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INSULATION COATINGS WITH HIGH DIELECTRIC BREAKDOWN STRENGTH

Insulating coatings play a crucial role in a multitude of applications. As the Industry 4.0 revolution unfolds the trend continues towards greater surveillance and monitoring of processes and workflows. This requires increased use of sensors or integrated sensor solutions. A reliable and proofed insulation is absolutely essential, especially in the case of sensor integration in technical, in most cases, metallic components. These insulation coatings, which are also used in other components and markets, must have a low defect density and a high dielectric breakdown strength. Research is therefore in progress at the Fraunhofer IST into processes by which defect-free insulating coatings can be produced on the industrial scale.

Vacuum deposition of insulating coatings

Silicon and aluminum oxide coatings deposited by vacuum coating processes are frequently used for insulation and functional purposes. Basically and depending on requirements, processes for depositing from the gas phase (Chemical Vapor Deposition CVD) and from the solid-state target (Physical Vapor Deposition PVD) are used here. Both methods have a number of advantages but also some disadvantages.

Silicon oxide films can, for example, be produced at a good quality and high rate by plasma enhanced CVD (PECVD). However, these processes react very sensitively to changes in batch loading and component dimensions. Aluminum oxide, on the other hand, is harder to produce by PACVD and is instead typically generated by radio-frequency sputtering from a ceramic target. Unfortunately the deposition rate is very low. As regards cost-effectiveness, a high deposition rate with high coating quality is however desirable for PVD processes.

Reactive MF sputtering of highly insulating Al_2O_3 coatings

While stoichiometric films with good insulating properties can be produced by conventional radio-frequency sputtering from a ceramic Al_2O_3 target, reactive sputtering processes also offer the potential for considerably boosting deposition rates. The reactive process does however confront the user with some special challenges. To generate a low-defect coating, arcing events must be avoided as much as possible in the deposition process. These arcs often arise between the metallic racetrack and redeposition zones, i.e. areas where the target surface is oxidized. A very fast reaction in the event of an arc is critical here. The use of tubular cathodes can minimize the formation of oxide layers on the target surface and thus also the creation of arc discharges.

Characterization of highly insulating Al_2O_3 films on the industrial scale

A reactive process was developed at Fraunhofer IST by which highly insulating Al_2O_3 coatings can be generated. While conventional coatings with a thickness of approx. 5 µm have breakdown voltages in the range of 500 – 1000 V, specimens made by the new process exceeded the maximum test voltage of 5000 V. The deposition rate for the coatings was in the range of 2 µm/h (see diagram on the right side).

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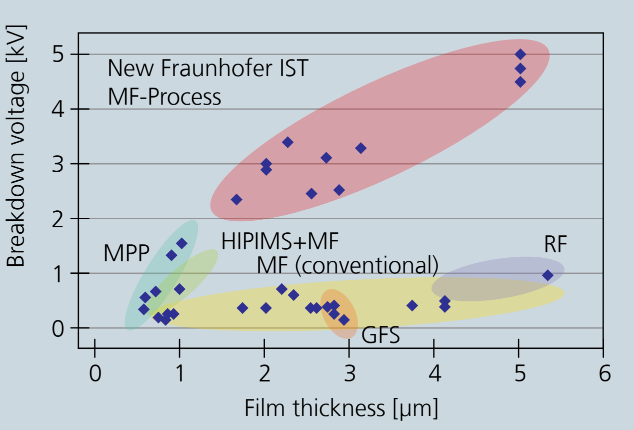
In further evaluation of the process from the point of view of industrial requirements, a carrier was fitted out over its full area with metallic reference samples in an inline coating system with cathode lengths of around 500 mm. The area under investigation on the carrier measured approx. 400 mm x 400 mm. The 5 µm Al_2O_3 coating was given a metallic top layer and a high-voltage tester (according to DIN EN 60243-1) then applied to check the breakdown voltage and defect density.

In all test specimens the breakdown voltage at the various points of measurement was higher than 2000 V. The majority of all measuring points had a breakdown voltage beyond 5000 V. Short-circuiting to the substrate could not be detected in any of the test pieces. The current process should now be expanded and qualified to cover also non-planar substrates.

Breakdown voltage of Al_2O_3 coatings as a function of the film thickness and the used deposition process.



1 Inline coating system with dual magnetron for reactive Al_2O_3 deposition.

2 Ball bearing with thin film strain gage on its external radius.

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