Avionics: Atmospheric Pressure Plasma Case Study

by Inès A. Melamies,
BLUE RONDO INTERNATIONAL AND
Tim Smith, PLASMATREAT NORTH AMERICA

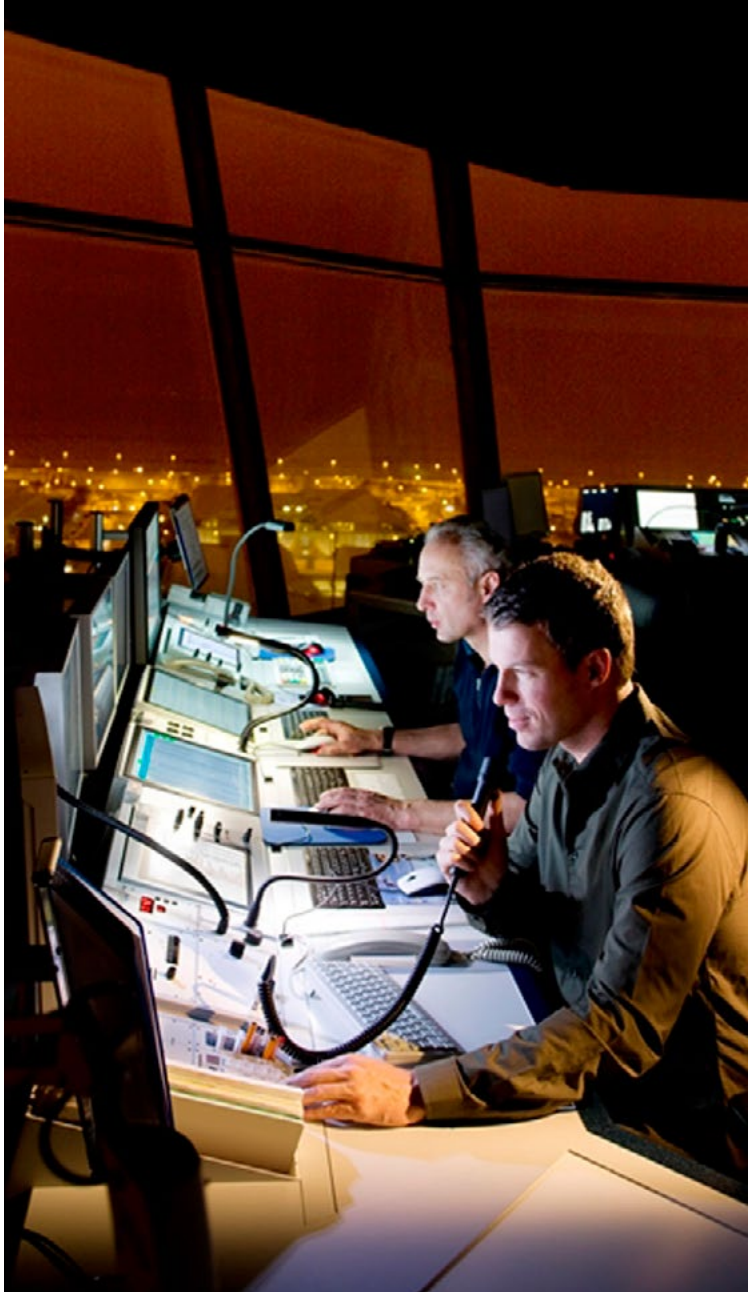

Figure 1: The safety of billions of air travelers depends on uninterrupted radio communication between air traffic controllers and pilots. (Photo: Rohde & Schwarz)

The aviation industry's requirements regarding the integrity and service life of safety-relevant components far outweigh those of other industries. Due to its virtually zero potential, an atmospheric pressure plasma process secures not only the adhesion of the conformal coating of SMD-boards in aircraft radio communication, but does so without any damage of the highly sensitive electronic components.

According to the International Civil Aviation Organization (ICAO) some 3.1 billion passengers made use of the global civilian air transport network in 2013[1] and have thus relied 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 depends to a large extent on clear communication between air traffic controllers and pilots, and relies 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 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, 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 unit: a circuit board fitted with several hundred tiny plastic-coated SMDs (surface-mounted devices). The function of this SMD assembly is to reliably tune the antennae, thereby ensuring overall radio communications.

Unexpected Adhesive Problem

Conformal coating came to an abrupt end one day when it was discovered that the transparent protective coating had lifted on around 50 transistors. Since nothing whatsoever had changed in the assembly, pre-cleaning or coating process, it became apparent that the root of the problem could only lie with the component material itself. And sure enough, when questioned, the supplier confirmed that it had changed the composition of its plastic blend. This is a problem frequently encountered by processing companies that are reliant on plastic components produced externally since even the slightest alteration to the composition can be enough to totally change the surface characteristics of the material. This news from the supplier was alarming, because there was no alternative to the new plastic blend. There was simply no other certified manufacturer available who could produce these particular electronic components.

"We had to find a solution as quickly as possible to ensure the adhesion of the conformal coating," explains Michael A. Schneider, mechatronics 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

As is well known, materials are made more receptive to adhesion by means of activation; in other words, by pretreating them so as to increase their surface energy. This is the most important measure for determining the probable adhesion of an adhesive layer or coating. Reliable, long-time stable adhesion is conditional on the material surface being ultra-clean and the surface energy of the solid material being higher than the surface tension of the liquid—in this case the coating. Various pretreatments are available to achieve these two conditions, with wet chemical substances still the most widely used.

Difficult Choice

But finding the right pretreatment for these highly sensitive electronic components seemed almost impossible at first. Schneider: "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 (e.g., explosion protection) and disposal." 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. CO_2 snow blasting, which cleans but has no activation capability, was also rejected. 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 SMD assembly. "We seemed to be very far from finding a way around this

Figure 2: Avionics specialist Michael Schneider (left) and plasma expert Peter Langhof (right) standing in front of the Openair-Plasma system. (Photo: Plasmatreat)

problem," recalled the engineer, "but then I stumbled across a solution at an automation trade fair. This is where I discovered atmospheric pressure plasma."

The Solution

The pretreatment process developed and patented under this brand name by Plasmatreat GmbH in the mid-90s is now used throughout the world in almost every branch of industry. The environmentally friendly in-line technology works under normal ambient air conditions, thereby dispensing with the need for a vacuum chamber.

The plasma process performs two operations in a single step: It simultaneously brings about the microfine cleaning and strong activation of the plastic surface. The rise in temperature of the plastic surface during plasma treatment is typically less than 30°C and substrates can be transported through the plasma jet at speeds of several hundred meters per minute. For electronic components, patented rotational nozzles with a special gentle action are used.

Schneider was soon convinced of plasma's powers of activation, but now the manufacturing specialist had to face a complete different question: Would the sensitive electronics survive the plasma treatment unscathed?

It was clear from the very first tests performed on a plasma system supplied on loan that this plasma technique had not damaged the electronics. The surface energy of the plastic transistors which had caused the whole problem increased from below 30 dyne in the inactivated state to over 70 dyne following plasma treatment. The final visual UV inspection, which every SMD component undergoes before

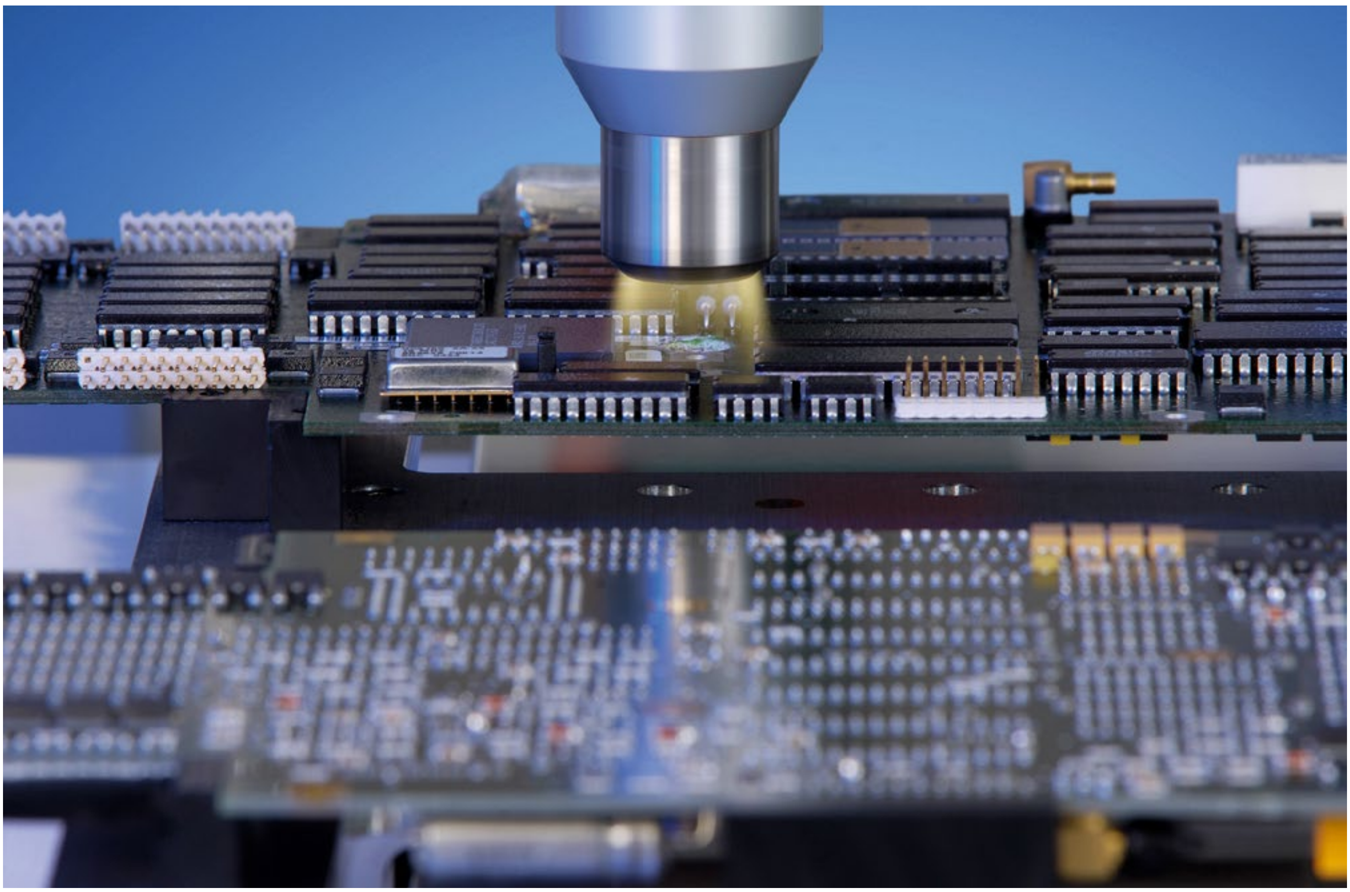

Figure 3: The smoothly working rotary plasma jet cleans and simultaneously activates the surface of the plastic components just before conformal coating. The pretreatment is done in a matter of seconds without damaging the sensitive electronics. (Photo: Plasmatreat)

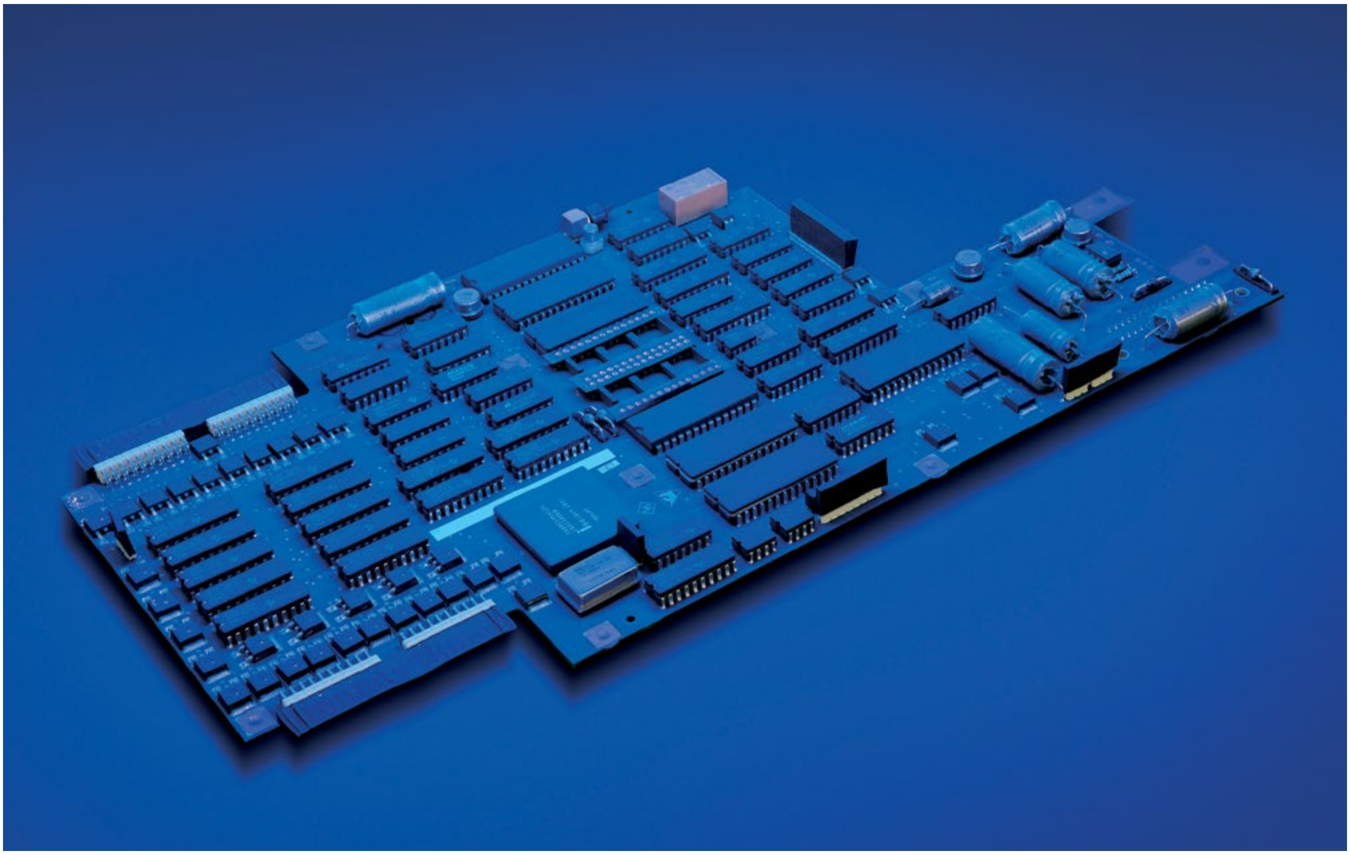

Figure 4: The coating's adhesive bond is visually inspected under UV light before the SMD assembly is mounted in the radio. Then a burn-in test is performed to verify its stability (Photo: Plasmatreat).

assembly, also showed that there was not a single area where the coating had lifted.

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 that is performed post-production on tuning controls. 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. Mostly they are located in the nose of the aircraft where very different temperature and humidity conditions prevail. 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. What most air passengers don't realize is that all passenger planes are obliged to carry two sets of radio equipment on board; the second as backup in case the first one fails. If a plane lands at its destination with a defective radio system, it has to stay on ground until a spare radio set has been acquired and fitted.

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. Burn-in is performed on the finished radios under operating conditions (i.e., powered up and with antennae). The test consists of a series

Figure 5: The XK/FK 516 shortwave radio guarantees airborne communications. The FK 516 antenna tuning unit with built-in tuning control (left); the matching amplifier (right).
(Photo: Rohde & Schwarz)

of eight-hour cooling and heating cycles; after a four-hour cooling cycle at -55°C, the temperature in the burn-in chamber is pushed up to +70°C in a matter of a few minutes and held for a further four hours before plunging back down equally rapidly to start the next cooling cycle.

These cooling/heating cycles are repeated nine times, amounting to three days. During this time the radio system experiences a non-stop exposure to rapid and extreme temperature variations (Figure 5). If the plasma had damaged the electronics, the components would eventually have failed during this test. It would equally have become apparent if the coating's adhesion to the plastic would have not been sufficient.

Summary

Test results were conclusive: The electronics functioned perfectly and the coating adhesion was long-time stable. Schneider said, "This plasma technology reduced the number of process steps and enhanced the quality of our product within a very short space of time." **SMT**

References:

1. ICAO 2013 Air Transport Results.

Inès A. Melamies is a journalist based in Germany who has written extensively on atmospheric plasma-jet technology.

Tim Smith is vice president of engineering and operations of Plasmatreat North America and director of the Canadian Technology Center in Ancaster, Ontario. For more information, contact tim.smith@plasmatreat.com.