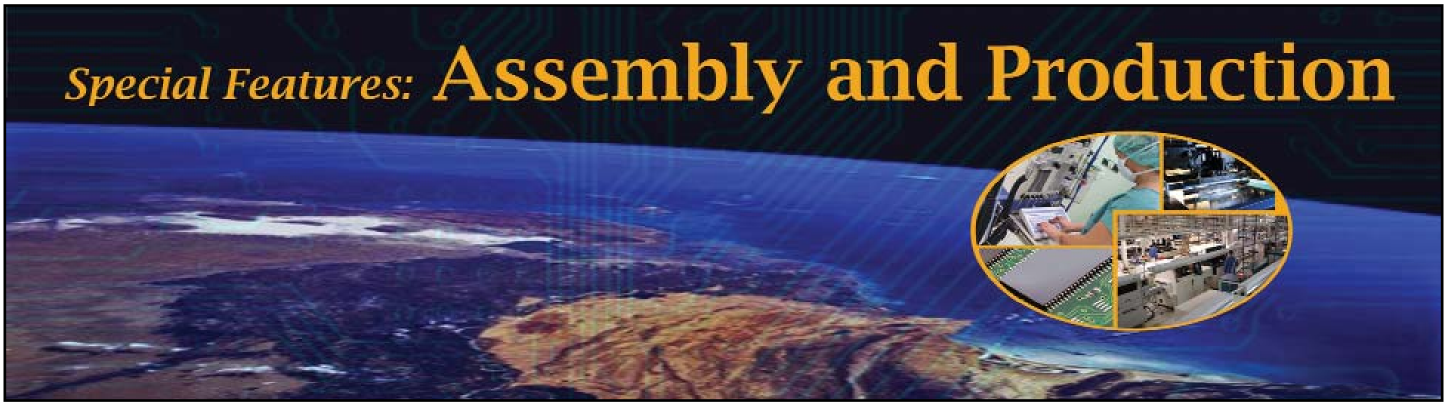
Reprinted with permission from the October, 2017 issue of ...



EMI Shielding: Improving Sidewall Coverage with Tilt Spray Coating

By Mike Szuch, Akira Morita and Garret Wong, Nordson ASYMTEK; Mike Sakaguchi and Hiroaki Umeda, Tatsuta Electric Wire & Cable Company Limited

EMI shielding has always been an important component of RF devices, but the demands of today's Bluetooth, Wi-Fi, 3G, LTE, wearable, and IoT devices have created a special set of hurdles for the manufacturing engineer. These devices rely on different radio frequencies that can interfere with one another and cause unwanted electromagnetic interference (EMI). In the past, "metal cans" or "lids" were used to shield entire groups of sensitive components from interference. This is no longer feasible, as manufacturers continue to design thinner, smaller devices that leave very little space to house electronic components. As a result, it has become increasingly important to develop reliable EMI shielding solutions at the individual component level through the application of thin conductive coatings.

Multiple technologies have been explored to apply EMI shielding to individual components. The leading three technologies are sputtering, plating and spray coating. Currently, sputtering is the most popular method. However, it is also the most expensive method and has some limitations when coating the sidewalls of components. Reduced sidewall coverage not only affects the overall package shielding performance, but may also lead to issues with shield grounding and reliability.

Plating has also been viewed negatively due to environmental considerations, capital expense and requirements for masking to prevent plating the wrong areas. In contrast, spray coating has been viewed as an attractive solution due to the relatively low capital equipment investment, high productivity (UPH), ability to accommodate multiple components and coating patterns, and the reduction of waste when applying expensive EMI shielding materials.

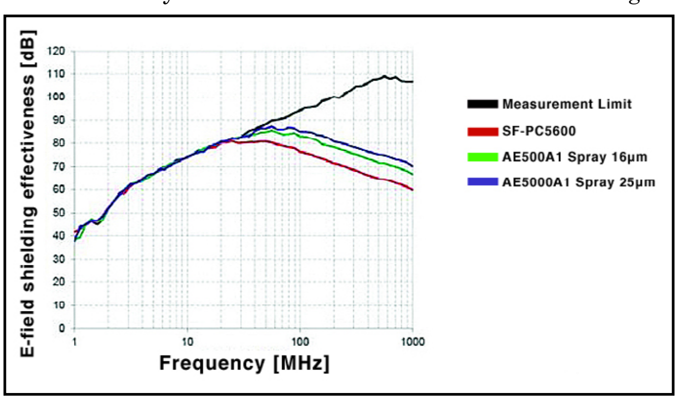


Figure 1: sample test performance of Tatsuta AE5000A-1 fluid relative to a tape-adhesive EMI shield material, SF-PC5600.

Like sputtering, however, one of the significant concerns with spray coating has been reduced coverage along the sidewalls of components when material is sprayed from a vertical position. New material formulations are overcoming prior minimum thickness limitations of spray-coated materials, allowing coating thicknesses below the 25 µm level that allow proper legibility of laser markings on coated components.

Nordson ASYMTEK has partnered with a number of fluid formulators to explore the use of a tilted spray applicator to improve directional spray accuracy and sidewall coverage. One such company is Tatsuta Electric Wire & Cable Company Limited. Nordson ASYMTEK studied the application of Tatsuta's AE5000A-5 EMI shielding material from a tilted spray applicator. The company specifically analyzed the sidewall thickness relative to the top layer thickness of the sprayed material.

Spray-Coated EMI Shielding

Spray-coating technology for thin layers of material has been around for decades, primarily used for applying environmental encapsulation and protective coatings to PCBs. Application of this technology to EMI shield spray coating has been highly desirable as the cost of coating equipment is typically one-tenth the cost of equipment for alternate technologies, and can be just as productive as the more expensive options.

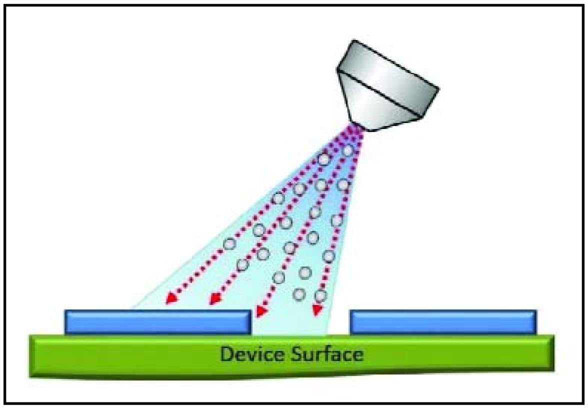


Figure 2: tilted spray coating applies fluid at an angle to the top and sidewalls of component surfaces.

The smaller size of the equipment (compared with PVD sputtering or electroplating equipment) and the ability to integrate the equipment in-line with a curing oven for the sprayed material allows for significant automation. Early tests with spray-coated materials, however, revealed two notable problems: less than 50 percent sidewall thickness compared with top surface thickness and EMI shielding performance requiring thicker coatings.

Sample	Number of Sample	Measurement item \ Head speed		Test 1	Test 2	Test 3
Tatsuta dummy coupon2	20	Pad Resistance (mΩ)	Ave S.D.	60 7.1	53 2.2	53 1.9
		Paste surface Resistance (mΩ)	Ave S.D	54 2.2	50 1.8	48 1.8
		Paste thickness (μm)	Top Side	12.5 8.9	13.0 7.6	13.7 7.3

Table 1: Test results with dummy coupon 2 (0.2 in. [5 mm] pitch).

Spray-coated shielding materials are made up of many small particles and attach to the target surface with a bonding epoxy or adhesive. Spray-coated materials have larger grain boundaries and gaps between conductive particles, due to the adhesives used to bind the particles together and to the target component. Surface-level contacts between particles assume the conductivity of the coating, creating a Faraday cage.

But, the physical contacts provide less conductivity than covalent bonding, sputtering and plating. This, in turn, leads to degradation in electrical performance of the coating and generally requires a thicker coating than covalent bonded materials in sputtering and plating processes, ensuring conduction and avoidance of "pinhole" failures. Pinholes are gaps between particles that can result in areas where EMI radiation can penetrate the shield and reduce shield efficacy. New fluid formulations with different particle shapes and atomized spray-coating technology help to address the challenges of reducing coating thickness, while avoiding pinholes through consistent particle distribution.

New Material Formulations

For recent tests, Nordson ASYMTEK used Tatsuta AE5000A-5, which is revised from the company's AE5000A-1 fluid. This fluid has been shown to provide good EMI shielding performance results at various thicknesses. Figure 1 shows sample test performance of the AE5000A-1 material at 16 and 25 µm thicknesses relative to a tape-adhesive EMI shield material, SF-PC5600.

Target performance for an EMI shielding material is to achieve greater than 50 dB at frequencies of 1GHz and above for radiation. More recent testing of EMI shielding is examining performance at lower frequencies where inductive and conductive interference from neighboring devices on a PCB or flex circuit have a more pronounced effect on overall device performance.

Sample	Number of Sample	Measurement item \ Head speed		Test 1	Test 2	Test 3
Tatsuta dummy coupon3	20	Pad Resistance (mΩ)	Ave S.D.	74 9.0	63 2.5	62 4.7
		Paste surface Resistance (mΩ)	Ave S.D	63 2.1	59 3.3	55 2.3
		Paste thickness (μm)	Top Side	12.3 8.3	12.7 8.1	13.1 8.0

Table 2: Test results with dummy coupon 3 (0.2 in. [5 mm] pitch).

One additional consideration for targeting thickness of the EMI shielding materials is the legibility of any pre-existing laser marking on the target device after coating is applied. Laser marking post-coating is not feasible, as the laser marking would create holes in the EMI shield. In earlier testing performed by Tatsuta, it was determined that at a maximum target thickness of 15 µm for the EMI shield coating, typical device laser marks could still be read.

Tilted Spray Considerations

Initial attempts with spray coating of EMI shielding materials also focused on vertical spraying of the fluid. With a vertical spray, the fluid is atomized at the spray nozzle and applied to the target component in a conical pattern, with the bulk of the particles and adhesive traveling in a vertical direction toward the target.

As such, top surface coverage is very good and can be created with a uniform thickness using controls in the spray coating equipment. However, this vertical dispensing method limits application of the shielding to the sidewalls of the components, thus creating an incomplete

Faraday cage and leaving the components susceptible to EMI. In past testing with multiple fluids from various suppliers, such as Tatsuta, Parker Chomerics and Clariant, vertical spray coating of the fluids would often lead to a sub-50 percent ratio between top layer thickness and sidewall thickness of the spray-coated fluid. Limited sidewall thickness coverage has slowed the acceptance of spray-coated EMI shielding materials.

In order to improve the sidewall coverage with spray-coated materials, Nordson ASYMTEK began testing tilted spray coating. By tilting the spray-coat applicator, sprayed particles are focused more directly toward these vertical surfaces to increase the chance of adhesion to the sidewall of the target component.

In the company's exploratory testing, the spray valve was tilted to a 30° angle from the vertical position. The design of the tilting system enabled the applicator to tilt in either the x or y axes to allow for spray coverage along all four sides of a component device. However, even with a tilted spray, neighboring devices created trenches and obstructions preventing uniform coverage of the sidewalls of a device. As a result, the company explored various pitches between devices to determine the minimum distance required between neighboring devices to achieve target sidewall coverage.

Test Setup

In the initial test setup, Nordson ASYMTEK chose two types of dummy test coupons, both 0.4 x 0.4 in. (10 x 10 mm) with 0.05 in. (1.25 mm) thickness to confirm that sprayed fluid adhered consistently to both types of common component surfaces. "Dummy coupon 2" was an FR-4-type material. "Dummy coupon 3" was a coupon with sample molding compound exterior. In this setup, devices were mounted with a set 0.2 in. (5 mm) spacing between them.

In the secondary test setup, the company wanted to determine the minimum pitch between devices to achieve coverage improvement. In this test setup, dummy coupon 3 devices were mounted at 0.02, 0.04, 0.08, and 0.12 in. (0.5, 1.0, 2.0, and 3.0 mm) pitches.

In each test, multiple line speeds were tested to adjust the resulting coating thickness for both the top and sidewall. The more time that a target surface was exposed to the spray from the spray applicator, the more fluid and particles adhered to the target surface. Higher line speeds generally resulted in thinner coatings, while slower line speeds resulted in thicker coatings.

The results from the 0.2 in. (5 mm) pitch test for both dummy coupons 2 and 3 resulted in similar thickness results between the component types. Depending on the line speed, top layer coating thickness was approximately 13 µm. Sidewall thicknesses varied from 7 to 9 µm depending on the line speed. The ratios of sidewall-to-top-layer thicknesses ranged from 53 to 71 percent. For both components, higher line speeds resulted in better coating thickness ratios and thinner top layers.

Figure 3 shows example images from cross-sectioned samples for both dummy coupons. It can be seen that coverage across sidewalls and the top surface is complete. It is important to note from these images that the sprayed shield material also sufficiently covered the corners of the dummy coupons, ensuring a consistent shield around the device.

Variable-Pitch Test Results

In examining the sprayed shield coverage on the components, a quick gauge for shield performance can be observed from the surface roughness of sprayed material. Rougher surfaces are more prone to pinhole failures and appear matte. A glossy surface finish generally denotes a more even coating with lower roughness and better consistency. In this test, top layer coverage and appearance was very good. However, sidewall coverage for device pitches below 0.08 in. (2 mm) was poor. It was possible to still see underlying features from the test vehicle (copper foil lines), indicating incomplete shield coverage.

For testing with the variable-pitch mounted dummy coupons, two line speeds were run, based on the results from the 0.2 (5 mm) device pitch test results in tests 2 and 3. Sidewall thicknesses were then measured for both sides of each device to examine the effect of the device pitch on the resulting sidewall-to-top-layer thickness ratio. In both cases, the best results were achieved at 0.12 in. (3 mm) pitch between devices and resulted in comparable sidewall thickness ratios as the results from the 0.2 (5 mm) pitch test. However, results at 0.08 (2 mm) pitch were also notable with a greater than 50 percent sidewall thickness ratio. Below 0.08 in. (2 mm) pitch, the sidewall coverage dropped off significantly, indicating poor coverage and matching with previously observed results.

Test results with the Tatsuta AE5000A-5 material produced less than 15 µm coating thickness with EMI shielding performance, meeting targets at the 1 GHz frequency. Furthermore, a sidewall-to-top-layer thickness ratio greater than 50 percent was achieved when using the tilt spray applicator. It is recommended that a minimum of 0.08 in. (2 mm) pitch between devices is used to achieve adequate sidewall coverage, but pitches of 0.12 in. (3 mm) or greater will provide the best coverage. Further improvements to the coverage ratio may be achieved through fine-tuning of the dispense pattern, line speed and spray-coating parameters.

Tilt spray applications provide performance and coverage results to rival existing EMI shielding. It can now be considered a viable, lower-cost alternative for applying EMI shielding to components.

Contact: Nordson ASYMTEK, 2747 Loker Avenue West, Carlsbad, CA 92705 ☎ 760-431-1919
E-mail: akira.morita@nordsonasymtek.com
Web: www.nordson.com *and*
Tatsuta Electric Wire & Cable Company Limited, 5201 Great American Parkway, Suite 320, Santa Clara, CA 95054 ☎ 408-850-7166 E-mail: m-sakaguchi@tatsuta.com
Web: www.tatsuta.com ❒

See at productronica, Hall A2 Booth 345