HiPIMS technology opens up new possibilities for decorative plastic coating

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Abstract
The use of the modern HiPIMS (High-Power Impulse Magnetron Sputtering) technology promises a significant increase in quality in the field of plastic finishing in order to open up new, market-relevant applications. In addition to the advantages and possibilities that HiPIMS technology offers for the decorative market, the functionality of HiPIMS is explained and what should be taken into account when integrating it into existing DC sputtering systems for coating plastics.

1. Motivation
Poor adhesion or a lack of robustness of PVD layers often frustrates the desire in the decorative field to apply a robust PVD coating directly (without primer coating) to the plastic substrate or conversely a PVD coating to a primer (with no protective lacquer) in order to save process costs, to minimize scrap, to get a better gloss finish, to be able to reproduce structured plastic surfaces perfectly, or to implement a pre-coating for electroplating. The HiPIMS process offers opportunities of successfully achieving these goals.
2. What does HiPIMS mean?

HiPIMS (High-Power Impulse Magnetron Sputtering) is a modern PVD process that boosts the interaction between the plastic and the PVD coating to a whole new level. Responsible for this is a pulser unit that can be integrated into DC magnetron sputtering systems with little effort. This pulser handles the constant energy supply pulsed during a DC sputtering process. Short pulses (e.g. 50µs) with significantly higher energy than is the case in DC magnetron sputtering and with relatively long off-times increase the plasma density significantly so that a significant portion of the coating material is ionized during the PVD process.
3. Integration into a DC sputtering system

The possibility of integration into existing technologies is a great advantage for a new technology in gaining acceptance. HiPIMS technology can take advantage of this by a relatively simple incorporation of the pulse generator between the DC generator and the cathode (target).

![HiPIMS system at the Kunststoff-Institut Lüdenscheid equipped with a Magpuls MP 2 pulse generator and a Plasus Emicon plasma emission spectrometer](source: Kunststoff-Institut Lüdenscheid GmbH)

In planning the upgrading of a DC sputtering system to an HiPIMS system, the most important aspects are:

- Output of the DC generator
- Cathode area
- Power supply between pulse generator and cathode
- Plasma monitoring options

**Output of the DC generator:** The DC generator, which in every DC sputtering system is responsible for the constant energy supply to the cathodes, must be able to deliver sufficient power to achieve the desired HiPIMS effect (significant ionization of the coating material). In HiPIMS processes, process temperatures are usually higher, so that the aspect of low thermal stability must be taken into account when coating plastics. It is therefore not advisable to purchase a very powerful DC generator for the upgrade if the plastic substrates would already be thermally damaged at only a moderate or low utilization of the DC generator. There
is thus a high probability that the output of the existing DC generators is suitable for the HiP-IMS processing of plastics.

**Cathode area:** The larger the existing cathode area, the more powerful the pulse generator must be. The pulse generator must supply sufficient current per area, which makes the cost of purchasing a suitable pulse generator higher for large cathode areas than for small cathodes. 1A/cm² is used as a guide value for the required current strength of the pulse generator.

**Power supply between pulse generator and cathode:** The power line must have a sufficiently large cross-section. The peak current with HiPIMS is many times higher (e.g. over 300 A) than the current in DC sputtering with a constant current. The power supply line between the pulse generator and cathode should be as short as possible in order to keep interference sources and electrical resistance to a minimum. The best possible result can be achieved by connecting the pulse generator directly to the cathode.

**Plasma monitoring options:** The sputtering process is a complex process. In addition to parameters such as process pressure, process gas, cathode current, target material, substrate temperature, BIAS and distance to the target, the HiPIMS process extends this parameter list to include the duty cycle at the pulse generator and the associated peak current, as well as the ionization of the coating material. To be able to establish an optimal setting for the HiP-IMS process (e.g. the highest possible degree of ionization), it is necessary to monitor the species in the plasma by means of a so-called plasma monitoring. For this purpose, an optical sensor connected to the spectrometer via optical fibers is aligned with the plasma zone directly above the target surface.
As soon as the plasma is ignited, the emitted light is directed to the analyzer. Each species in the plasma produces characteristic intensities for different wavelengths. Within the wavelength spectrum from 200 nm to 1000 nm, atoms and ions in the plasma can be detected via their characteristic peaks.

The peak area for the ionized coating material can be significantly increased by a suitable setting of the pulse duty factor at the pulse generator. It should be noted that the peak areas (integrated) are not to be regarded as absolute values and the ion/atom peak ratio is not representative of the ionization content of the coating material in the process. It is rather a rela-
tive value that should help to set the optimal process (the maximum achievable level of ionization) for the target material in question. Nor does it make sense to compare the ion/atom peak ratio to other target materials.

4. Advantages and new opportunities

The ionized coating material improves interactions with the surface of the plastic and generates more homogeneous and more robust layer properties. This opens up new possibilities for the decorative field. This offers opportunities for more robust coating systems using just a single layer of lacquer. The spectrum of protective lacquers that can be used in direct metalization can be enlarged here and this robustness achieved due to improved adhesion. Furthermore, such a layer system offers the possibility of precisely reproducing fine structures in the plastic substrate (e.g. eroded surfaces). Layers deposited by the HiPIMS process have an improved reproductive capability (which is also useful in gold coating for SEM images).

![Fig. 6: Schematic of the better reproductive capability with HiPIMS (left, in DC sputtering, atoms close off the recess; right, with HiPIMS, ions reproduce the recess) (source Kunststoff-Institut Lüdenscheid GmbH)](image)

With a suitable primer coating and a suitable PVD material, the protective lacquer can be dispensed with in order to significantly reduce the costly wastage that arises with the protective coating. A more homogeneous layer structure results in an increase in the degree of gloss, which improves the appearance for high-gloss surfaces.

In plastic electroplating, the REACh regulation requires in the long term a renunciation of the chromium (VI), which is currently used in pickling ABS plastics. Here HiPIMS technology of-
fers opportunities for presenting an alternative pretreatment with the same strong adhesive bond as with a chromium (VI) pickle.

HiPIMS technology also offers reactive sputtering processes that are more stable and particularly relevant to dark PVD optics (e.g., chromium carbide, DLC layers). The biggest drawback of HiPIMS technology is that the layer growth rates for the coating of metals, depending on the target material, are sometimes significantly reduced for metallization processes. This disadvantage is only of minor importance for decorative applications since sputtering times are generally very short (up to 1 minute) and ventilation time is the decisive factor for the cycle times. Within the group project ‘PVD coating of plastics 3’ the advantages and disadvantages as compared to DC sputtering are examined and presented.