Adapted version from the German original: productronic 11-2009

Atmospheric plasma treatment of circuit boards

Without Vacuum

One of the internationally active manufacturers of high-grade potentiometric and non-contacting position transducers and rotary sensors, the Novotechnik in Ostfildern near Stuttgart, already focused on environmentally-friendly production in the 90ies when the pre-treatment of circuit boards had been effected for a long time by means of low pressure plasma in a vacuum chamber. The atmospheric pressure Openair plasma process developed and patented by Plasmatreat however, opened up even broader possibilities.

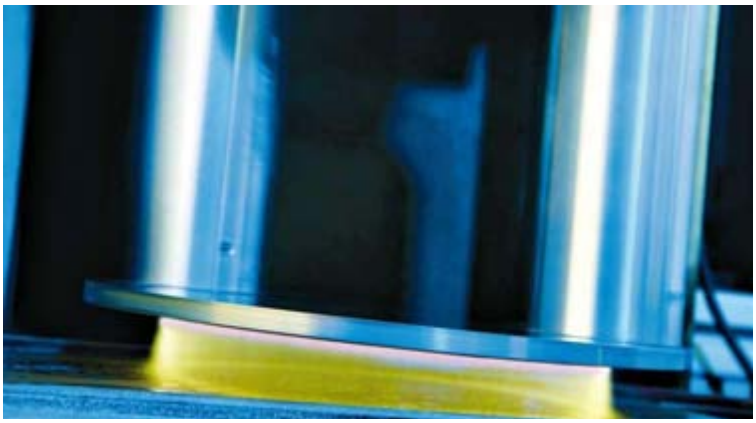

Photo Plasmatreat
Fig.1. The rotation jet has two atmospheric plasma sources for inline cleaning and neutralization of the circuit board while activating the material surface so strongly that it becomes receptive to all coating, printing or adhesive bonding processes.

Photo Novotechnik
Fig. 2. Position transducers operate under harsh environmental conditions and at high positioning speeds.

The low-pressure method applied by Novotechnik proved to be efficient. But as an enclosed system, it also bore its disadvantages for production: While vacuum chambers are perfectly suited for batch processes, they are less suited for the pretreatment of large quantities. The process times used to be too long. What's more: Integration into the existing screen printing lines was not possible either. In addition the operation was very labor-intensive since one person had to equip the low-pressure chamber first before taking out the components manually thereafter.

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Having decided to increase production from the year 2000 onward, the company looked into an alternative process – and made a discovery. The solution was again a plasma process but this time without the above limitations (Fig. 2).

Plasma is based on a simple physical principle. By supplying energy the states of matter change: from solid to liquid and from liquid to gas. If further energy is added to a gas it becomes ionized, i.e. the electrons gain more kinetic energy and leave their atomic shells. Free electrons, ions and molecular fragments are formed. Plasma is produced. This "4th state of matter" however, can scarcely be used at normal pressure because of its instability (Fig.3).

The atmospheric pressure Openair plasma process developed and patented by Plasmatreat,

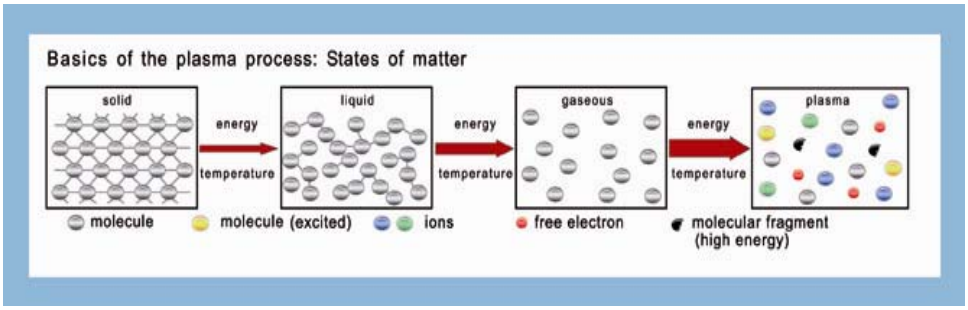

Fig.3. Plasma is also called the 4th state of matter. Diagram Plasmatreat

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Steinhagen, in 1995, opened up new possibilities: By developing and using plasma jets it became possible for the first time to integrate this state of matter, scarcely used so far in industry, into production processes ("in-line application) and thus make plasma usable under normal atmospheric conditions for the pretreatment of the surfaces of materials on a large industrial scale. Through contact with the surfaces of materials the added energy of the plasma state is transferred to the material surface and made available for subsequent reactions on those materials. This process creates surfaces having ideal properties for accepting paints, print, adhesive bonding or foaming.

Electrically neutral plasma beam

The method is based on a nozzle principle for the most varied component geometries. Unlike the complex plasma low-pressure systems (vacuum chamber), the plant is now integrated into the production line for continuous process sequences and operates under completely normal atmospheric conditions (Fig. 4). The jets are driven solely by air and by high voltage. Christian Buske, CEO of Plasmatreat: "A particular feature is that the emergent plasma beam is electrically neutral and as a result possible applications are greatly extended and simplified. Its intensity is so high that treatment speeds of several 100 m/min can be achieved."

The typical rise in temperature of a plastic surface during treatment amounts in this case to $\Delta T < 20$ °C. This plasma system is characterized by a threefold action: It activates the surface by selective oxidation processes, simultaneously discharges the former and brings about microfine cleaning of the surfaces of metals, plastics, ceramics and glass. In close collaboration with the Fraunhofer IFAM the technique was developed further: For the purpose of nano-coating a precursor material was added, and today the process is used for coating deposition and the functionalization of surfaces.

Sensitive sensors

Leading-edge automotive technology without sensors is hardly conceivable nowadays. Typical examples in the field of motor management are the detection of the throttle valve position (Fig. 5) and of the pedal position. Electronic pedal value modules comprise a pedal lever housing, a rotary sensor and a mechanical system for simulating the traditional accelerator pedal feeling for the driver. The accelerator pedal sensor supplies the controller with the position of the accelerator pedal and influences the air/fuel mixture through the position of the throttle valve. All printed circuit boards of these sensors are produced by Novotechnik using the screen printing process in combination with a specifically developed, high-grade conductive ink.

"Openair" under test

Once the sensor manufacturer had set their eyes on the atmospheric plasma process from Westphalia - after having been made aware thereof by a customer, the automotive industry supplier Hela - and carried out initial tests, the potential of the innovative technology soon became obvious. "The system could be easily integrated into our process and the throughput increased by saving labor at the same time," reports Dr. Tobias Eckert, Head of the Potentiometr Technology Centre at Novotechnik (Fig. 6). These tests took two to three months and included testing of the surface activation, testing of the adhesion (cross-cut) as well as comprehensive "service life tests" for quality assurance. In the course of the latter, the load types and load cycles which the product could be exposed to in service are simulated by means of specific test devices.

A customer, for example, demanded evidence for a throttle valve product that the component is capable of being operated at over 10 million cycles on the motor with no significant changes in its electrical properties. To rank this challenge correctly you should know that this number corresponds to a travelled distance of about 1 million kilometers. Moreover, production by Novotechnik is governed by the general rule that technical modifications may not be simply and easily introduced. It is only after the production and handing over of samples to the customer and their testing and release that technical innovations may be adopted.

Photo Plasmatreat
Fig.4. The circuit boards undergo a continuous process from the equipment via the plasma system through to the screen printing plant. Novotechnik's space-saving plasma plant serves four screen printing lines.

Photo Novotechnik
Fig.5. Complete throttle valve with flap, integrated actuator and sensor. Pretreatment with Openair Plasma is effected before the integrated sensor circuit board is coated.

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Photo Plasmatreat
Fig.6. Dr. Tobias Eckert, Head of the Potentiometer Technology Centre at Novotechnik, sees the use of the atmospheric plasma technology as a "milestone" for sensor production.

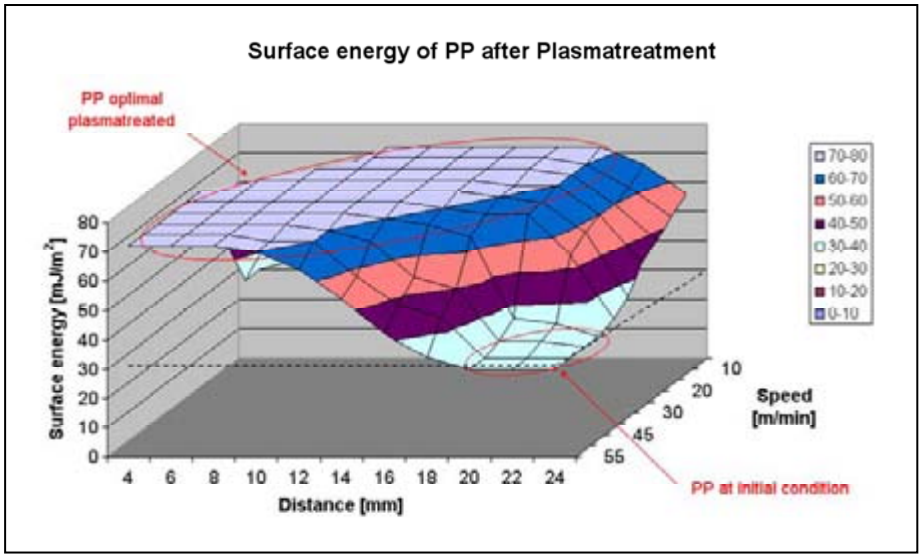

Fig.7 Diagram Plasmatreat
The figure shows a plastic surface that was pretreated as a function of distance and speed with plasma. Treatment renders the surface polar and the surface energy rises to >72 mJ/m2 with a large process window.

Activation of PCB surfaces

The pretreatment of the printed circuit board surfaces primarily deals with their activation, i.e. the increase in surface energy. It is the most important measure for evaluating the probable adhesive strength of an adhesive layer or coating. Plastic materials, for example, usually provide a low surface energy., mostly between 28 and 40 mJ/m2. But good conditions for adhesion can only be obtained by experience from 38 to 42 mJ/m2 onward. A plasma treatment, i.e. a strong activation of the material surface however, can bring about a distinct increase in surface energy. Trials at Plasmatreat have revealed that values up to over 72 mJ/m2 become possible for most plastic materials (Fig. 7). The result: Not only previously incompatible substrates can be bonded but also adhesion of water-based adhesive or painting systems on very adhesive-resistant surfaces such as unpolar plastic becomes possible in most cases. Whether the surface to be treated is of plastics or metal – pretreating the circuit boards by means of plasma makes virtually all adhesive bonding, printing and coating processes feasible.

Atmospheric plasma at Novotechnik

The Openair process was introduced by Novotechnik into production at the end of 2000 for the very first time (Fig. 8). The manufacture of the FR4 circuit boards which are of glass-fiber reinforced epoxy material used for electronic circuits as a standard, is performed in a clean room environment. The material is prestructured, i.e. it is received with etched conductive track structures. The panels designated for the

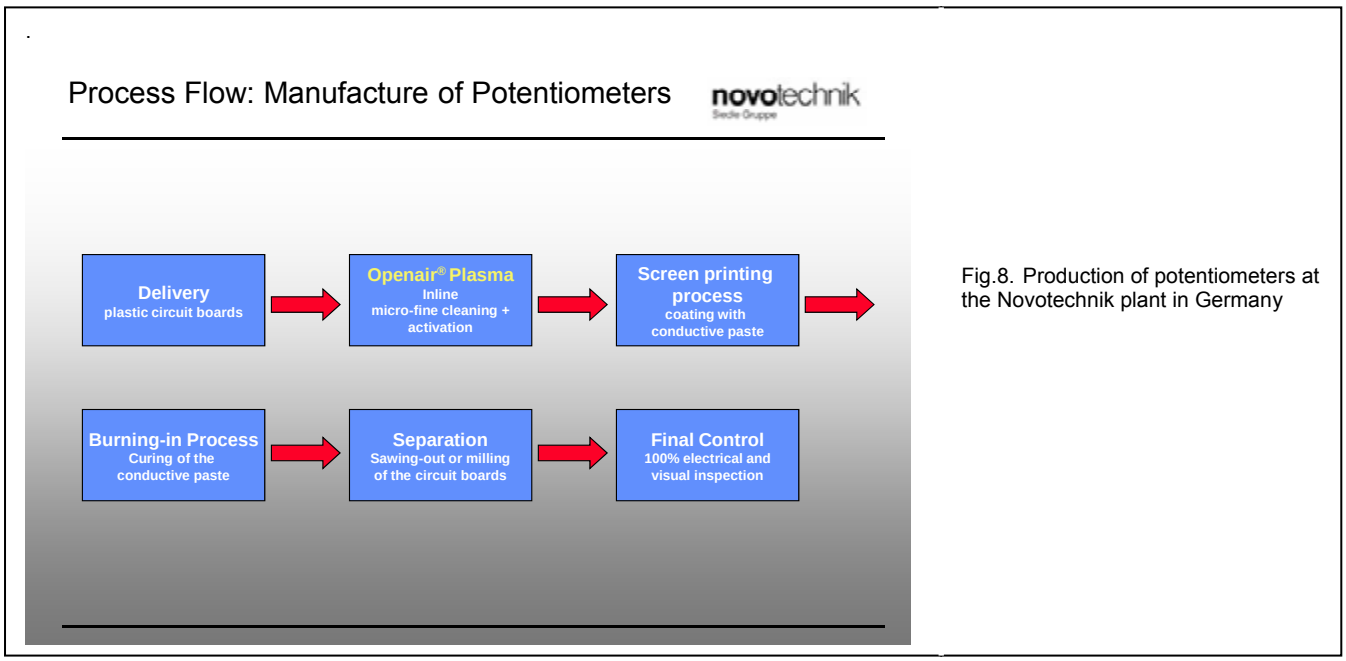

Fig.8. Production of potentiometers at the Novotechnik plant in Germany

potentiometric sensors and having a size of 130 mm x 240 mm may contain up to 70 circuit board blanks. Plasma treatment is necessary to ensure good wetting of the substratum with the conductive paste, also called conductive ink, in the screen printing process on the one hand and to achieve good adhesion of the conductive ink on the substratum on the other. Positive and important side-effect: The plasma flowing onto the surface at almost ultrasonic speed furthermore removes particles adhering to the surface and neutralizes the electrostatic charge of the circuit board after unpacking. The plasma process takes at most 1 s for the activation of the panel. Thereafter, the panels are transported to the printing plant where printing with conductive ink takes place by applying the screen printing process. The conductive inks produced by Novotechnik are in-house developments tailored to the respective applications. "They are actually the heart of a potentiometer because it is the quality of the conductive ink that determines the lifetime of the sensor in operation," elaborates Dr. Eckert.

Since the flow behavior of the conductive inks tends to change during the screen printing process and influences the electrical properties it is necessary to control the screen printing process. For this purpose the wet film thickness is determined by taking samples at random throughout production and by measuring the relevant electrical parameters of the already burned-in components. So Novotechnik allows for in-time detection of electrically effective changes and intervention already while the order is in progress. Once the curing process in the furnace is complete, the components are separated (Fig. 9) and subjected to 100 % electrical and visual inspection on the computer. Finally they are either mounted into a housing together with a wiper or delivered individually to customers who in turn mount the potentiometers into their systems.

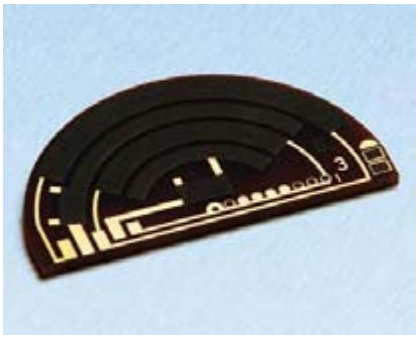

Photo Plasmatreat
Fig.9. The equipped panels are stoved and cured in the furnace after printing. The circuit boards, once separated, are subjected to a 100% visual and electrical inspection.

Conclusion

Besides components for the automotive industry, the Swabian sensor manufacturer also subjects sensor circuit boards for use in other industrial applications such as round potentiometers for control systems in shipbuilding or on wind turbine gearboxes, to plasma treatment. Dr. Eckert is extraordinarily pleased with the results of the plasma treatment: "I can declare the change from the low-pressure plasma chamber to the employment of the integrated Openair technology as a milestone in the further development of our sensor production. By doing so, we have tripled the throughput. The process is highly efficient, safe, fast and therefore cost-effective. One plasma plant is enough for supplying several screen printing lines. The system works extremely reliably and provides minimal susceptibility to failure so that high availability is ensured for the continuous production of our sensors." Since the introduction of the Openair plasma technology Novotechnik has produced and delivered far more than 50 million activated individual components. Up to the present time no adhesion problems with the coating have shown up.

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