Plasma Sources and Feedback Control in Pretreatment Web Coating Applications

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Abstract

Web coating vacuum technology traditionally has offered a low cost, large production manufacturing process for coating of paper, plastic and fabric webs. Many emerging applications such as barriers, thin film photovoltaic cells on polymers and organic electronics increasingly rely on web coating technology for entering the market as a price competitive solution with good performance.
One of the main requirements is the product consistency from the beginning to end of roll, from roll to roll and from country to country where the process is being run. The key aspect of the process is the substrate preparation for the application of the functional coating in order to manage web outgassing and surface activation prior to coating deposition.
The present paper explores the use of state of the art plasma treaters and feedback process control to determine the right process parameters necessary to ensure good film adhesion and establish trouble-free long running campaigns.

Introduction

Roll to roll web coating technology is widely used for coating polymers, metal foils, textiles and papers for any number of applications. These range from commodity type products such as wrapping paper and food packaging to higher end products such as window film laminates and OLED displays. In many cases, the surface energy, texture and chemistry are not suitable for creating a strong bond with the coating to be applied. It is therefore common that the substrate material needs some type of pre-treatment in order to remove contaminates and to functionalize the web surface. Hollow cathode, linear microwave, ion and magnetron sputtering sources are some of the pre-treatment sources available for commercial processing. Examples of these sources are shown in Figures 1 and 2. The type of source to be used depends on the system design, substrate material and cost/maintainability of the source itself.

Outgassing of the substrate material is an issue with all web coaters. A web coating system usually consists of a wind/unwind area (chamber) and a processing chamber. As the web is unwound, it will outgas water vapor and other contaminates which should be ideally pumped away. However, there is quite often limited isolation between the wind/unwind and process chambers. This allows for some transfer of gas flow between chambers. In many cases, the pre-treatment source is located outside of the process chamber in the unwind zone of the system. The extent of outgassing of a given roll of material depends on a number of factors. The main influences are the environment in which the roll has been stored and the environment in which the machine is running.

In this paper, we present a case study using a planar magnetron source for the pre-treament of a polymer web. Oxygen and argon are the process gases. There are two systems running identical processes in two different countries. In one country (A), the environment is cooler with low humidity, while the other is warm and has high humidity. The issue to be resolved is that the stainless steel target on the source needs to be changed every 6 months in country A, but needs changed every week in country B. This variance leads to variability in the web pre-treatment and quality. The goal is to understand what is causing the differences and to maintain consistent web pre-treatment regardless of the environmental and web conditions.
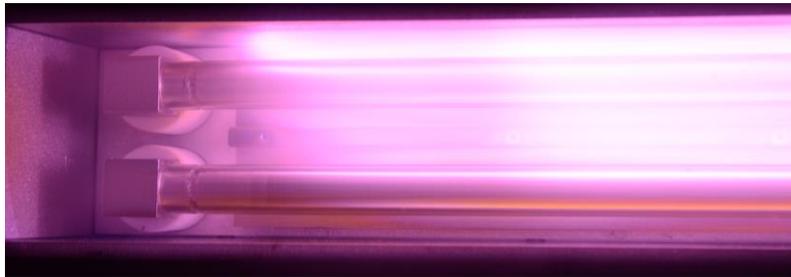

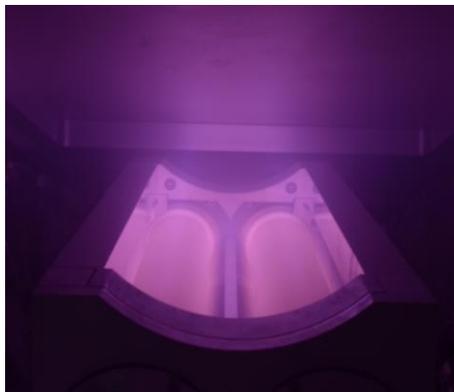Figure 1. AC MF dual electrode plasma source. Source: Gencoa Limited

Figure 2. AC MF dual magnetron plasma source. Source: Gencoa Limited

Experimental

A planar magnetron (Figure 3) with a stainless steel target using oxygen and argon as process gases was used to pre-treat a polymer web.

Figure 3. Planar magnetron pre-treatment source.
Source – Gencoa and Bobst Manchester (formerly General Vacuum).

The environmental conditions varied between two facilities as mentioned above. A Speedflo closed loop reactive gas controller equipped with a spectrometer and several plasma emission monitors was used to characterize the plasma and control the oxygen flow during the pre-treatment process. A 520 nm bandpass filter was used to monitor the chromium emission line intensity and as a control for the oxygen flow to the source. Figure 4 shows a typical schematic for such a control setup.
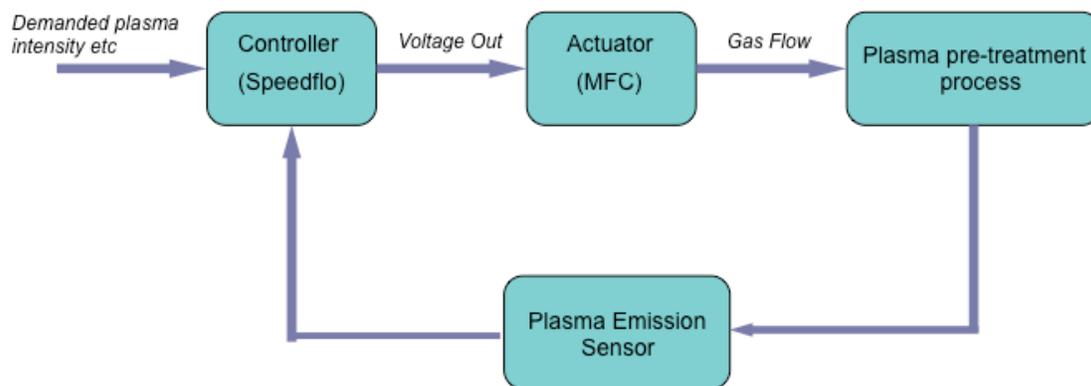

Figure 4. Control schematic.

An alternative to monitoring the treater's plasma directly is to use a remote plasma based sensor. In this method a small plasma is generated inside the sensor, and the emitted light is then analyzed by a spectrometer – giving a composition of the species present in the plasma and hence the vacuum. The concept is illustrated in Figure 5.
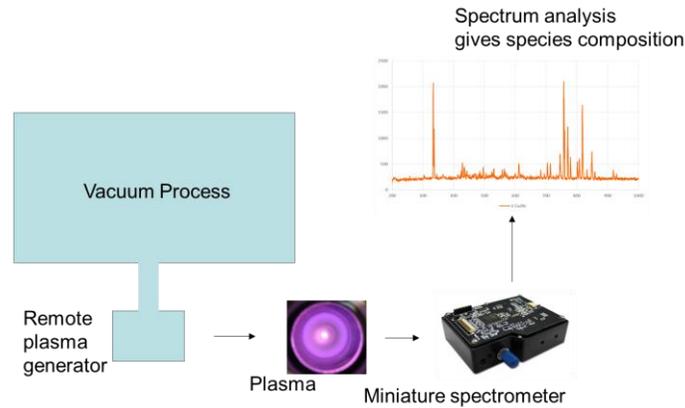

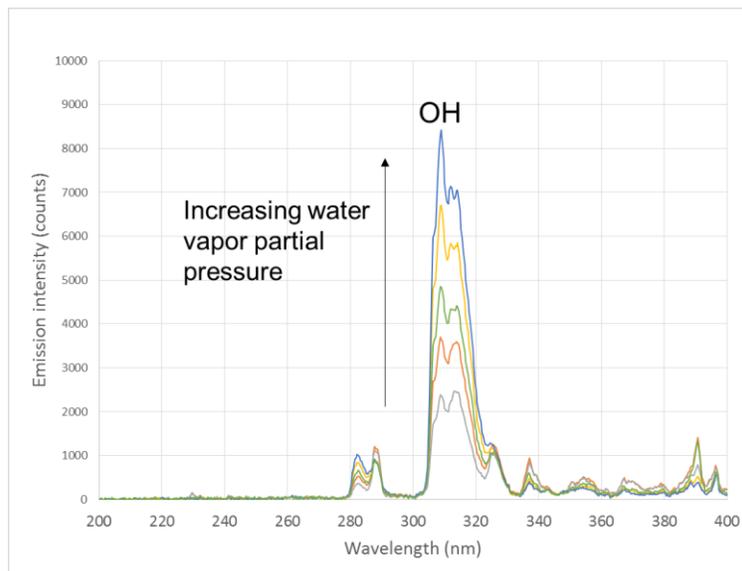Figure 5. Remote plasma emission spectroscopy sensor concept

Figure 6. Remote plasma emission spectroscopy sensor reading for increasing water vapor partial pressure

The advantage of this method is that the level of outgassing from the web can be assessed independently from treatment device. For instance, the effectiveness of the plasma treater can be monitored and controlled by measuring water vapor before and after the plasma treater. Figure 6 shows the spectrum from the sensor as water vapor partial pressure is increased in the vacuum. Another advantage is that this method is effective with any web treatment and is not restricted to plasma sources.

Results

In order to characterize the plasma in the pre-treament zone, a hysteresis curve was generated by ramping the oxygen flow up and down with a constant Ar flow and power (Figure 7). The visible spectral emission lines were the plotted in order to study variations in emission intensity as a function of oxygen flow. The target voltage was also monitored.
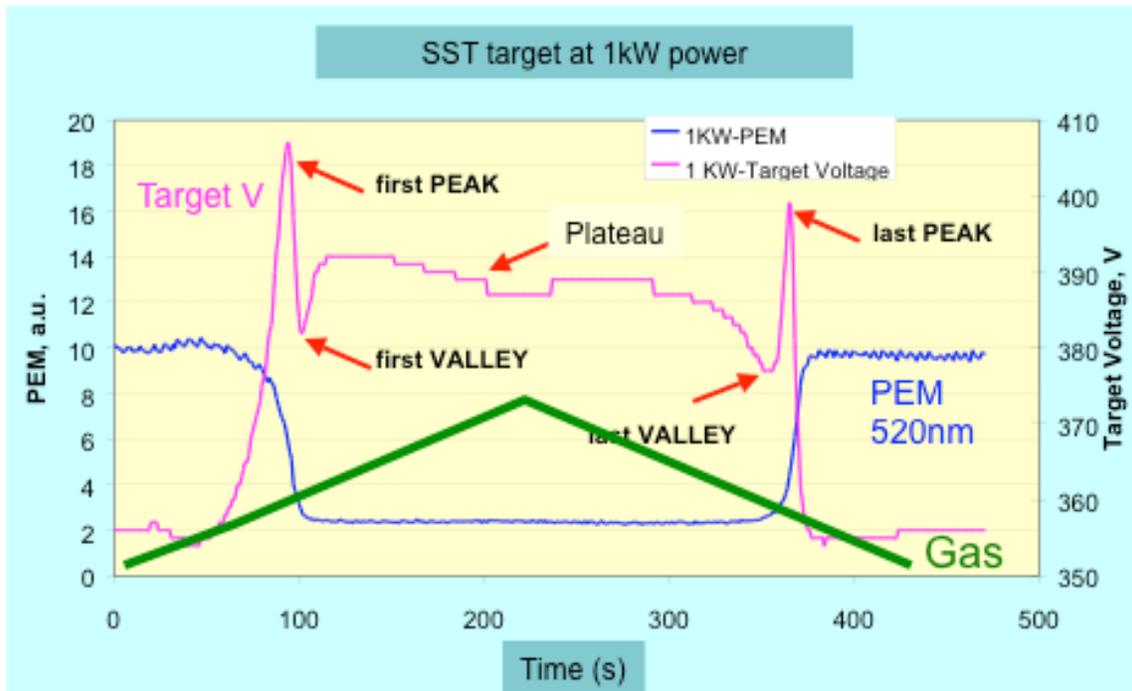

Figure 7. Hysteresis as a function of oxygen flow.

As the oxygen flow increases, there is a definite and defined reduction in the chromium emission line at 520 nm. As the oxygen flow is decreased, the chromium emission intensity increases following the reverse trend as with increasing flow. The voltage, however, shows an irregular behavior making it unsuitable as a control parameter. Using the chromium emission line as a control parameter, the conditions in the pre-treatment zone can be maintained (Figure 8).
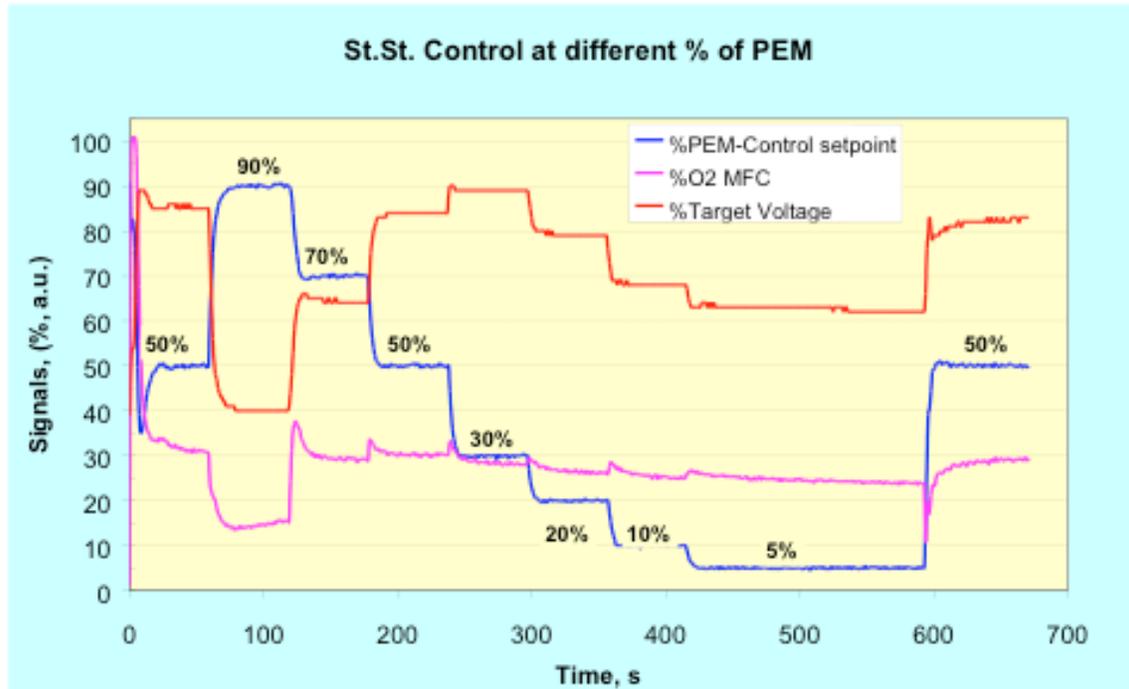
Figure 8. Closed loop control of chromium intensity at various setpoints.

By maintaining the same chromium emission intensity for the pre-treatment process at both plant sites, the process and target exchange rate were made the same.

Discussion

In the sputtering process, a certain amount of target material is removed from the target surface. Depending on the process conditions, the sputter rate can be kept low while the plasma generated in front of the magnetron can be used to modify the web surface. When the right amount of metal is sputtered from the target surface, it can act as a getter material, which reacts with the oxygen process gas as well as the outgassing from web. This helps to create a "clean" environment for pre-treatment. As water vapor is a primary contaminate due to the nature of polymers as well as humidity, the process needs to be controlled in order to maintain these "clean" conditions. By controlling the chromium emission intensity as shown in Figure 8, these processes can be kept constant.

It is also critical that the process be controlled so that no excess metal is deposited on the web itself. This can lead to a reduction in target life and "seed" layers being deposited on the web surface. These seed layers can react during

subsequent processes or cause unwanted effects such as absorption for optical films.

Conclusions

The main advantage of magnetron sputtering for pre-treatment is the getter effect, which when combined with closed loop feedback control can accommodate for varying environmental and web conditions. Plasma emission monitoring is a very powerful technique, which can be used not only for planar magnetron pre-treatment sources, but for other plasma sources as well.