



# SPRAY PYROLYSIS OF ALUMINUM OXIDE TO DEPOSIT LAYERS ON WAFER MATERIALS

## THE TASK

Alternative concepts are sought for the backside passivation of lower cost solar cell wafers. Conventional passivation is based on using aluminum paste and a screen-printing process. However, this layer is causing wafer bending in subsequent heat treatment steps during cell fabrication. This can be avoided by using an aluminum oxide thin film as a passivation layer. Aluminum oxide layers have a high fraction of negative charge carriers, which is especially suitable for field effect passivation in p-doped silicon surfaces.

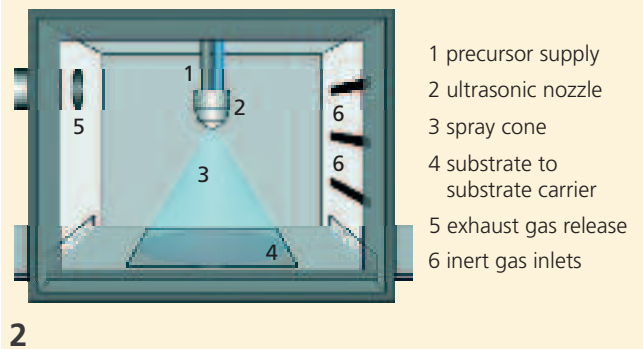
Typical methods for high quality aluminum oxide film deposition on silicon are atomic layer deposition (ALD) and plasma enhanced chemical vapor deposition (PECVD). The task is to develop an alternative process operating at atmospheric pressure. The focus is on using safe, easy to use and low cost precursors for the deposition. The use of vacuum chambers should be avoided and the process should be scalable and suitable for inline installations. High deposition rates are essential to manage a throughput of 3600 wafers per hour.

## OUR SOLUTION

Fraunhofer IWS engineers are developing an ultrasonic spray pyrolysis process for the deposition of aluminum oxide films. The spray process works at atmospheric pressure in air or nitrogen. An ultrasonic nozzle (frequency 120 Hz, flow rate 1 ml min<sup>-1</sup>) atomizes the precursor solution. Due to the nitrogen flow the produced aerosol forms a hollow cone and is guided toward the heated substrate.

Shortly before reaching the substrate the aerosol transforms to its vapor phase. Subsequent vapor deposition forms the aluminum oxide on the substrate surface. A thermocouple measures the temperature in the heated graphite holder. The ultrasonic nozzle is scanned across the substrate by a 2-axes linear motor system, which creates a homogeneous spray pattern.

*Schematics of the spray chamber*

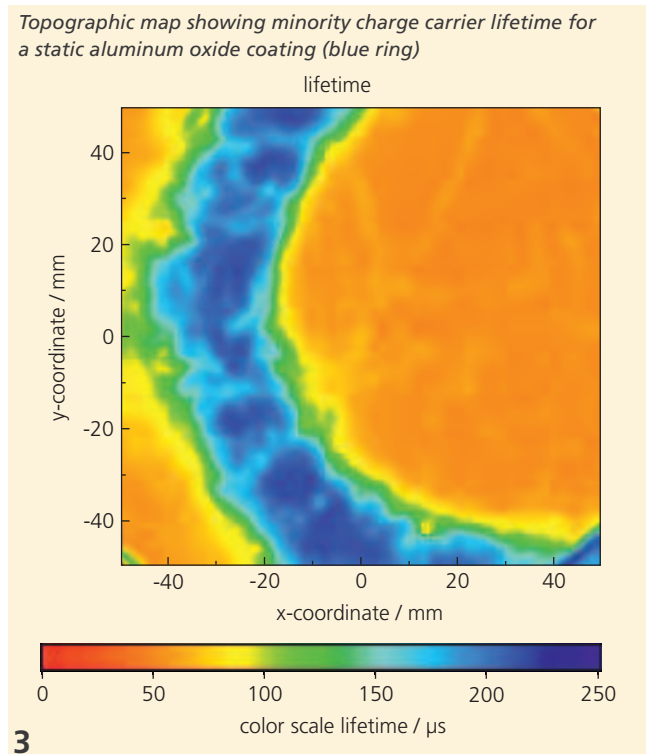


## RESULTS

The test precursor solution was composed from a mixture of aluminum acetylacetonate, methanol, diethylene glycol monobutyl ether and 3 or 33 % water. The films were deposited onto 156 mm x 156 mm substrates, which had reference films of aluminum oxide (ALD) on the backside.

Microwave detected photoconductivity measurements (MDP) were performed to evaluate the coating quality. The measurements determine the effective charge carrier lifetime (LTL) with spatial resolution in passivated p-type (1 - 5 Ω cm) CZ-silicon wafers (525 μm thick).

The effective charge carrier lifetime on wafers with sprayed aluminum oxide films was 260  $\mu\text{s}$  (Fig. 3). This results in an effective recombination speed of 113  $\text{cm s}^{-1}$ . This speed is determined by the sprayed aluminum oxide coating. The substrate temperature during the deposition process is 340  $^{\circ}\text{C}$ . Subsequently a thermal annealing step for the sprayed coatings to activate the aluminum oxide coatings is not necessary.



The aluminum oxide coating should have a thickness of about 15 - 20 nm for optimum passivation. The deposition rate with the used precursor mixture was 16.6  $\text{nm min}^{-1}$ , which is comparable to typical PECVD deposition rates. No particle contamination of the coating occurs during the deposition. The average roughness of the coating is 0.55 - 0.59 nm.

The water vapor concentration increase from 3 to 33 % improved the passivation effect of the pyrolysis sprayed aluminum oxide coatings. A high water vapor fraction improves the defect saturation with hydrogen at the interface  $\text{AlO}_x/\text{SiO}_2$  (chemical passivation).

Spray pyrolysis is also useful to deposit other coating systems such as transparent conductive films (TCO).

The results were obtained within the project S-PAC – Saxony Photovoltaics Automation Cluster – Chemnitz/Dresden (03WKBW03C). This project is part of the BMBF initiative “Innovative Regional Growth”.

**1** *Ultrasonic nozzle with  
heat sink*

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