspective and local support.