Applied Research for Vacuum Web Coating: What is Coming Next?

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Introduction

Applied research for vacuum web coating is like a seismographic sensor for new topics that will push forward the industrial application of this technology. The objective of this paper is to concisely present some current R&D topics which show interesting potential for future industrial use.

Ultra-thin flexible glass

Ultra thin flexible glass combines flexibility with the great properties of glass. However, to explore this unique combination of properties for the industry, there is an R&D need for vacuum thin film coating of this material. VON ARDENNE GmbH has developed a roll-to-roll coating unit that has been installed at Fraunhofer FEP's lab and that is now being used in several R&D projects. The focus of this R&D projects is to explore vacuum roll-to-roll coating technologies for ultra-thin flexible glass.

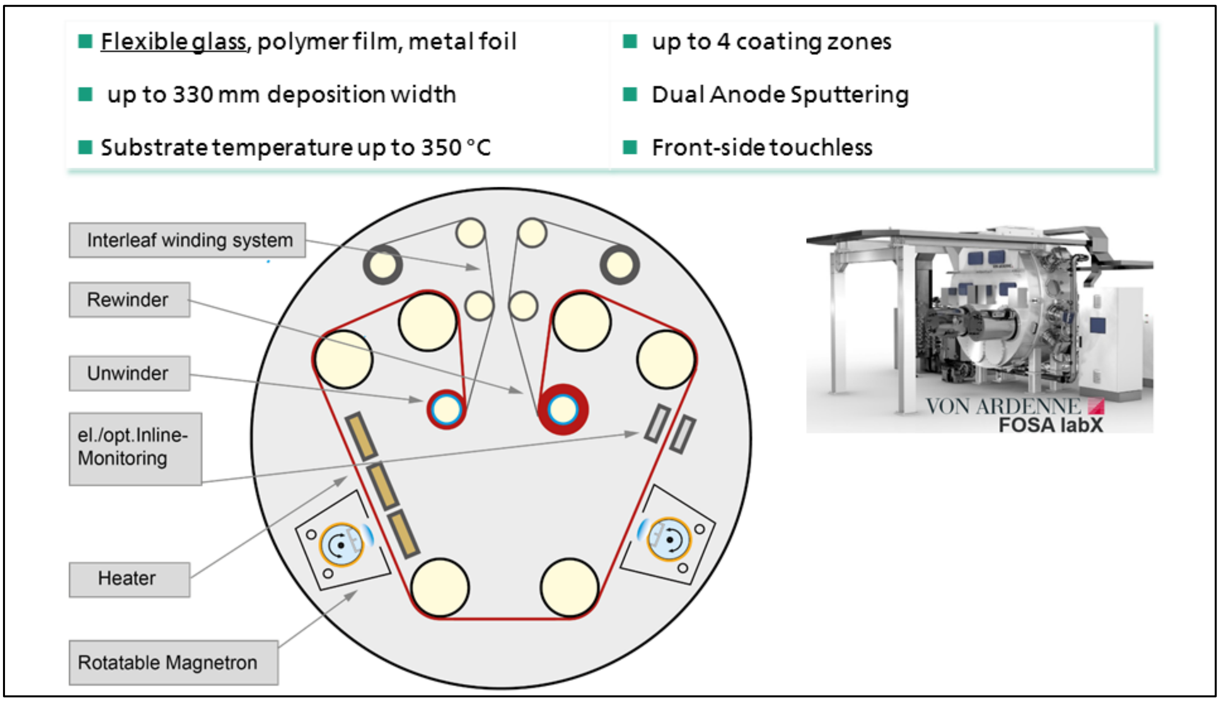

Figure 1: Schematic of the pilot coater *FOSA labX 330 glass* for roll-to-roll coating of flexible glass (VON ARDENNE GmbH)

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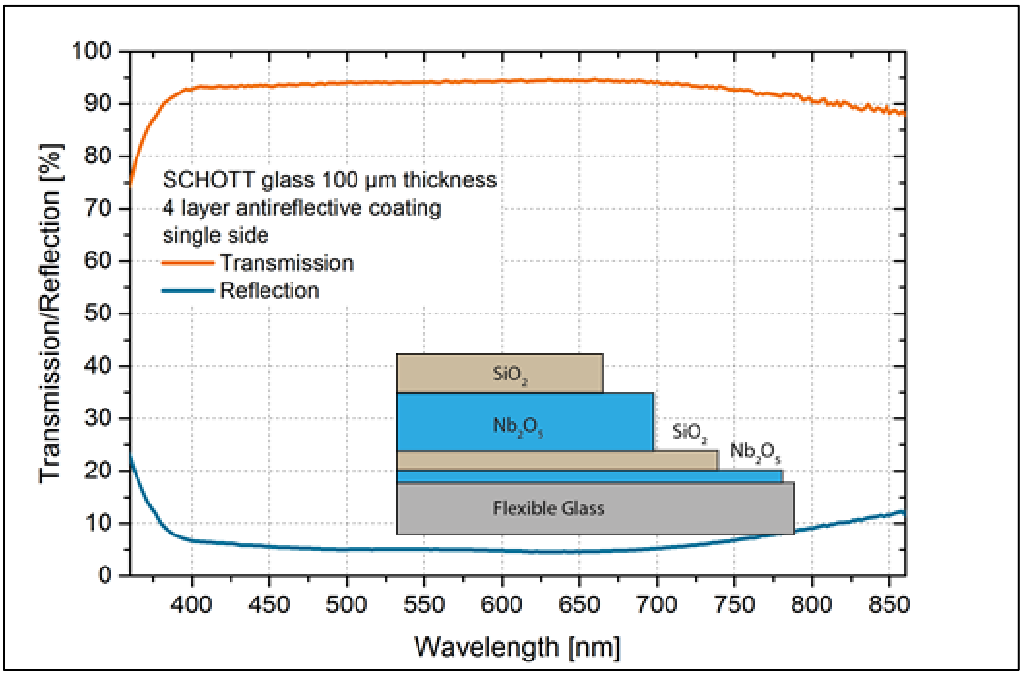

Figure 2: AR reflection coatings on flexible glass made by roll-to-roll coating using FOSA labX 330 glass (VON ARDENNE GmbH)
(Project KONFEKT, funded project by BMBF /Federal Ministry of Education and Research, contract nr. 13N13818)

High rate PECVD process

Plasma Enhanced Chemical Vapor Deposition (PECVD) is a well-established technology, also for vacuum web coating. However, there is still a need to push deposition rate and productivity to open the door towards interesting industrial applications like

- protective layer on barrier film
- adhesion promoting layers
- anti-fingerprint coatings
- color coatings

We have developed a high-rate PECVD technology that is based on hollow cathode plasma sources. This process works at a low pressure between 0.1 - 5 Pa. The dynamic deposition rate reaches 2000 nm m/min. The plasma source has been scaled up to a web width of 2.85 m.

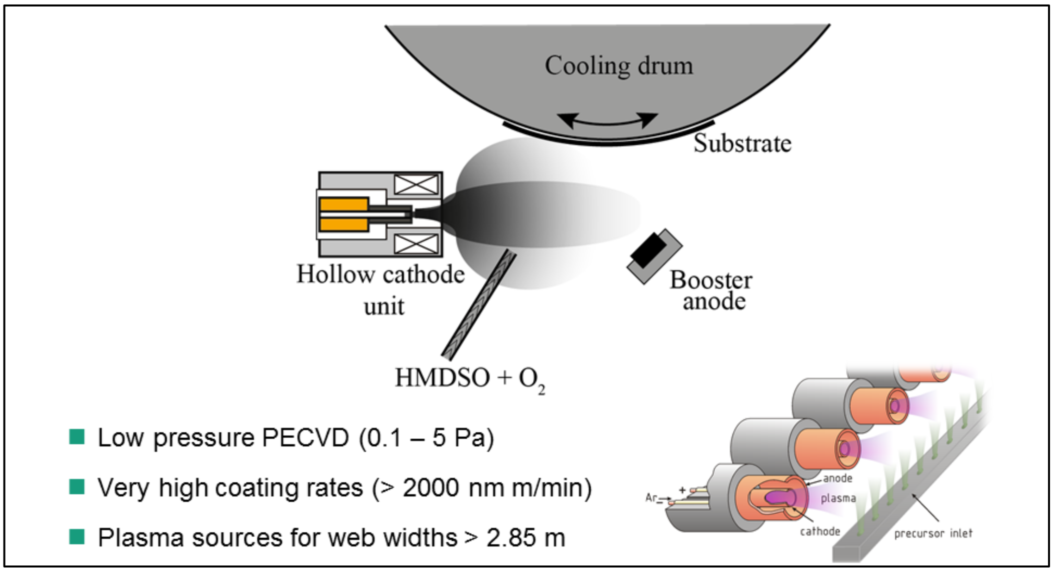

Figure 3: Principle of the arcPECVD technology, a high rate PECVD process based on hollow cathode plasma sources

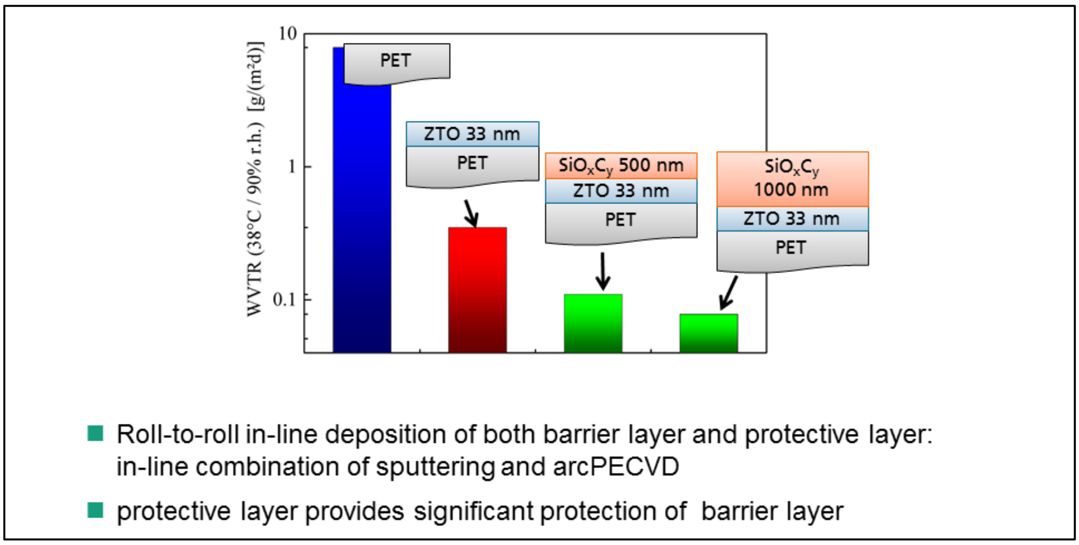

Figure 4: Protective coating on a barrier layer. The ZTO barrier layer has been deposited by sputtering. The SiO_xC_y layer has been deposited in-line by arcPECVD.

Advanced packaging films

Transparent barrier technology based on aluminum oxide has been on the market since several years. The number of installations has increased significantly and one can consider it as a well established technology. However, there is still a need for further development:

- for barrier films with advanced product quality (barrier, convertability)
- for a wider range of polymer films (including biopolymers)
- for retortable packaging

We have developed a technology that adds a plasma support to the AlO_x-process. This technology has been installed together with Applied Material WEB Coating GmbH in a TopMet® Clear HAD web coater.

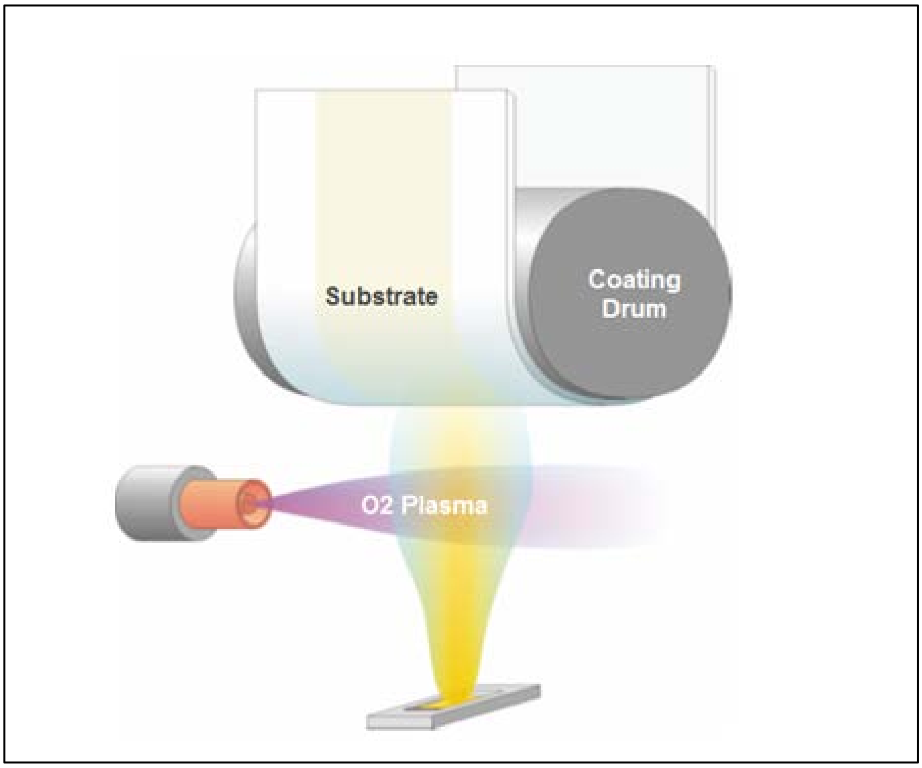

Figure 5: Plasma supported evaporation of AlO_X: HAD-AlOx technology

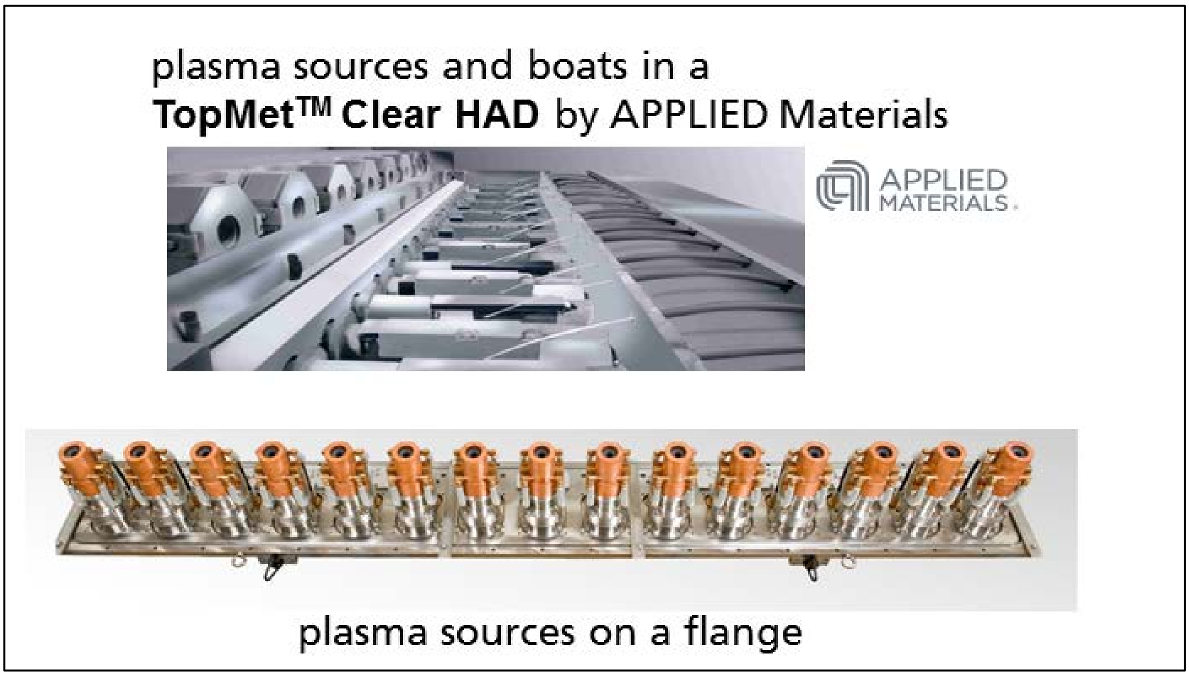

Figure 6: Plasma supported evaporation of AlO_X: HAD-AlOx technology

Substrate	Uncoated WVTR	Standard AlO_x WVTR	Plasma Assisted AlO_x WVTR	Uncoated OTR	Standard AlO_x OTR	Plasma Assisted AlO_x OTR
PET (12 µm)	40-50	≤ 0.7	**≤ 0.35**	100-140	≤ 1.6	**≤ 0.8**
BOPP (17 µm)	4-7	≤ 7	**≤ 0.30**	2000-2500	≤ 50	**≤ 35**

WVTR: Water Vapor transmission rate, measured in g(m² d) at 38°C, 90 % r. h.
OTR: Oxygen transmission rate, measured in cm³/(m² bar day) at 23°C, 0 % r. h.

barrier values may vary depending on substrate and process conditions

- Optical transmission ≥ 98%
  (measured inline during coating process)
- web speed 8 m/s

APPLIED MATERIALS

Source: Neil Morrison,
Applied Materials WEB Coating GmbH
Presentation at AMI Coral Springs, Florida, USA, 2017

Figure 7: Barrier performance on PET and BOPP, comparison between standard technology (without plasma support) and HAD-AlOx technology (with plasma support)

Polymer film type thickness		OTR [cm³/m² x d x bar] (23°C, 0 % r. h.)	WVTR [g/m² x d] (38°C, 90 % r. h.)
PLA	20 µm	25	25
CPP	20 µm	50	0.5
PE	20 µm	40	0.9

barrier values may vary depending on substrate and process conditions

- Optical transmission ≥ 98%
- web speed 8 m/s

Figure 8: Barrier performance of AlO_x layers on non-conventional polymer films (HAD-AlO_x-technology)

High barrier films for encapsulation of flexible electronics

There is an increasing need for high barrier films for encapsulation of flexible electronics. We have put a lot of focus not just developing new barrier layer stacks but in

- systematic investigation of roll-to-roll sputtering process including winding procedure
- development of substrate smoothing layer based on electron beam curable coatings

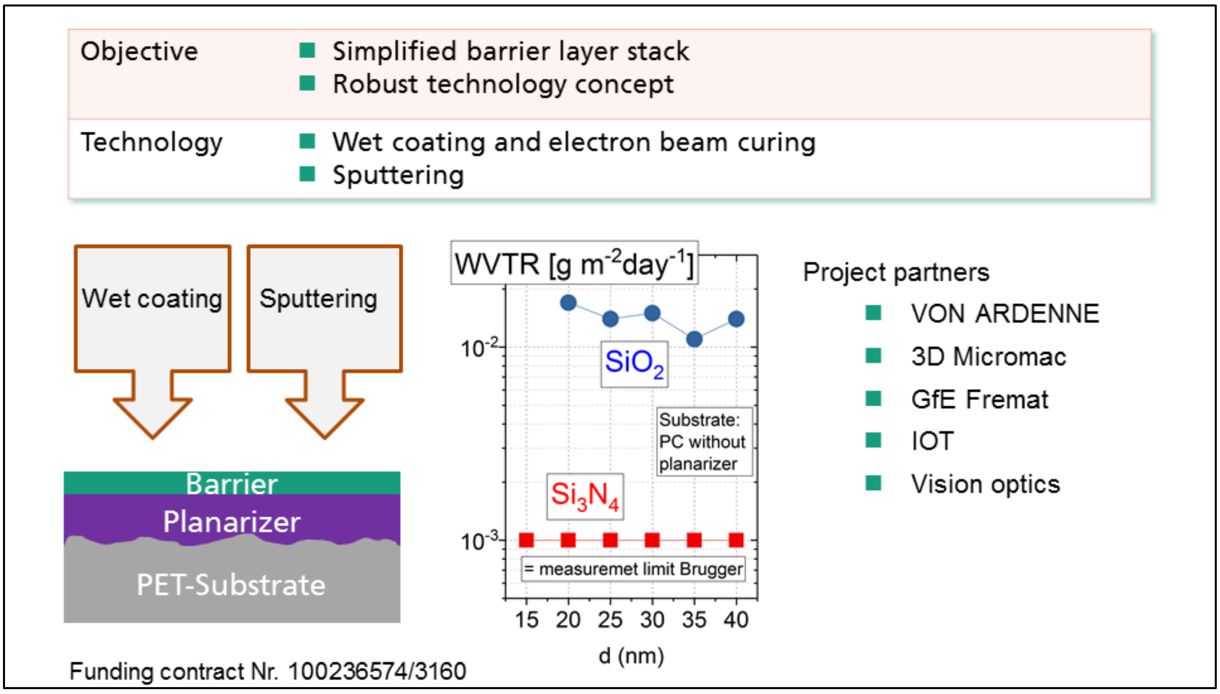

Figure 9: Objectives and concept of the project OPTIPERM
(Funded project by the European Union, contract nr. 100236574/3160

Flexible materials for batteries

Electromobility is pushing more and more into markets. At the same pace it becomes more and more clear, that batteries are still in the vast need of improvement with regard to technical parameters and of course with regard to cost. So, existing technologies need to be rethought and alternatives have to be considered. Vacuum thin film technologies can offer process alternatives for various parts of the battery. They can provide thin film deposition of a large variety of materials, with good quality and purity and a wide range of film thicknesses can be achieved. Possible applications range from thin conductive coatings for current collectors or thin metallic lithium anodes to silicon anodes and solid-state electrolytes.

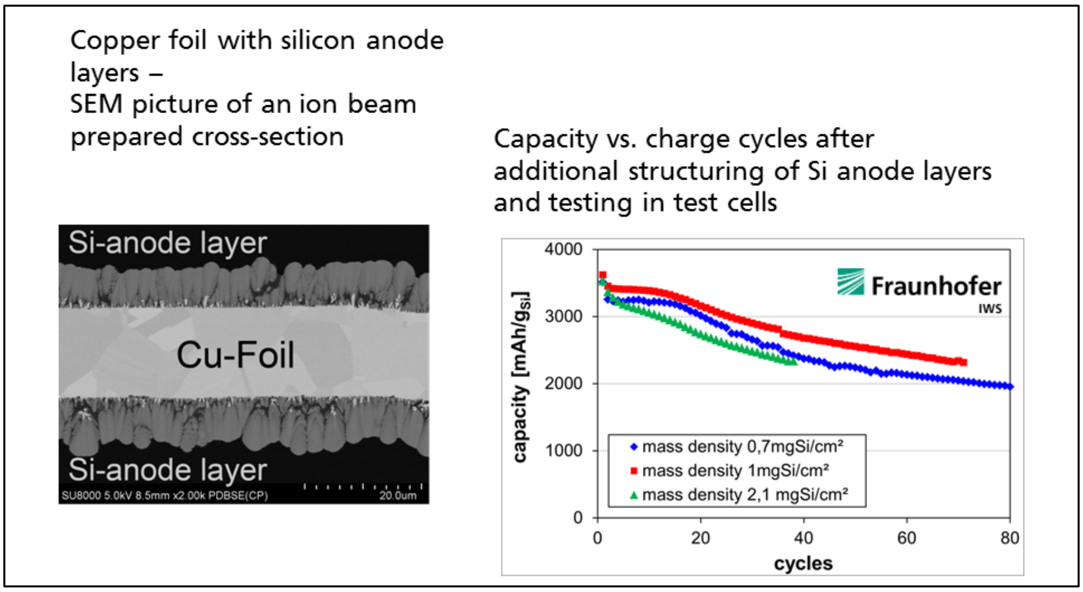

Figure 10: Si-anodes on copper foils, deposited by roll-to-roll vacuum processes, for lithium-sulfur batteries

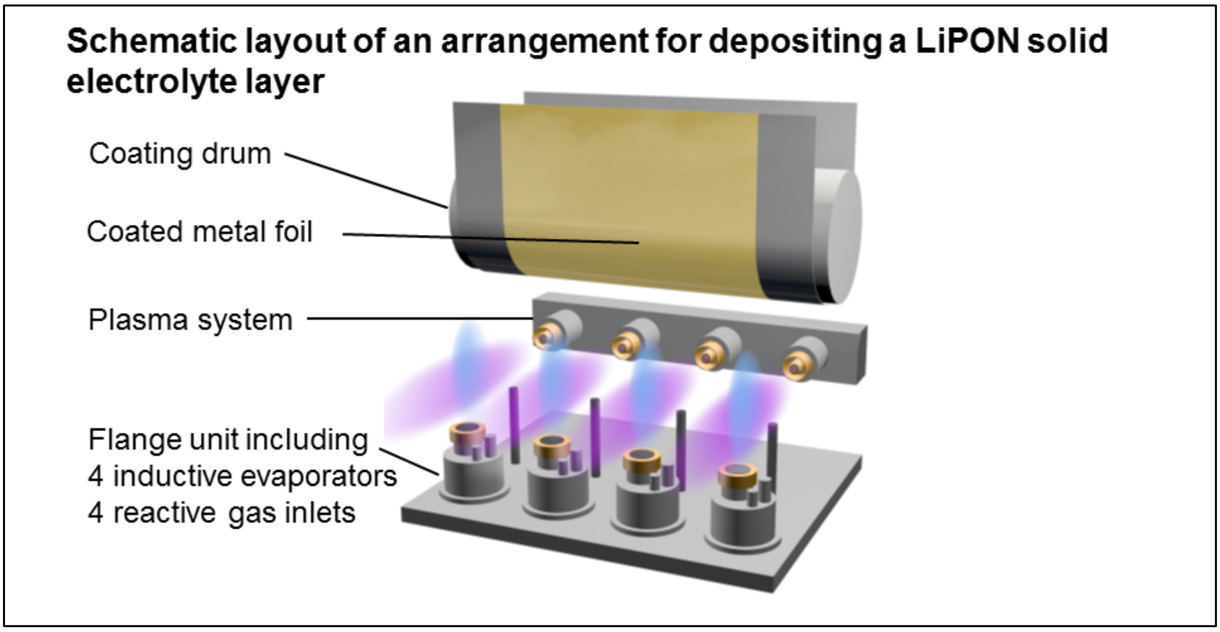

Figure 11: Concept for a vacuum thin film process to deposit LIPON solid electrolyte (Funded project ProSolitBat by BMBF /Federal Ministry of Education and Research, contract number 13N13236)

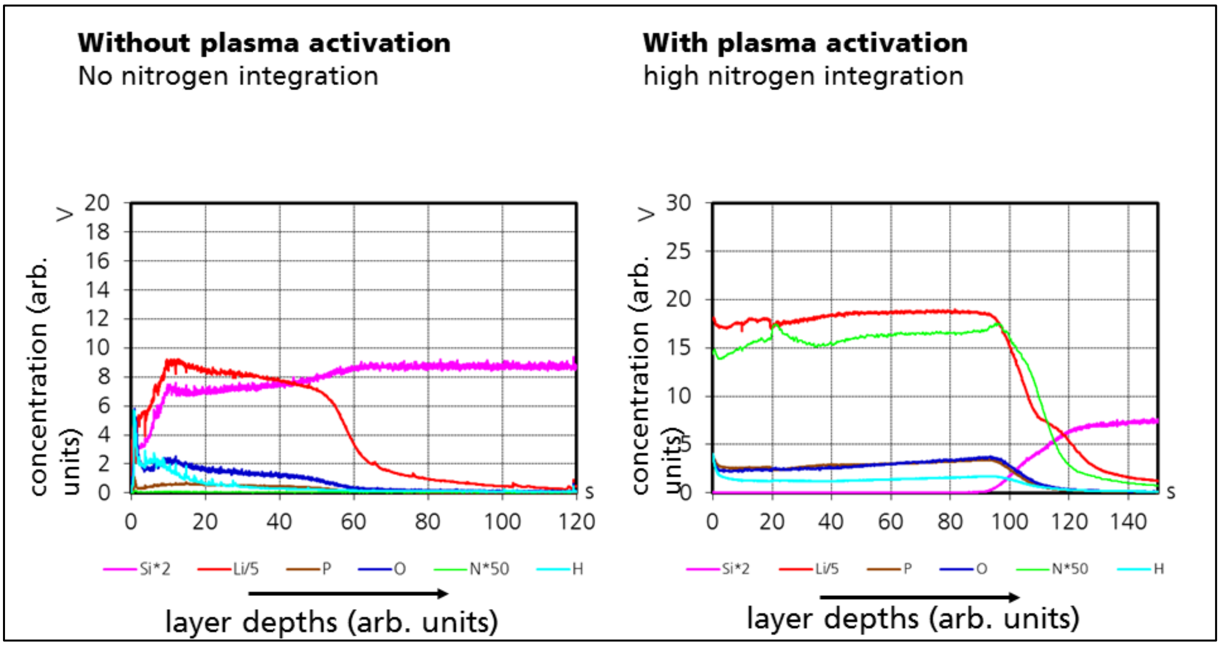

Figure 12: LIPON layers deposited by a plasma assisted vacuum coating technology. (Funded project ProSolitBat by BMBF /Federal Ministry of Education and Research, contract number 13N13236)

Functional films for architecture and outdoor use

Fluoropolymer webs and membranes commonly exhibit superior optical properties such as high transmittance over a broad wavelength range and very good outdoor stability. Therefore fluoropolymer films are used in architecture, e.g. in membrane roofs and facades in stadiums, shopping malls and airports or as front-side encapsulation for solar cells. However, thin film deposition on fluoropolymer webs – both in vacuum and at atmospheric pressure – faces several critical challenges comprising poor mechanical and thermo-mechanical properties –

especially low dimensional stability and low elastic modulus, high and textured surface roughness and low adhesion of thin layers.

We have developed a technology to deposit barrier layers on fluoropolymer webs. The unique mechanical properties of fluoropolymers require specific processing conditions for vacuum coating compared to commonly used substrates like PET and PEN – especially in roll-to-roll processing.

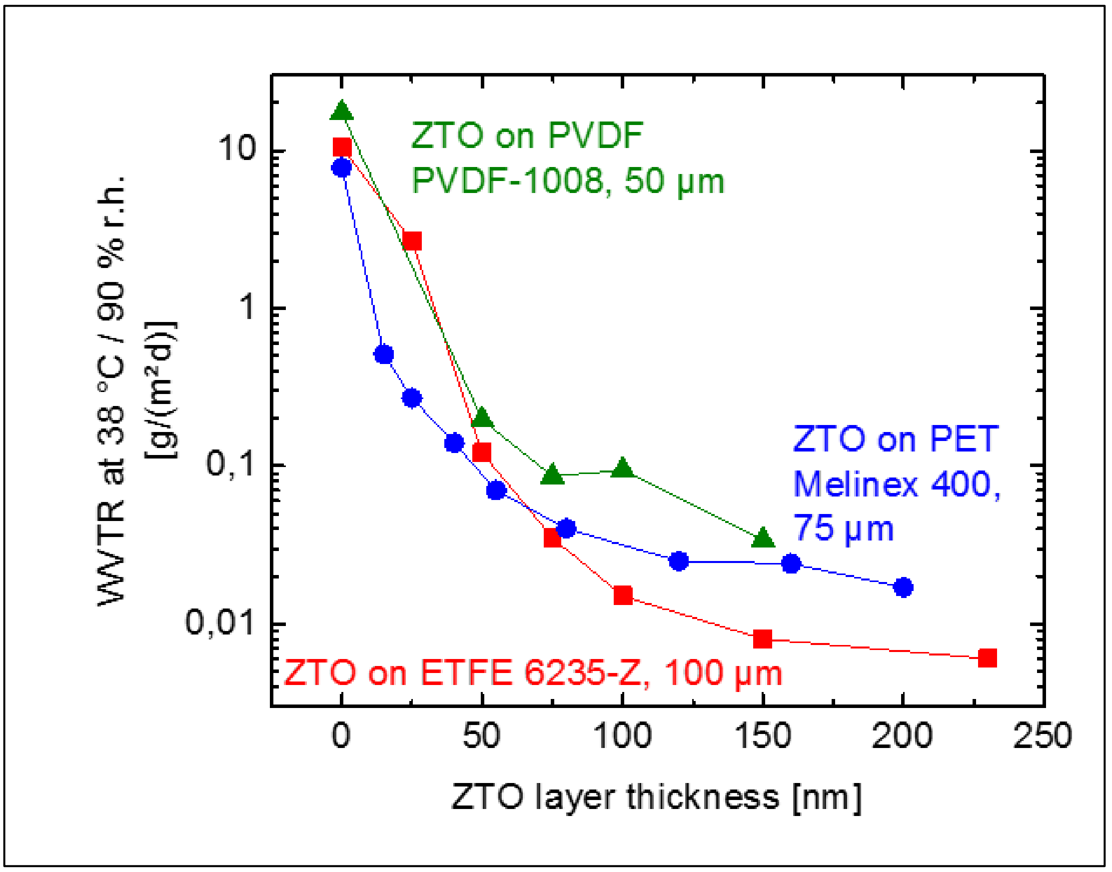

Figure 13: Water vapor transmission rate (WVTR) of barrier layers, comparison of fluoropolymers (PVDF and ETFE) with PET-film as substrate