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Interaction of polyamide 6 with galvanized steel and the influence of surface pretreatments

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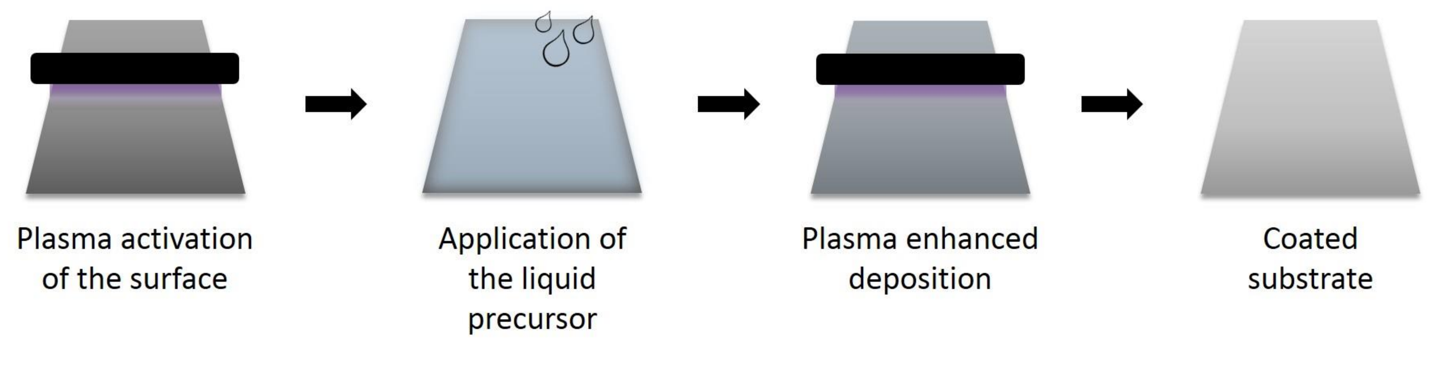
Introduction

Lightweight construction has been the subject of research for several years now and is more important than ever in the latest debate about saving greenhouse gases. A current trend is the use of multi-material systems, e.g. sandwich composites. These hybrid materials often consist of two metallic cover layers and a polymer core material. Under stress, such components often fail at the interface between the composite materials. In order to improve adhesion, the interface is therefore pre-treated physicochemically. In industry, this step is often time-consuming and not yet fully understood.

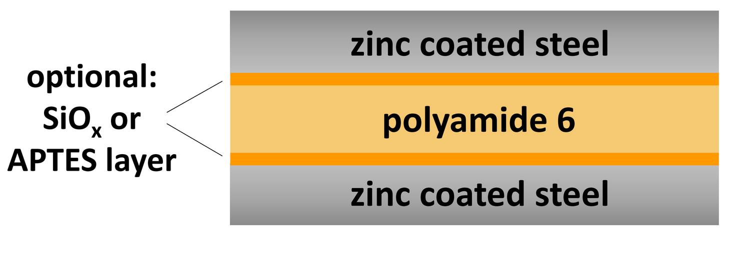
In this work the adhesion between a galvanized steel and polyamide 6 was investigated. In addition to an untreated zinc coating, a SiO_x layer and a conventional aminosilane-based adhesive were investigated with regard to their adhesion behaviour. The layers were each deposited in a modified plasma enhanced chemical solution deposition (PECSD) process. In addition, the influence of a subsequent air plasma treatment on the adhesion was studied. The adhesion was investigated mechanically using a T-peel test and the exposed fracture surfaces were studied microscopically (CLSM, AFM) and spectroscopically (XPS).

Experimental setup

Applying adhesion agent with a modified PECSD process:



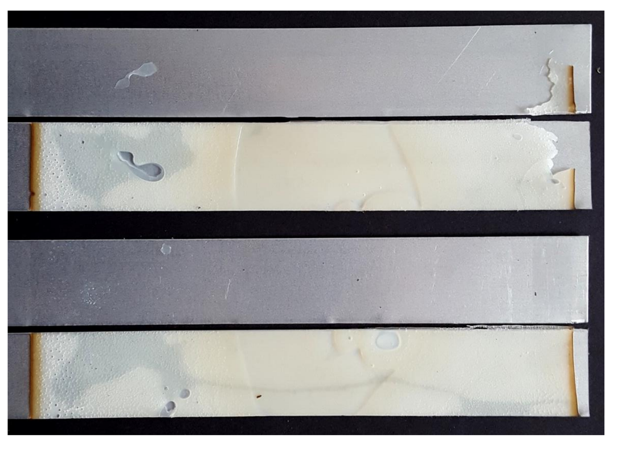
- Use of hexamethyldisiloxane (HMDSO) or (3-Aminopropyl)triethoxysilane (APTES) as liquid precursors
- Formation of a solid film of SiO_x or APTES
- Optional subsequent plasma treatment in air

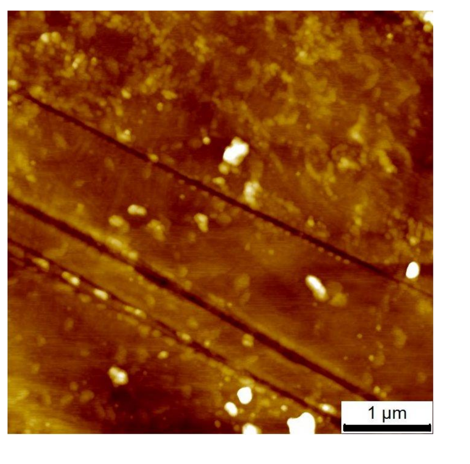


Preparation of sandwich composites:

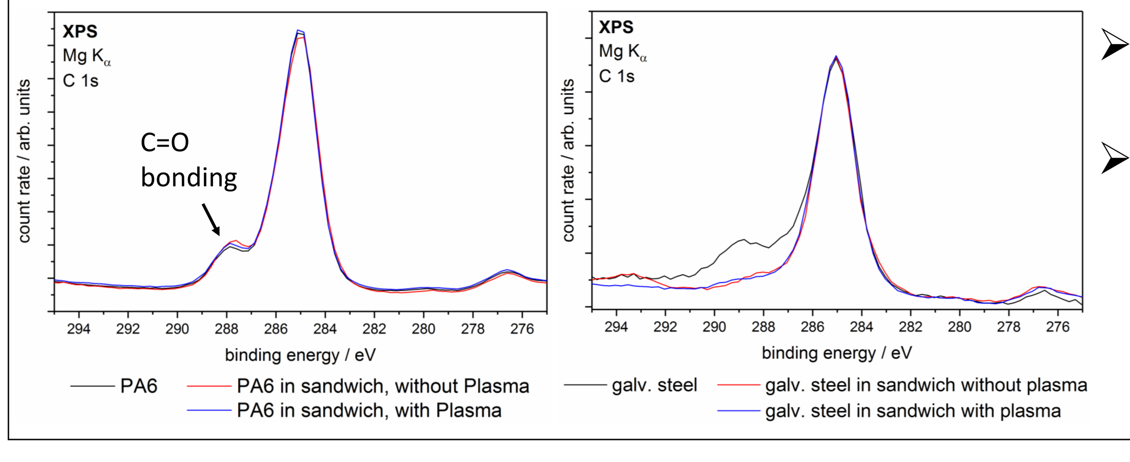
- Variothermal hot pressing process
- Pressing at 260 °C for 10 s at 7 bar.
- Cooling process first air-cooled, then water-cooled.

(I) Sandwich without adhesion agent



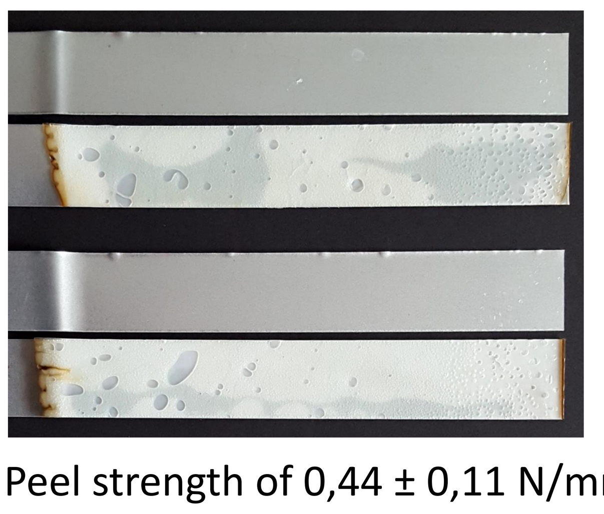


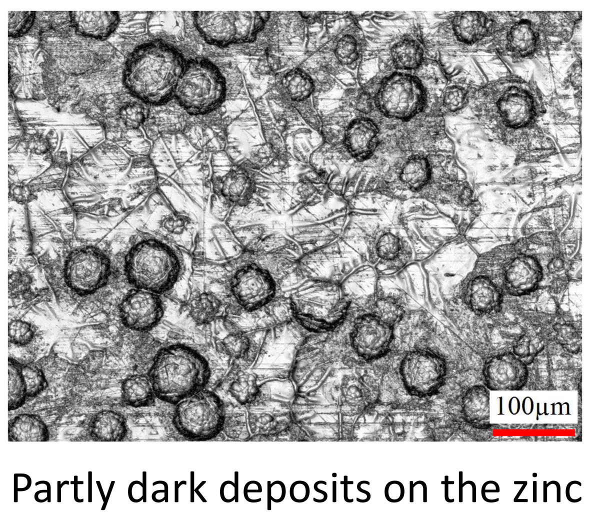
- Peel strength of 2,35 ± 0,24 N/mm
- Plasma treatment lowered the peel strength
- AFM indicates a thin film of PA6 on some parts of the zinc coating



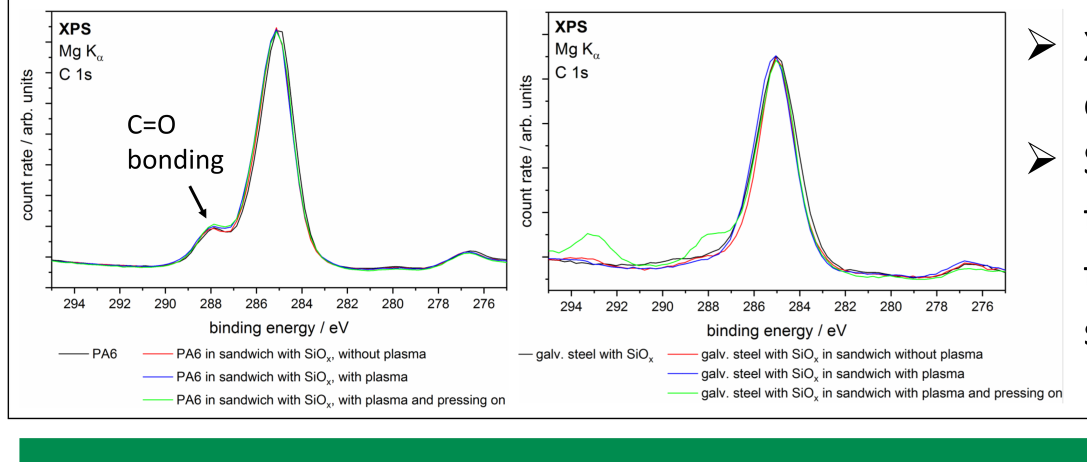
- No change of the polymer surfaces in XPS
- XPS shows small amounts of PA6 on the zinc coating

(II) Sandwich with SiO_x



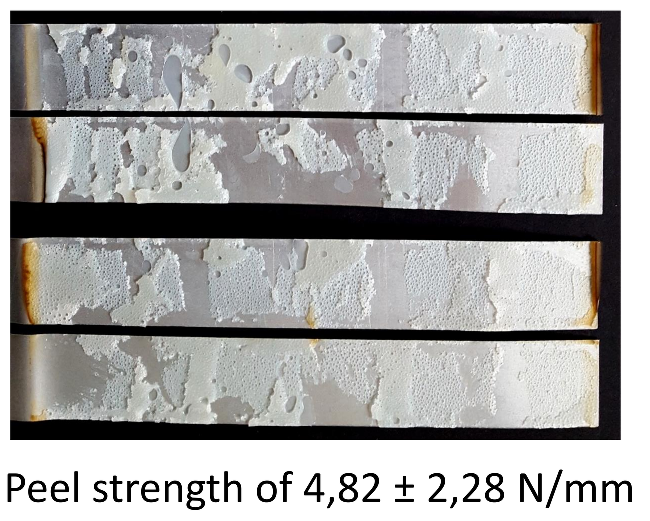


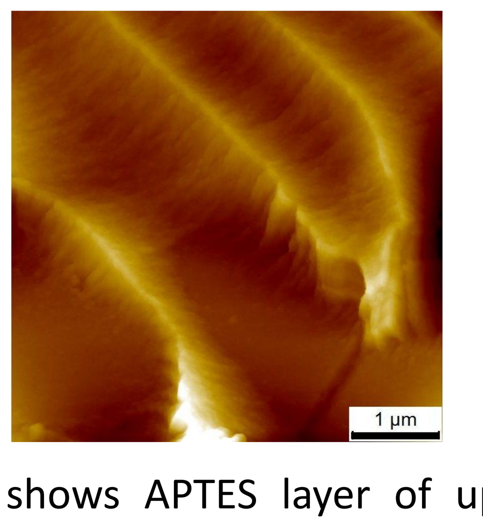
- Peel strength of 0,44 ± 0,11 N/mm
- Mainly adhesive failure
- Sandwich without plasma treatment was unstable
- Partly dark deposits on the zinc coating
- Only the plasma treatment leads to a change in topography



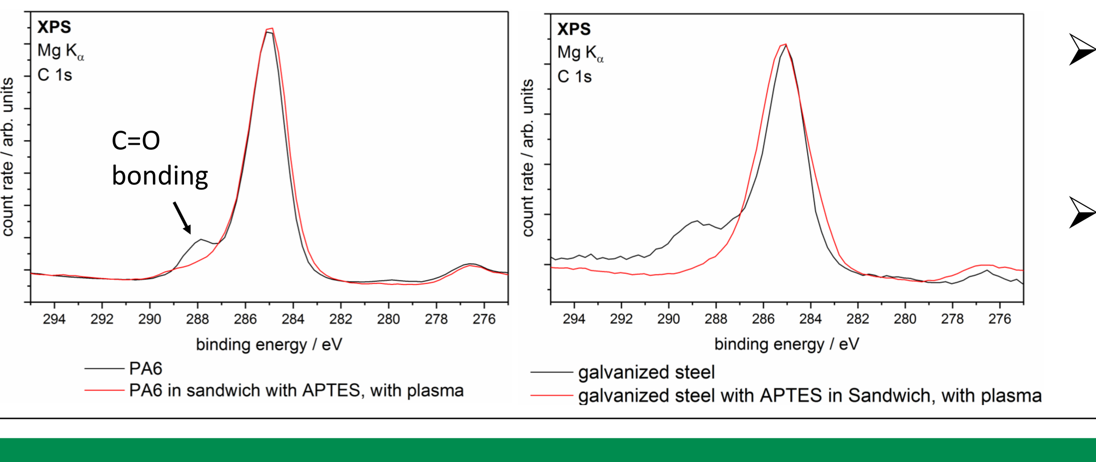
- XPS shows no differences on the polymer surfaces
- Sandwich with reduced time between plasma treatment and pressing shows adhesions of PA6

(III) Sandwich with APTES





- Peel strength of 4,82 ± 2,28 N/mm
- Adhesive and cohesive failure
- Adhesion at the interface is partly stronger than the core material
- AFM shows APTES layer of up to 200 nm on both surfaces
- Cohesive failure within the adhesive agent layer



- XPS indicates an APTES layer on the PA6 and the steel
- Probably formation of a chemical bonding to both substrates

Summary

- The SiO_x layer leads to low adhesion due to the lack of bonding to the organic substrate. It is not suitable as an adhesion agent.
- APTES forms chemical bonds to both substrates, achieves high adhesion and is well suited as an adhesion agent.
- The effect of the subsequent plasma treatment remains unclear. The activation of the surface via plasma shows a strong time dependence.

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Atom- und Molekülphysik an Oberflächen

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