New Approaches for Plasma Technology and Surfaces: Multifunctional Coatings in Only a Single Processing Step

The Fraunhofer IFAM has been involved in adhesive bonding technology for more than 40 years – and hence has also been involved with the surfaces of materials which are bonded or coated. For these surfaces and their properties play a key role: indeed, many materials require customized pretreatment and modification to give the additional functionality which provides the component with its usage value. The section Plasma Technology and Surfaces (PLATO) at the Fraunhofer IFAM was founded at the start of the 1990s and has been involved in many important developments in this sector right through to market introduction. These are used today in virtually all sectors of industry – including the electronics industry, car manufacturing sector, medical technology sector, and packaging industry.

Fig. 1: Antimicrobial coating of catheters via plasma technology.

Materials are cleaned and activated using a wide range of techniques. This allows adhesives, sealants and paints to adhere better to these materials. They are then coated to give the materials new functions: scratch resistance, anti-soiling properties, water-repellant properties, corrosion resistance and dehesive (namely non-adhesive) properties. The PLATO section has many ongoing partnerships with industrial companies, but constantly seeks new fields and areas of application to form new customer circles and open up new markets. Due to future-oriented development work and promising results from R&D projects, new strategies for functionalizing materials or products via suitable surface pretreatment constantly arise. Special attention at the moment is being put on the development of methods which allow multifunctional coatings to be generated in a single processing step. The bringing together of hitherto separate functionalization steps should shorten production processes and allow layer combinations which up until now have involved considerably higher processing complexity.

Surface Technology is a Cross-sector Technology

New developments in one area always have implications for other areas. Functional surfaces are required everywhere – in the aviation and aerospace sectors, in the car manufacturing industry, in electronics and production engineering, in machine construction, and the consumer goods' industry. The low pressure plasma technology of the Fraunhofer IFAM is a proven and recognized technology. It was used, for example, to develop the PermaCLEAN$^{PLAS®}$ coating – an ultra-thin plasma-polymer anti-adhesion coating. Lacquers and paints only adhere very weakly to its surface. In the lacquering industry, gratings are coated with this coating. It is resistant to cleaning with extremely high water pressure. Due to PermaCLEAN$^{PLAS®}$ it is considerably easier to free the gratings of paint residues.

There are various dehesive films with a similar effect, for example the patented anti-soiling surface DryCLEAN$^{PLAS®}$ or the release layers BestSkin$^{PLAS®}$ and ACMOS Coverel®. The coatings are generated via plasma-assisted deposition and grease, dirt particles, and even adhesives hardly adhere to them. Components coated in this way – for example for molding processes – mean that for example the plastic components can be more easily removed from the molds. Traditional release agents are not required for processing the plastic components and hence cleaner plastic components can be manufactured. Other successful work of the PLATO section ranges from adhesion promotion to reliable corrosion protection right through to anti-bacterial coatings for biological-medical systems (Fig. 1)

Advantages of Combining PVD and CVD Coating

The developments and experience of the PLATO group provide the basis for new challenges in new areas. Particularly interesting is the generation of multifunctional films in a single processing step by utilizing synergies. In general up until now, there has been a process for each specific surface functionalization. The PLATO scientists are now working to adapt similar processes to each other so that in the future they can be carried out in a single step process. An example of the principle is combining PVD (Physical Vapor Deposition) and CVD (Chemical Vapor Deposition) for transparent polycarbonate plastics. These are used for vehicle headlights, helicopter domes and helmet visors (Fig. 2). Both processes run under vacuum, with layers being applied to a substrate by either physical deposition or chemical reaction. Due to the treatments, the polycarbonate plastics have scratch protection and protection against ultraviolet radiation. Up until now two process steps were necessary. The PLATO scientists now want to combine these in one application and even improve the quality of the coating. The addition of an anti-soiling or water-repellant layer is also possible, facilitating the cleaning the components. Future users not only have cost benefits due to the shorter process times but also profit from the high-quality multifunctional coatings.

Combining Processes at Atmospheric Pressure

The linking of several processing steps is not only being undertaken for vacuum applications but is also being attempted for atmospheric pressure processes. An example of this is combining aerosol processes and atmospheric pressure plasmas (AP plasmas). AP plasmas already allow very good corrosion protection to be achieved via plasma-polymerization: The layers provide a barrier to water, electrolytes and oxygen (Fig. 3). If the coating is mechanically damaged, the substrate can corrode locally to a limited extent at those spots.

Scientists at the Fraunhofer IFAM are currently working on an active corrosion protection layer in which chemical inhibitors are embedded. They are released on there being damage to the layer and

Fig. 2: Transparent scratch protection for plastic surfaces.

protect the material at the damaged spot via an inhibition effect.

Via suitable feeding, particles can be specifically treated in the AP plasma. These can be fed dry or also in the form of an aerosol into the reactive

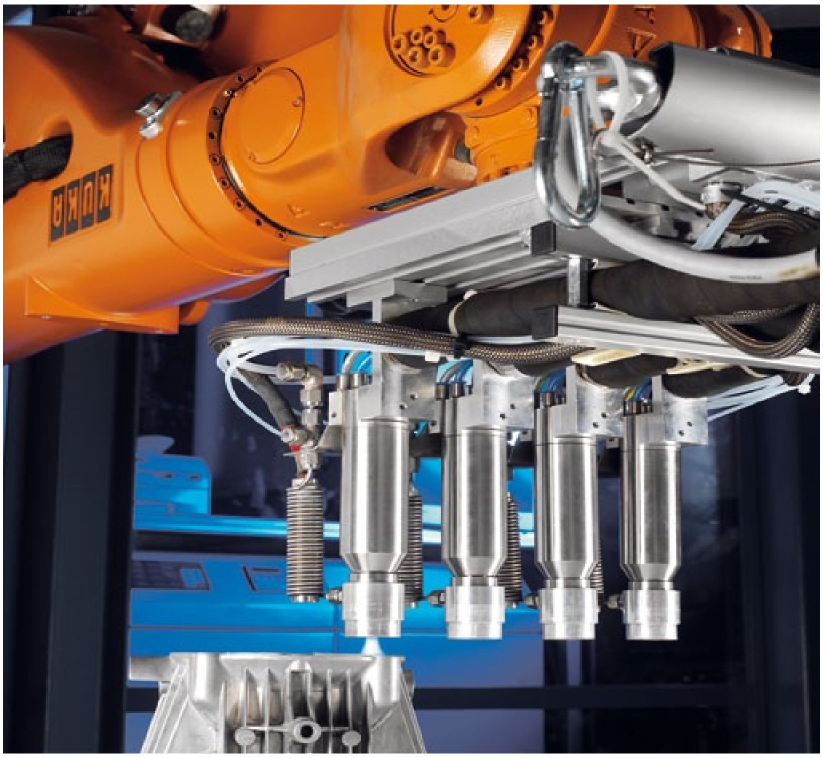

Fig. 3: Corrosion protection for aluminum pressure-die casting components using atmospheric pressure plasma technology (AP plasma technology).

zone of the discharge. This is interesting, for example, for the functionalization of carbon nanotubes (CNT). When used in plastics or coating materials the new fillers can, for example, increase the strength or conductivity. Due to the functionalization of their surfaces and their increased chemical reactivity, the carbon nanotubes can be more uniformly dispersed in the coating material, and in higher quantities, and this increases the efficiency.

In addition, new ways of particle feeding and particle treatment in the reactive discharge zone are being investigated. The aim is to adapt the plant and processing conditions to achieve as high as possible treatment efficiency, without adversely affecting the desired properties of CNTs.

VUV Irridation and Aerosol Treatment in a Single Step

Another approach is to provide materials with functional coatings via a combination of aerosol application and vacuum ultraviolet radiation (VUV). The technology of VUV radiation is still a new field for the PLATO group. Due to the excellent equipment which includes an ultra modern VUV excimer plant (Fig. 4 and 5), PLATO is able to realize different process steps under various atmospheres.

Interesting for the medical sector is the goal of the Fraunhofer IFAM to generate customized surface functionalities via radicals. This involves reactive atoms or molecules which are excited via VUV radiation or via a plasma. They are used to generate specific biocompatible layers – important, for example, for implants to prevent rejection by the body. These biological systems are also interesting for the areas of adhesion promotion and the functionalization of textiles.

Fig. 4: VUV excimer plant of the Fraunhofer IFAM for activating and coating surfaces.

Fig. 5: Internal view of the VUV excimer plant.

Selective surface functionalization via low pressure plasma (LP plasma) and wet-chemical post-treatment is similar: A surface provided with many functionalities after activation with LP plasma is made so uniform that only the functionality desired for the planned application remains on the surface. This allows, for example, the specific requirements of biocompatible materials – for example a heart valve made of special steel or implants made of titanium – to be met.

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