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Surface Technology in Avionics – a Question of Safety



In civil aviation, the safety of billions of passengers depends on the correct functioning of electronic airborne radio communication systems.

Photo: Rohde & Schwarz GmbH & Co. KG

If airborne communications between the pilot and the control tower fail, the safety of passengers can no longer be guaranteed. The circuit boards built into the radios must be optimally protected from moisture ingress – and thus from technical malfunctioning – by applying a conformal coating. For one world-leading system manufacturer, atmospheric pressure plasma ensures the long-time stable adhesion of the protective coating to the plastic-encapsulated electronic assemblies.



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The high safety requirements in the aviation industry are far more rigorous than those in other industries. In December 2018 the International Civil Aviation Organization (ICAO) reported that 4.3 billion civilian air passengers put their trust in air travel last year, and thus on the quality and reliability of air traffic control systems. The main task of air traffic controllers is to guide aircraft on the ground and in the air by radio to prevent collisions. Passenger safety largely depends on uninterrupted communication between the traffic controller and the pilot and this communication is itself reliant on the correct functioning of electronic aircraft radio systems. Crews on long-haul flights use shortwave radios to communicate with air traffic control, and to stay in touch with their airlines from anywhere in the world. These devices allow uninterrupted communication even on routes over the poles where satellite networks cannot be used.

Rohde & Schwarz, a leading manufacturer of wireless communications and EMC test and measurement equipment and broadcasting and T&M equipment for digital terrestrial television, also manufactures these airborne radios, which are required to meet the highest safety standards. These high-

tech systems are produced by the subsidiary Rohde & Schwarz Messgerätebau GmbH at its manufacturing plant in Memmingen, which is responsible for assembly, final testing and shipping of almost all the company's products. Barely a single long-haul aircraft in the world lands or takes off without the assistance of an XK/FK 516 shortwave radio produced by this specialized Bavarian company. At the core of the FK 516 antenna tuner developed specifically for civilian airborne radio communication and long-haul flights is the tuning control, a circuit board fitted with several hundred components. The function of this electronic assembly with its tiny plastic-encapsulated parts is to reliably tune the antennae, thereby ensuring overall radio communications.

Unexpected adhesive problem

Conformal coating, a production process which the company had been using without a hitch for several years, was suddenly disrupted when it was discovered that the transparent protective coating had lifted on around 50 plastic-encapsulated transistors. Since nothing whatsoever had changed in the assembly, pre-cleaning or coating process, the root of the problem

could only lie with the component material itself. And indeed it did: When questioned, the supplier confirmed that they had changed the composition of the plastic. A problem frequently encountered by processing companies that are reliant on plastic components produced externally is that even the slightest alteration to the composition, remnants of release agents from the injection molding process or invisible dust particles can be enough to totally change the adhesive characteristics of a plastic surface. Since there was no other certified manufacturer for these particular electronic components at the time, at Memmingen they saw no alternative. »We had to find a solution as quickly as possible to ensure the adhesion of the conformal coating«, explains Michael A. Wahl, mechanics engineer in charge of production technology at Rohde & Schwarz. »Without a reliable adhesive bond it would no longer be feasible to continue manufacturing the tuning control units.«

Surface activation

Surface energy is the most important measure for determining the probable adhesion of a coating. With plastics, reliable adhesion is conditional on the material surface being ultra-clean and the surface energy (mJ/m²) of the substrate being higher

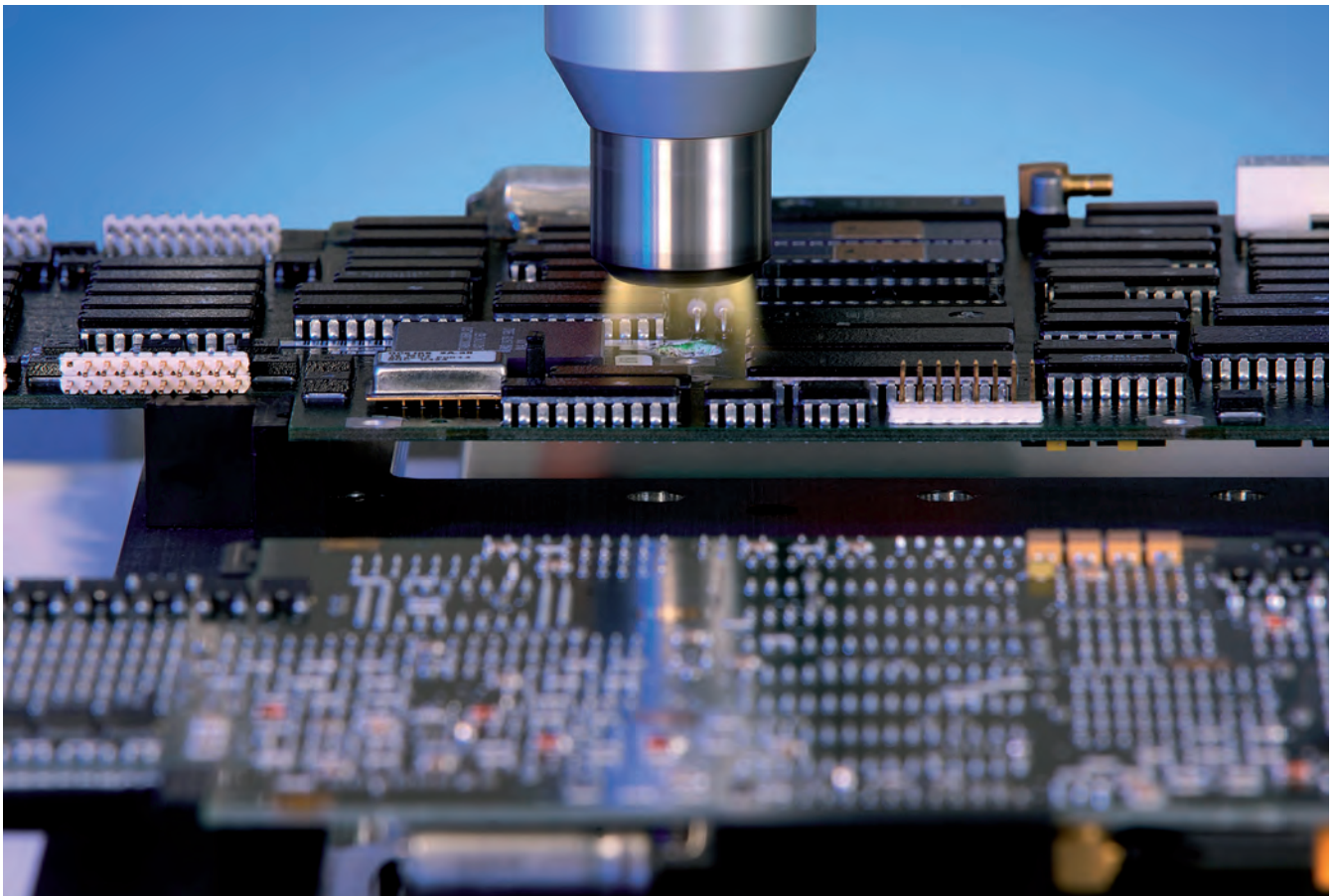
than the surface tension (mN/m) of the liquid adhesive or paint. Materials are made more receptive to adhesion by means of activation; in other words, by pretreating them to modify their molecular structure and so increase their surface energy.

But finding the right pretreatment for these highly sensitive electronic components seemed almost impossible at first. Wahl: »Activation using a solvent-based primer was not an option for us. Partly because these substances are extremely harmful to the environment, and partly because they would incur enormous costs in terms of health and safety such as explosion protection and disposal.« CO₂ snow blasting, which cleans but has no activation capability, was also rejected. The electronic engineers also ruled out laser pretreatment on the grounds that the uneven surface of the material would have made the coupling efficiency unpredictable. Furthermore, with this process the plastic could not be activated at the same time. The final method under consideration was a low-pressure plasma treatment; a highly effective activation process, but not suitable for this purpose because the vacuum would have drawn the fluid out of the wet electrolytic capacitors contained in the assembly. The situation initially seemed hopeless, until Wahl discovered the solution at an

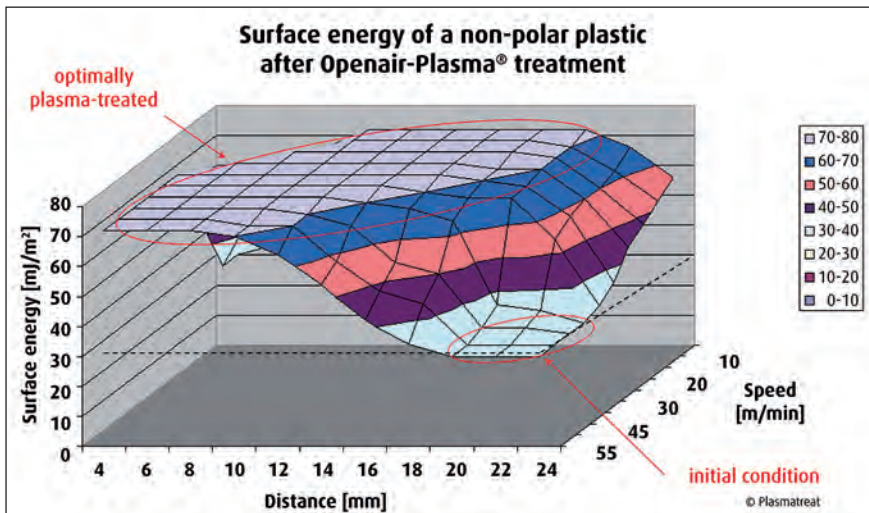
automation trade show that was taking place at the time. This is where he came across atmospheric pressure plasma, or more precisely, »Openair-Plasma« jet technology from Plasmamatreat.

The solution

The pretreatment process developed by the plasma specialist from Westphalia back in the mid-90s is now used throughout the world in almost every branch of industry. The environmentally friendly in-line technology works under perfectly normal production conditions, so does not require a vacuum chamber. The process performs three operations in a single step lasting only a matter of seconds: It simultaneously brings about the microfine cleaning, electrostatic discharging and strong activation of a plastic surface. The plasma is produced inside the nozzles by an intensive, pulsed arc discharge and conditioned at the nozzle outlet. The surface is activated through the chemical and physical interaction of the plasma with the substrate. The result is homogeneous wettability of the material surface and strong, long-time stable adhesion of the adhesive bond or coating. During plasma treatment, the temperature of plastics typically rises by less than 30 degrees Celsius and substrates can be transported through the plasma jet at speeds



The »Openair-Plasma« jet rotating at high speed gently activates the plastic-encapsulated components in a matter of seconds without damaging the sensitive electronics.
Photo: Plasmamatreat



The diagram shows a non-polar plastic surface which was activated with plasma as a function of distance and speed. Treatment renders the surface polar and the surface energy rises to $>72\text{mJ/m}^2$ (72 Dyne) with a large process window. Fig.: Plasmatreat



The »Openair-Plasma« cell has helped ensure the safety of tuning control units at Rohde & Schwarz for seven years. Photo: Plasmatreat

of several hundred meters per minute when static nozzles are used. For electronic components, however, this manufacturer uses special rotary nozzles with a particularly gentle action.

Wahl was soon convinced of the plasma's powers of activation, but the manufacturing specialist had one further question: Would the sensitive electronics survive the plasma treatment unscathed? It was clear from the very first tests performed on a rental system that the plasma had not damaged the electronics, since the special nozzle technology used in this process ensures that the plasma beam impinging on the surface is virtually potential-free.

The surface energy of the plastic transistors which had caused the whole problem increased from below 30mJ/m^2 in the inactivated state to over 70mJ/m^2 following plasma treatment. The final visual UV inspection which every single electronic assembly undergoes before being mounted also showed that there was not a single area where the conformal coating had lifted. But that still didn't satisfy Rohde & Schwarz – the most challenging test was still to come.

The endurance test

The aviation industry's requirements regarding the integrity and service life of safety-relevant components far outweighs those of the automotive industry, whose requirements are themselves recognized as being very tough. One example of this is the burn-in test which is performed post-production on tuning controls at Rohde & Schwarz.

To understand the rationale behind this test, it's helpful to know that airborne radios are rarely installed in the plane's air-conditioned and pressurized engine area. Due to lack of space, most are located in the nose of the aircraft where very different temperature and humidity conditions prevail at altitudes of 10,000 to 15,000 meters. The radios' electronic assemblies must satisfy aeronautical equipment standards, and in particular the requirement to operate at temperatures ranging from -55°C to 65°C . This is why it is so important to ensure that the protective coating is fully bonded to the electrical components. Even the smallest leak would result in moisture ingress, potentially leading to complete failure of the radio communications system.

The purpose of the burn-in test is to investigate continuous operation and accelerated ageing of electronic components. As the toughest load test available for electronic circuit boards, it is used to detect manufacturing faults which were not

picked up earlier and to identify components that would fail in continuous operation. In Memmingen the test is performed on the finished radios under operating conditions, i.e. powered up and with antennae. The test consists of a series of eight-hour cooling and heating cycles; after a 4 h cooling cycle at -55°C , the temperature is pushed up to $+70^{\circ}\text{C}$ in a matter of a few minutes and held for a further 4 h before plunging back down equally rapidly to start the next cooling cycle. These cold/warm cycles are repeated nine times, amounting to three days. In that period of time the airborne radio faces a non-stop exposure to rapid and extreme temperature variations. If the plasma had damaged the electronics, the components would eventually have failed during this test. It would have become equally apparent if the coating had been poorly bonded to the plastic.

Convinced by plasma technology

Even after this test, the results were conclusive: The electronics functioned perfectly and the coating adhesion was stable. The plasma technology provided by Plasmatreat to optimize adhesion had proven its worth on all counts and under the most challenging conditions. The Memmingen-based airborne communications specialist returned the borrowed equipment and



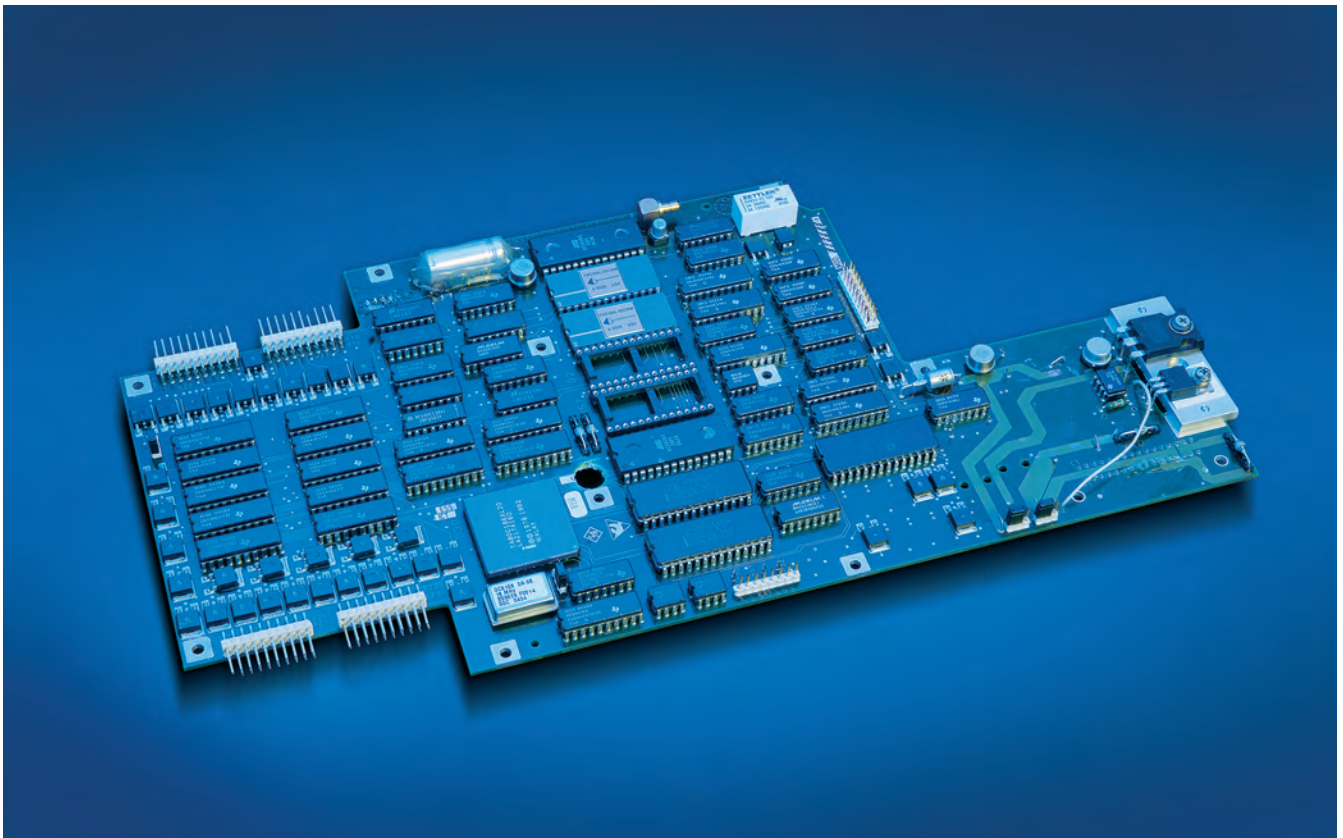
The shortwave radio guarantees airborne communications: left, the antenna tuning unit with built-in tuning control; right, the matching amplifier.
Photo: Rohde & Schwarz GmbH & Co. KG

purchased its own plasma cell which has now been running for seven years in continuous production helping to ensure the safety of the tuning control units. In the meantime, the company has added several electronic assemblies for radio systems used in different types of aircraft to its range – and their plastic components are plasma-treated too. »We greatly value the high degree of process reliability afforded by the »Openair-Plasma« process and its effective monitoring capabilities. These two factors combined with the user-friendly design were what persuaded us to choose

this system in the first place« explained Michael Wahl, before adding: »This plasma technology enabled us not only to reduce the number of process steps but also to enhance the quality of our product within a very short space of time.«

Details of the companies referred to in the article:
Plasmatreat GmbH
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The protective coating's adhesive bond is visually inspected under UV light before the electronic assembly is mounted in the radio. Then a burn-in test is performed to verify its stability.
Photo: Plasmatreat