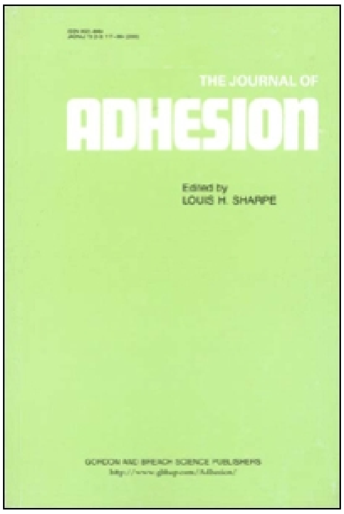

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Adhesion Between Metals and Polymers as a Three-Dimensional System

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Long Abstract

Adhesion Between Metals and Polymers as a Three-Dimensional System†

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KEY WORDS Adhesion; boundary layers; discontinuous phases; interface zones; interphases; oxide layers.

Adhesion science in a technical sense is the study of reactions in boundary layers. From a macroscopic point of view the result is the adhesive joint strength dependent on the magnitude of the adhesion forces without hints on the nature of these forces. So the question of the nature of adhesion has at least to be answered for technical applications by using other measurement techniques. From the microscopic point of view adhesion is of interdisciplinary nature, where molecules or atoms act with each other across the interface. Mainly adhesive bonds are based on these interactions of different bodies like metals and polymers or other material discontinuities. So far we can speak about a "chemical adhesion". But in practice there we realize a "technical adhesion" with more or less sharp discontinuities.

† This is the long abstract of a paper presented orally at the Tenth Annual Meeting of The Adhesion Society, Inc., Williamsburg, Virginia, U.S.A., February 22–27, 1986.

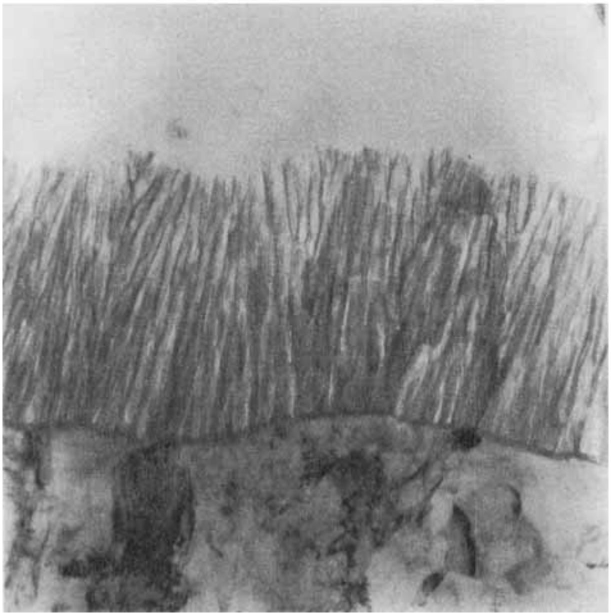

FIGURE 1 PAA-oxide layer with the Al-cladding, barrier layer and primer. Magnification 51,000×.

FIGURE 2 Ti-oxide layer with the Ti-surface and primer. Magnification 175,000×.

This aspect shall be described in terms of adhesive bonding in the aircraft industry, which in general means the joining of aluminium.

There we realize a composite containing the metal sheet with a rather ductile and deformable cladding of 99.5% pure Al. After a pretreatment process, *e.g.* Phosphoric Acid Anodizing (PAA), there is a dense barrier layer of aluminium oxide. Furthermore, there is the main oxide layer with a split top area Figure 1. The whole oxide layer is penetrated by a polymer, a primer or an adhesive. The oxide layer becomes a composite, a reinforced oxide. The properties of the resin in the oxide are still unknown, but the reactivity of the resin in the aluminium oxide is different from that of the bulk material. The interactions of the resin with the oxide can lead to a weak boundary layer above the oxide. The primer is filled with pigments which make the primer brittle, because it has to promote the adhesion and to reduce aging mechanisms and does not have to fulfil the mechanical aspects of the adhesive. At least there is the discontinuity between the primer and the adhesive.

All the different zones of adhesive Al-bonds are of different

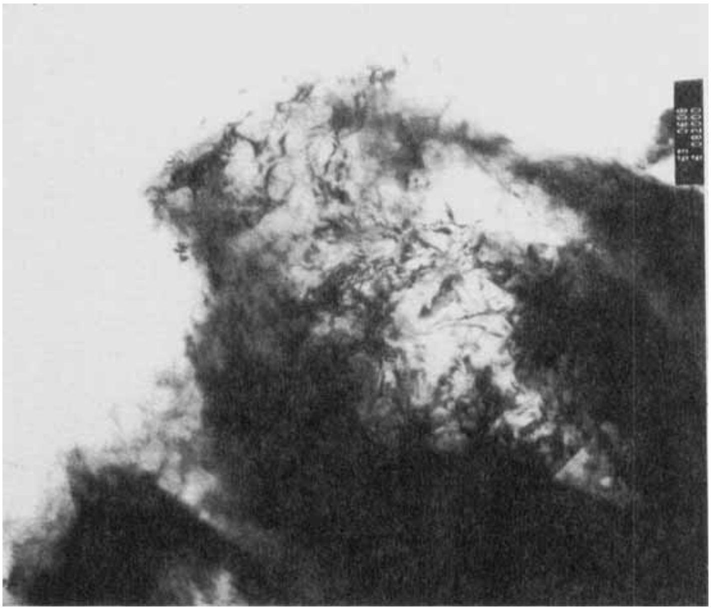

FIGURE 3 Steel–polymer-bond, no oxide is detectable. Magnification 82,000×.

elasticity and thickness—all together about 60 μm. It is a zone of different material discontinuities and all together they are adhesion in a technical sense. In other words, technical adhesion is the integral property of many single interfaces. This seems to be true not only for aluminium but also for many other metals, *e.g.* titanium and steel in perhaps a more limited fashion.

In titanium we commonly have bare material. By an etching process there results an oxide layer of about 3 nm, by an anodizing process about 60 nm, Figure 2. As a consequence there we have a technical adhesion zone of about 5 μm with less numbers of discontinuities. All mechanical conditioning factors have to be translated during this zone.

Much more critical is the situation in the case of steel bonds. Especially in C-steel there is nearly no oxide layer detectable, Figure 3. If no primer is used, we have a direct transition of mechanical requirements from joined part to the adhesive. In this case there is the highest stress concentration at a very sharp discontinuity.

The question arising from these facts is: Is it necessary to produce a rather large zone and many discontinuity phases between metal and polymer for a good bond?