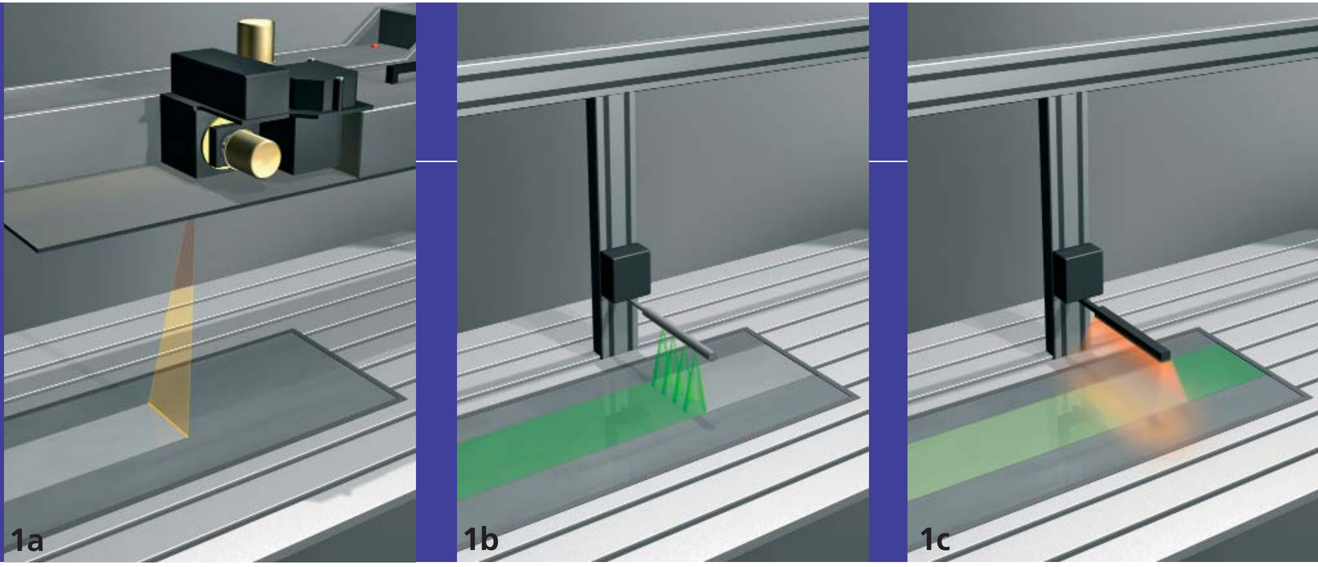


ORGANOPHILIC STRUCTURED METAL SURFACES FOR REPRODUCIBLE AND LONG-LASTING ADHESIVE BONDING

THE TASK

Many manufacturing industry branches strive for lightweight designs, energy efficiency and environmentally friendly processes. Examples include the automotive and aerospace industries which require the increased used of aluminum and titanium alloys to achieve their lightweight construction concepts. Adhesive bonding technology needs to achieve high initial bonding strengths but also enduring stability; especially when using cold curing adhesives. Reproducible bonding processes require surface preparation.

Conventional preparation processes for lightweight alloys are wet chemical techniques. More recently plasma and also laser processes are gaining momentum for this purpose in industry. Laser treatments are localized, work on nearly all materials and are scalable. Desired roughnesses and topographies are easily manufactured. The process is also dry and operates at high speeds in automated processing environments. As opposed to other techniques, no additional pre- and post cleaning steps are necessary.

Sometimes shipping, storage and other manufacturing processes introduce a delay between pretreatment and adhesive bonding. During this time the freshly cleaned metal surface interacts with environment and may get contaminated again. Thus the pretreatment effect is partially lost, and action is required.

OUR SOLUTION

A polymer film is deposited to preserve the quality of laser treated surfaces. Since the surface is laser treated the polymer film adheres very well. It interlocks mechanically with the surface but also chemically interacts with the metal oxide via functional groups.

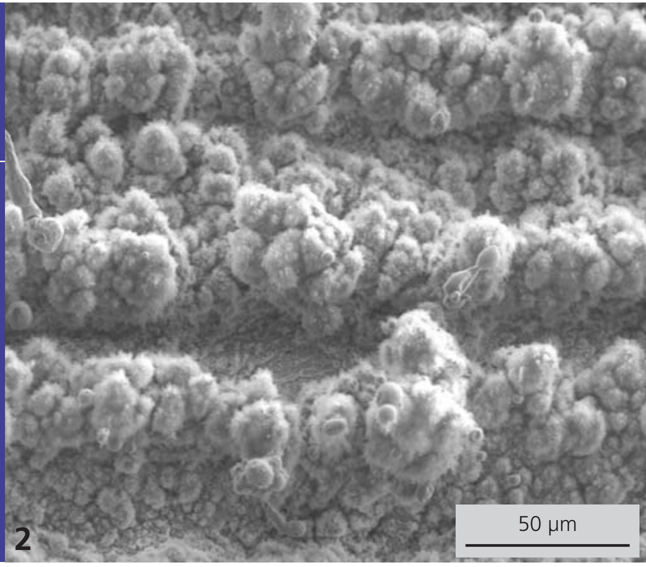
The reactive metal surfaces are dip-coated in or sprayed with water-soluble polyelectrolyte solutions. These consist of polyamines, -imines or carbonic acids. They dry quickly and protect the metal surface from atmospheric impact. The functional groups of the polymer later benefit the adhesive bonding process.

The complete process can be applied in series manufacturing as well as for manifold individual pieces.

RESULTS

The experiments were performed with various aluminum alloys. AW 5457 (AlMg3), a typical wrought alloy was used. Adhesives were energy saving 2K epoxy systems as well as hot curing 1K epoxies and epoxy bonding foils.

An Yb doped fiber laser was used in combination with a 2D scanner system and F-Theta optics to generate defined roughnesses on the aluminum surfaces (Fig. 2). The structuring increases the effective surface area and forms a fresh, thicker and structured oxide layer, which is ideal for adhesive bonding.



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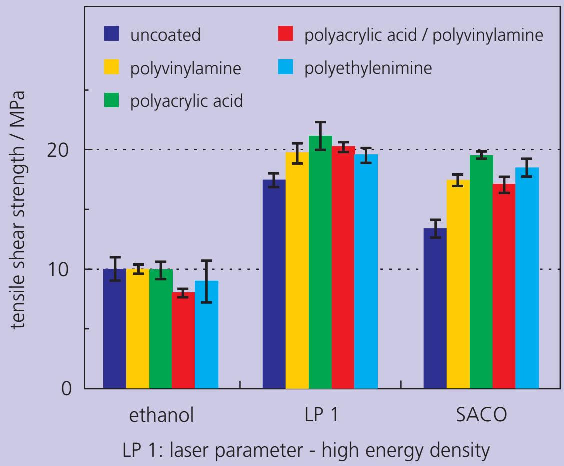
The coating is applied immediately after laser processing. Subsequent adhesive bonding increased the mechanical strength of the compound by up to 20 %, when compared to only laser processed samples (Fig. 3).

Tensile strength versus pretreatment conditions



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The coating effect becomes especially obvious when the samples were exposed to a 1000 h aging test. The coated samples show less strength reduction and a larger cohesive fraction when cross sections were examined. The increased cohesive fraction is caused by mechanical interlocking of the coating with the macroscopically roughened surface as well as the microscopic oxide structures in the metal surface. The chemical interaction of the coating with the functional groups of the adhesives plays a role as well. To simulate a storage process coated samples were aged for half a year under typical conditions. Then the samples were bonded.

The coated samples showed an increase of mechanical strength compared to coated samples that were not aged.

We also studied potential reactions between amine groups with the carbon dioxide in air. Coated samples were exposed to CO_2 for a longer period. No loss of mechanical strength was observed.

The two-stage pretreatment process is environmentally friendly, energy efficient and has no health risks associated with it. Lightweight metals and other materials can therefore be prepared for adhesive bonding without the risk of losing surface quality due to time delays.

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1 *Process schematics of the developed method (laser surface pretreatment, polyelectrolyte deposition and drying)*

2 *SEM image of a fiber laser structured AlMg3 surface*

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