TECH PAPER

CORONA & PLASMA SURFACE TREATMENT

What are they and how do they differ?

VETAPHONE
Corona & Plasma

Corona & Plasma Surface Treatment

What are they and how do they differ?

These are two of the most common questions asked about modern day surface treatment. Corona dates back to the 1950s while plasma is a more recent development – and fundamentally they serve the same purpose in allowing a liquid to adhere to a non-absorbent solid, but there are as many differences as there are similarities between the two processes and this Technical Paper sets out to explain what they are and how they work.

The origins

Why is surface treatment required? It began with the need to print on the new non-absorbent plastic materials that were entering the packaging market in the years following the Second World War. On absorbent materials like paper or carton, inks and varnishes will dry quickly, especially if the process is accelerated by heat. In the case of plastic substrates this will not happen because the liquid will 'bead up' on the surface of the material and never fully dry, and heat is not a good mix with plastic. The result is that the printed image can be easily smudged by any kind of abrasion – even a fingertip. Clearly, this was unsatisfactory, and a solution was required.

That solution proved to be surface treatment and was invented by Verner Eisby, the founder of Vetaphone back in 1951. What he discovered was an imbalance of surface energy between the liquid ink (higher) and the plastic material (lower) that was causing this 'beading'. What was needed was a technique that would persuade the ink to 'wet out' – that is spread more uniformly over the plastic surface. Better wetting would allow better adhesion – and so the process that is known universally today as 'corona' was begun.

Corona treatment explained

The secret behind improved wetting and the basis for corona treatment is the ability to modify the surface chemistry of the plastic substrate and thereby change its surface energy. This is best explained by taking an example of a popular plastic film used in everyday packaging, PE. One of the reasons for its popularity is its strength in relation to its thickness. This is because the chemical construction of PE involves very long molecular chains, which impart strength, but also inhibit wetting and adhesion. Adhesion can only occur where an oxygen molecule can attach itself to a carbon molecule, which is only at the end of each chain – the longer the chain, the further apart the ends, and the fewer the attachments. The problem for Eisby was how to break down the length of the molecule chains to improve adhesion without adversely affecting the integrity of the film.

The solution proved to be electricity – or to be more precise, the application of an electric discharge at close quarters to the filmic substrate. All plastic material has a natural surface energy that is measured in dyne/cm and it's this dyne value that surface treatment seeks to increase. To best illustrate how this happens Fig. 1 (p. 2) shows the inner working of a modern corona treater.

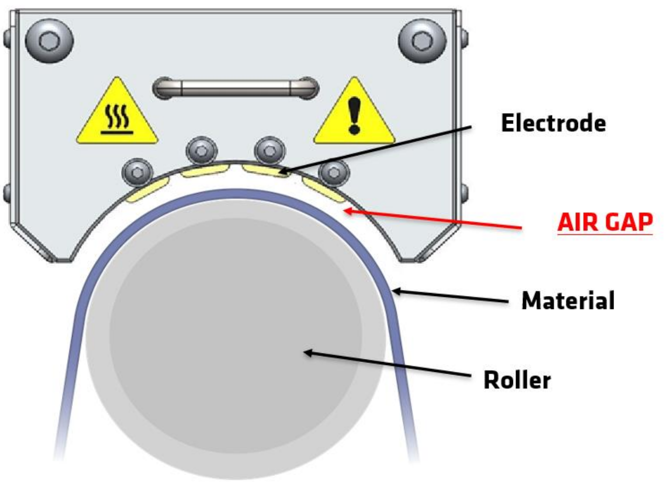
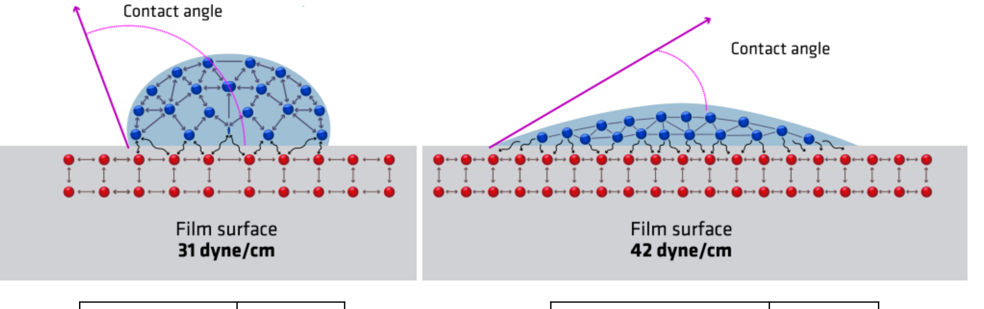


Fig. 1

The elements are the powered electrodes at the top facing the film material that passes over a roller. The critical feature is the air gap between the electrodes and the film. Critical because it needs to be maintained at the optimum distance to allow the discharge to 'jump the gap' but critical also because it needs to be wide enough to protect the film from the heat of the discharge. And it's in this air gap that the magic happens because the electric discharge modifies the chemical construction of the film surface by breaking the long molecule chains into shorter lengths. In doing so, it gives the oxygen molecules in the ambient air more opportunities to attach themselves to the carbon molecules at the ends of the shorter chains. The discharge also splits the oxygen into two molecules. One attaches to a carbon molecule at the end of each chain, the other attaches to other ambient oxygen molecules to become ozone (O^3), which needs to be extracted.

The result, is better adhesion and a boost to the dyne value of the film being treated (Fig. 2), which shows the poor wetting characteristics of untreated film substrates on the left with their natural dyne values, compared with the table on the right, which shows the improved wetting after corona treatment, and the higher dyne values that can be achieved and will be required for a variety of processes including printing with different ink formulations as well as coating and laminating. For illustration purposes, PP, low- and high-density PE, and BOPP, have been chosen, and each has different natural dyne values. In fact, these values can vary with the same material on different reels, so the importance of testing with a dyne pen cannot be overstressed.



Material - Basic	Dyne/cm
PP	29
PE-LD	31
PE-HD	32
BOPP	32

Process - Application	Dyne/cm
Print - solvent based ink	40-42
Print - water based ink	46-48
Coating	44-54
Lamination	46-56

Fig. 2

Plasma treatment explained

Moving on to the plasma process, there are striking similarities with corona in that the problem of adhesion on non-absorbent substrates remains unchanged, and the chemical make-up of the surface needs modifying to allow this to happen – but the plasma process takes place in a controlled environment where the ambient air is replaced by inert gases within the electrode chamber. By introducing a gas such as nitrogen, the electric discharge splits and accelerates the nitrogen molecules, now as NO^2 onto the surface to break up the long molecule chains and attach to the ends.

What separates corona from plasma is the lack of oxygen in the process, and by using nitrogen, or another inert gas, it is possible to fine tune the chemistry on the substrate surface because the gas can react with the carbonyl groups amine, amide, and imide (Fig. 3).

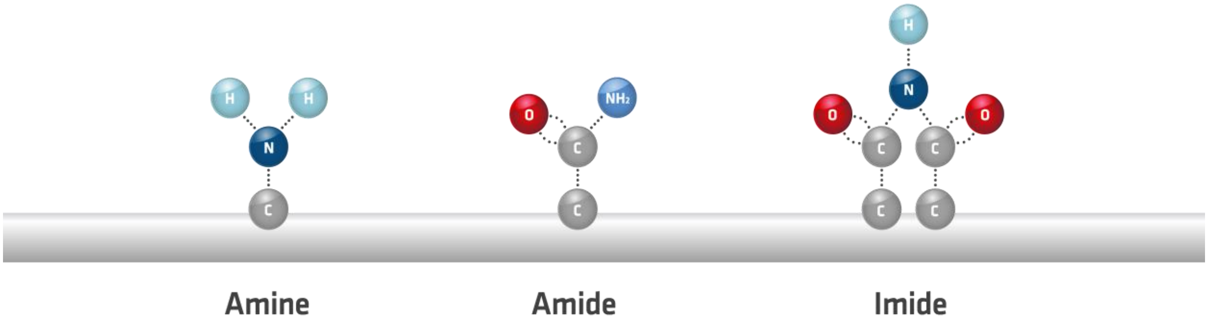


Fig. 3

These are chemical compounds that are formed by becoming attached to a nitrogen atom and are usually found in solid form at room temperature. Amine is a nitrogen molecule bonded with two hydrogen atoms, amide is a more acidic version with more and different atoms bonded to nitrogen, while imide is like amide but with a more complex molecular structure and more resistance to hydrolysis.

Different gases used in different ratios create different recipes (Fig. 4).

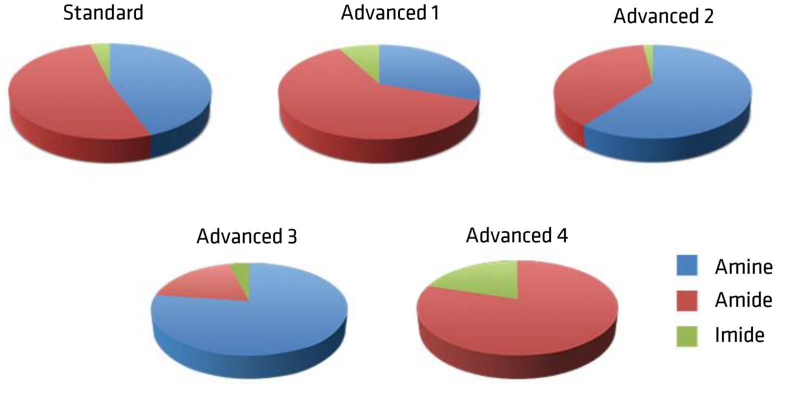


Fig. 4

The reason this is important is that it allows the adhesion process to be finely managed, which with today's more complex substrates that are being asked to perform increasingly more packaging tasks, opens new areas of opportunity. It is important to understand this because it has a direct effect of the behavior of the treated substrate. For example, a high amine content is very good for UV printing. Minor changes in the tuning can make all the difference but it's not always easy to predict, so testing is vital. Plasma works best if the next process is known in detail.

The technique, which is known as plasma grafting, can best be illustrated by using BOPP as an example. Fig. 5 shows the relative effects of using corona and plasma treatment on this material. For example, for printing with UV or water-based inks, a top-coated film is required that has different chemistry, because corona treatment cannot reach the required dyne level – the alternative is plasma treatment of the cheaper standard film. Another example is for clear-on-clear label applications with BOPP when both sides need to be printed - the front side can be corona treated, but reverse side will need to be plasma treated. That is why some press installations need corona and plasma treaters to handle different jobs on different substrates or treat different sides of the substrate.

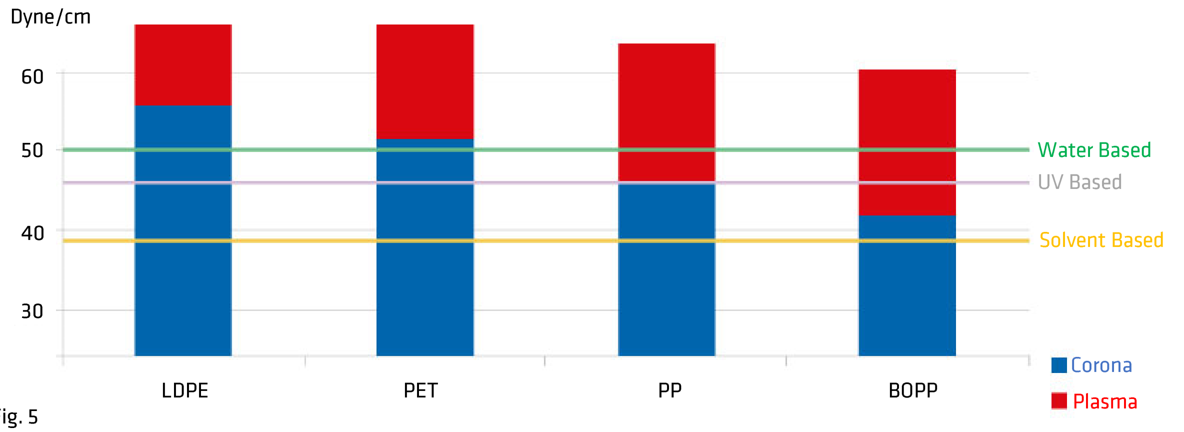


Fig. 5

Other advantages of plasma treatment are the higher dyne levels that it can achieve, and the longer shelf life the material will have once treated. For example, standard BOPP that is notoriously difficult to treat and has a natural dyne level of around 33 can be boost treated by corona to around 47 dyne, but as high as 60 dyne with plasma. Similarly, BOPP has a reputation for losing its dyne level quickly. Treated with corona it will fall from 47 back to around 37 dyne, while the same product treated with plasma will decline from 57 to 47 dyne and remain stable at 47 dyne for many months. However, BOPP treated with high-power plasma will attain 60 dyne and keep that value for more than one year, and in some cases much longer, see Fig. 6. However, it is worth noting that the cost of the extra power required for advanced plasma coating to sustain a high dyne level for a long period is more than double the standard plasma, which is already 6-8 times the cost of corona – so careful evaluation is needed of the task required.

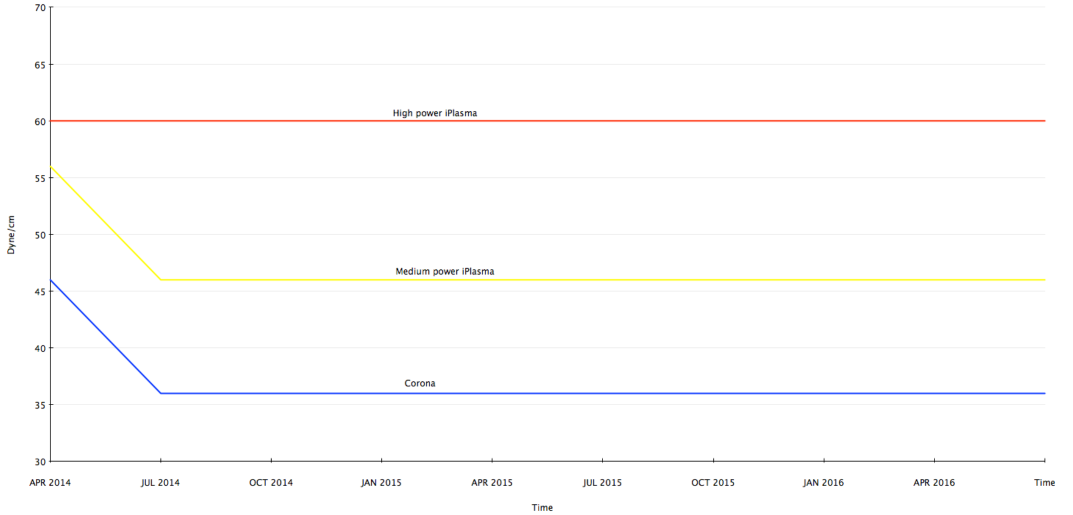


Fig. 6

Which is why it is important to see plasma as an R&D process. It is most definitely not 'one type fits all', which is why when asked by customers for the best plasma available, it is impossible to give a definitive answer without detailed research into the processes and intended use – there are too many variables that come into play for it to be that simple. What will work with one combination of gas, substrate, and ink is unlikely to work as well if any of the components is changed – and this can include supposedly identical products. Because the plasma process can be so finely controlled, the margins for error are consequently smaller and only by repeated stringent testing will the process be optimized.

The generator – where the magic happens

At this stage, it's important to explain in more detail how the electric discharge is generated and in turn what makes Vetaphone technology unique among surface treatment manufacturers. First, every Vetaphone treater, whether corona or plasma, is based on the same fundamental principles irrespective of size or market sector application. In fact, while the treater unit is where the magic is seen to happen, it's in the intelligent iCorona generator that the magic is created. The secret is in the 'resonance circuit', which records feedback from the electrode assembly at each discharge and allows the generator to be controlled to the precise frequency required.

Fig. 7 shows how the generator is matched to the optimum 20KHz frequency required to corona treat 40-micron PE. This maximizes treatment and optimizes power consumption. The problem occurs when the material is changed to, for example, a 12-micron foil that has different characteristics and treatment requirements of perhaps 18.3KHz (Fig. 8). The frequencies no longer match, and the process is not optimized. To overcome this and restore efficiency, all Vetaphone generators will adjust the frequency from feedback received from the electrodes and match it to the new 18.3KHz required (Fig. 9) – and the efficiency is restored.

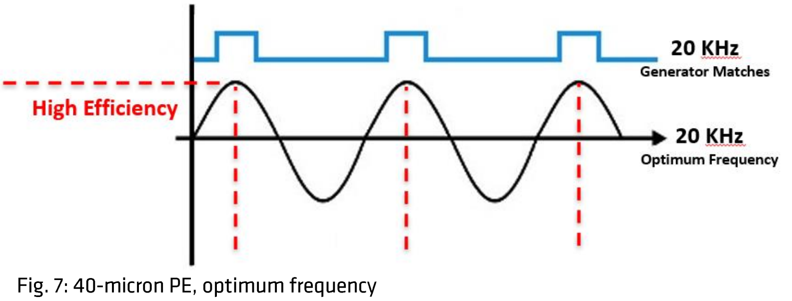


Fig. 7: 40-micron PE, optimum frequency

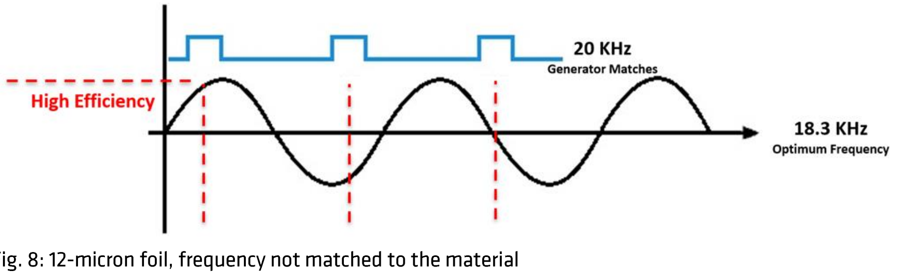


Fig. 8: 12-micron foil, frequency not matched to the material

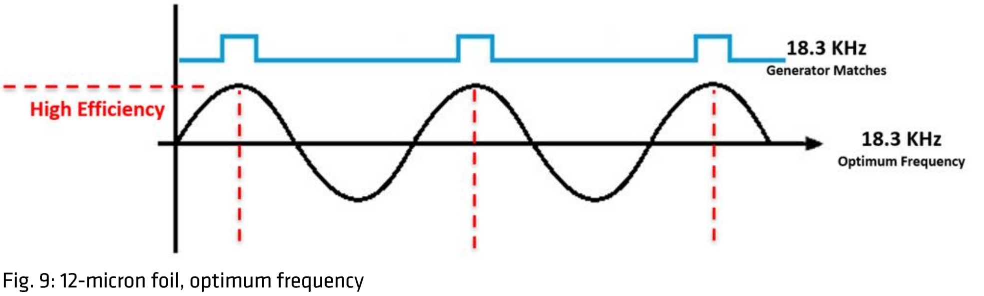


Fig. 9: 12-micron foil, optimum frequency

Apart from optimizing treatment by matching frequencies, the intelligent generator also removes excess heat from the process, and heat is a major issue if it is uncontrolled. In simple terms, corona treatment oxidizes the material surface allowing ink or varnish to adhere. Too little treatment results in poor adhesion, while too much can damage the material - both are the result of poor control of the electric discharge.

The importance of testing

With testing so crucial to optimized performance, Vetaphone opened a fully equipped Test Lab in 2020. This unique facility has the latest corona and plasma technology and is set up to run detailed tests under laboratory conditions. Available for existing and potential customers to use, the test lab is a sure-fire way of experimenting with new component combinations and developing new products without the expense or risk of full-scale commercial production.

The Test Lab is essentially a proof of concept and illustrates why plasma is only of real interest to companies that are developing new products because the investment level required for full scale commercial production is high, including major plant for water cooling of the electrodes, large capacity liquid nitrogen storage, and industrial-sized heating elements for converting it into gas.

The value of dyne

At this stage it is important to stress that surface treatment, whether corona or plasma, is not just about the dyne level that can be achieved or retained. High dyne levels are not always required – for example if good adhesion can be achieved at 40 dyne, then treating to a higher value will not improve the situation. And plasma is not always superior. For example, in lamination, certain adhesives require the presence of oxygen for good peel strength and oxygen is absent from the plasma process. Equally, corona works better than plasma on certain substrates like fabrics which often come with a silicone element that needs 'burning off' – again, this requires oxygen in the process which is absent in plasma treatment.

Continuing the theme of dyne levels in the context of corona or plasma there is an example that illustrates the variability of the equation. Using raw PE as the film and treating it to a level of 42 dyne required twice the power using plasma (20Watt/min/m2) than it did using corona (10Watt/min/m2). However, looking at peel strength, the plasma treated PE offered significantly better adhesion ranging from 291 to 376Nm against 265 to 323Nm.

The reason for the different peel strengths using the same treatment can best be seen on Fig. 10, which uses BOPP as the substrate. In each case it was treated to 40 Dyne using 20Watt/min/m2 but by four different methods: corona, plasma, plasma ADV1, and plasma ADV2, the latter two being variations of the dopant gases. What is immediately obvious is that another variable has appeared, namely the tape being used, in this case Tesa or 3M.

	Corona/Plasma Dosage	Dyne Level (dyne/cm)	Peel Strength N/m	Peel Strength N/m
BOPP Untreated	0	30	281N.m	162N.m
BOPP Corona Treated	20watt/min/m²	40	321N.m	254N.m
BOPP Plasma Treated	20watt/min/m²	40	369N.m	284N.m
BOPP Plasma ADV1	20watt/min/m²	40	359N.m	301N.m
BOPP Plasma ADV2	20watt/min/m²	40	358N.m	292N.m
			TAPE Tesa® 7445 PV2	TAPE 3M™ 610

Fig. 10

It is impossible for surface treatment manufacturers to determine the best dyne levels – this needs to be done by evaluating the substrate, ink, adhesive, or lacquer being used, and these values should be obtained from the respective manufacturers. Where Vetaphone can help is when adhesion problems are experienced that cannot be resolved in-house - then our huge depth of experience in all matters of surface treatment is available to tap into.

Which surface treatment is best?

As is now evident, there are more questions than answers when it comes to deciding between corona and plasma treatment. The decision will depend on which of the two works best in your process, and while that might sound simple, it more expresses the complexity of the situation. In most cases, corona is the best choice – it's simpler, cheaper, and highly effective, and unless your requirement is very specialized and likely to be very profitable, it's unlikely that the extra capabilities of plasma will be worth the significantly higher investment cost. The message from Vetaphone is 'come and talk to us.' We have all the experience and expertise you need and a Test Lab facility where we can put it all into practice for you.

If you'd like to know more or discuss any future project with us, we'd be delighted to introduce you to the Vetaphone resources that are available.

VETAPHONE
Corona & Plasma

Contact us for more information:

DK: +45 76 300 333

US: (312) 803-3691

sales@vetaphone.com

www.vetaphone.com