

Figure 1: Special rotation jets assure the smooth and large-area treatment of sensitive surfaces. The atmospheric plasma allows the 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. (Plasmatreat)

Atmospheric Plasma Treatment

How the Openair System Overcomes Adhesion Problems in Potentiometer Manufacture

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SUMMARY: The best possible adhesion of conductive inks applied by the screen printing process to the surfaces of sensor circuit boards is essential for manufacturers. Thanks to an atmospheric plasma process, throughput has tripled and adhesion problems have been reduced to zero.

Countless automation processes depend on the durable adhesion of the conductive ink. Therefore, an effective pretreatment of the substrate to be printed on, i.e., the cleaning and activation of its surface, is a mandatory measure. Various methods are available here. One still frequently used is the pretreatment with solvent-based chemicals. This method, however, is detrimental to the environment and often associated with high waste disposal costs.

Germany's Novotechnik (www.novotechnik.com) had already been focusing on environmentally-friendly production in the 1990s, when circuit boards were pretreated with low-pressure plasma in a vacuum chamber. This method was indeed efficient, but while vacuum chambers are perfectly suited for batch processes, they are less suited for the pretreatment of large quantities. With overly lengthy process times, integration into the existing screen printing lines was not possible either. Adding to this was the labor-intensive nature of the operation, since one person had to equip and another one had to empty the low-pressure chamber. After deciding to increase production from the year 2000 onward, the company discovered a plasma process that did not have the above limitations.



Figure 2: Position transducers operate under harsh environmental conditions and at high positioning speeds. (Novotechnik)

Atmospheric Plasma

In 1995, Plasmatreteat invented an atmospheric pressure plasma technology by the name of Openair-Plasma, in worldwide use today in almost all industrial sectors. By developing and using plasma jets, it became possible to integrate plasma, scarcely used so far in the industry, in-line into production processes, making it usable under normal atmospheric conditions for the pretreatment of the surfaces of materials on a large industrial scale.

The process is based on a nozzle principle for the most varied component geometries. Unlike low-pressure plasma, this process does not need a vacuum chamber, but operates under completely normal atmospheric conditions. The systems are made for simple in-line integration into automated, continuous production lines. The jets are driven solely by air and high voltage. 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 hundred m/min can be achieved. The typical rise in temperature of a plastic surface

during treatment amounts in this case to $\Delta T < 30\text{ }^\circ\text{C}$.

The surface activation that the plasma brings about results in a distinct increase in surface energy, so that completely new adhesion properties can be generated. Trials at Plasmatreteat have revealed that the surface energy of many non-polar plastics can be increased to over 72 dyne, an optimal precondition for adhesion in the painting or bonding process (Figure 3). It is even possible to achieve adhesion between in-

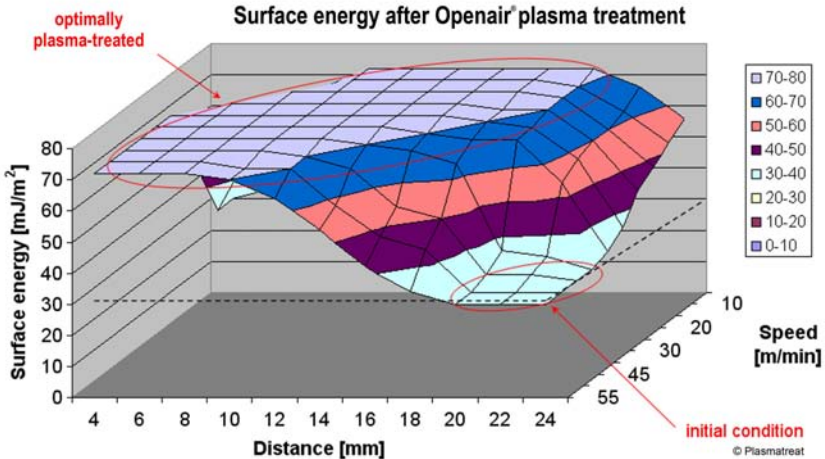


Figure 3: A non-polar plastic surface that was pretreated as a function of distance and speed with Openair plasma. Treatment renders the surface polar and the surface energy rises to >72 dyne with a large process window. (Plasmatreteat)



Figure 4: Complete throttle valve with flap, integrated actuator and sensor. Pretreatment with atmospheric plasma is effected before the integrated sensor circuit board is coated. (Novotechnik)

compatible plastics without bonding, simply by using plasma. Apart from the strong activation and microfine cleaning effects, the user benefits from the high electrostatic discharging effect of the free plasma beam, and also its ultrasonic emission speed, which effectively removes all loose and microfine particles from the surface. In close collaboration with the research institute Fraunhofer IFAM, Bremen, the technique was developed further: For the purpose of the functionalization of surfaces, the world's first atmospheric plasma-polymerisation process was patented and brought into large industrial use at TRW Automotive.

Under Test

The sensor manufacturer quickly realized the potential of the new plasma technology. "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 Potentiometer Technology Centre. The testing included 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 well-known car

Process Flow: Manufacture of Potentiometers

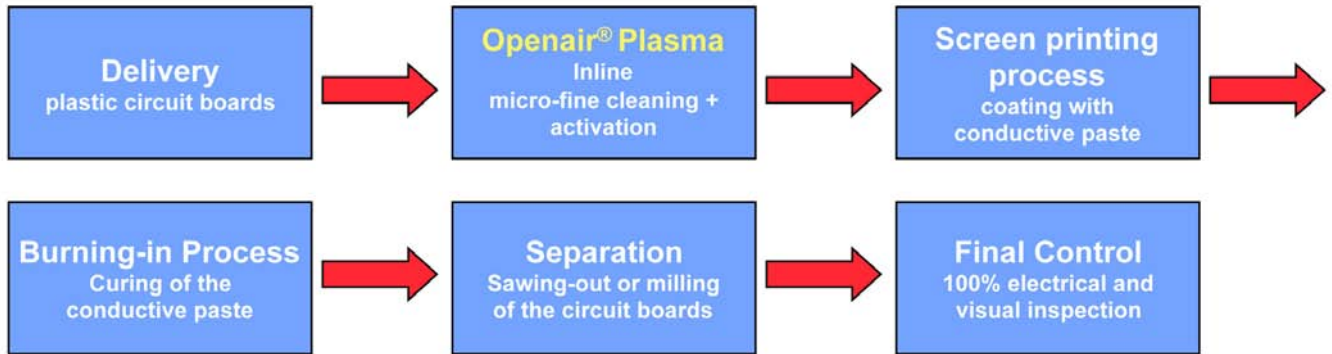


Figure 5: Production of potentiometers at the Novotechnik plant in Germany. (Novotechnik)



Figure 6: The Openair process takes at most one second for the activation of the panel, which may contain up to 70 circuit board blanks. Thereafter, the circuit boards are transported to the printing plant where printing with conductive ink takes place by applying the screen printing process. (Plasmatreat)

manufacturer, for example, demanded evidence for a throttle valve product that the component is capable of being operated at more than 10 million cycles on the motor with no significant changes in its electrical properties (Figure 4). This number corresponds to a traveled distance of about one million kilometers.

Moreover, production by Novotechnik is governed by the general rule that technical modifications may not be simply 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.

Circuit Board Printing with Atmospheric Plasma

The atmospheric plasma process was introduced into production at the end of 2000. The manufacture of the FR-4 circuit boards is performed in a clean-room environment (Figure 5). The material is prestructured, i.e., it is received with etched conductive track structures. The panels designated for the potentiometric sensors may contain up to 70 circuit board blanks. Plasma treatment is necessary to ensure good wetting of the substratum with the 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. One 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, one second 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 (Figure 6). 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," according to Eckert.

Conclusion

Apart from components for the automotive industry, the sensor producer also manufactures circuit boards for ship control systems and wind turbine gearboxes with this plasma system. The process is highly efficient, safe, fast and therefore, cost-effective. One plasma plant is enough for supplying several screen printing lines (Figure 7). The system works reliably and provides minimal susceptibility to failure so that high availability is ensured for the continuous production of sensors. Since the introduction of the atmospheric plasma-jet technology, Novotechnik has produced and delivered far more than 50 million activated individual components. Up to the present time not a single adhesion problem with the coating has developed. **PCB**

Inès A. Melamies is a journalist based in Germany who has written extensively on atmospheric plasma-jet technology. Plasmatreat (www.plasmatreat.com) is headquartered in Steinhagen, Germany. In close cooperation with international research institutes and universities, the company has advanced and patented a large number of research projects and processes and has engineering centers located in Germany, the United States, Canada, Japan and China.



Figure 7: The circuit boards undergo a continuous process, via the plasma system, through to the screen printing plant. The space-saving plasma plant serves four screen printing lines. (Plasmatreat)