Characterization of a-C:H layers on aluminum

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S.Onraet, W.P.Vellinga, M.Geers, J.Benedikt, M.v.d.Sanden, C.Schrauwen
Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, the Netherlands

Introduction

Plasma-deposited Amorphous Hydrogenated Carbon layers: a-C:H, are studied to replace hard chromium or anodised layers to protect aluminum surfaces
Mechanical parameters are retrieved from nano-indentation and tensile testing.

Deposition set-up

a:C-H layers are made on aluminum by an expanding plasma technique [1]. See Figure 1

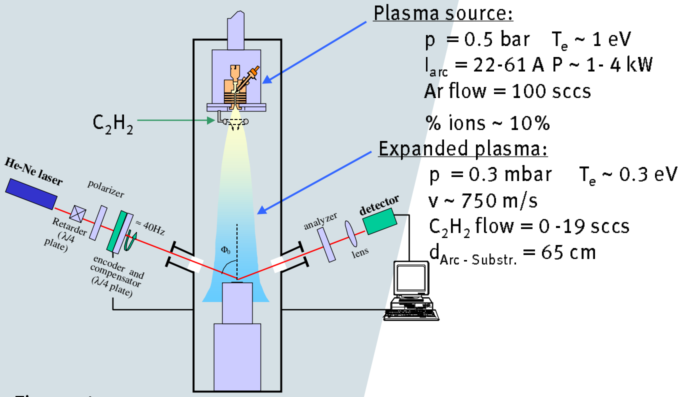

Figure 1 *Deposition Set-up*

Principle

Interaction of C_2H_2 with Ar^+ results in its ionization and subsequent dissociation/recombination:

$$Ar^+ + C_2H_2 \rightarrow Ar + C_2H_2^+$$
$$C_2H_2^+ + e^- \rightarrow C_2H^\bullet + H$$
$$\rightarrow CH^\bullet + CH^\bullet$$
$$\rightarrow C_2 + H_2$$
$$\rightarrow CH_2^\bullet + C$$

Dense, hard coatings are obtained with the highest $C_2H^\bullet$ concentration (plasma containing as much Ar^+ as C_2H_2) Critical-Loading[1]. Deposition temperature will play a dominant role in the residual stress, due to the difference in thermal expansion coefficients. Below the stability range, tensile stress will lead to cracking, while above, compressive stress will generate buckling.

Characterization

Hardness and E modulus can be retrieved from nano-indentation measurements (Berkovich indenter).

	E(GPa)	Hard.(GPa)
Uncoated Al *(Al 6063-T6)*	92±10	1.7±0.4
a-C:H *(critical loading- 1 μm- 150°C dep. Temp.)*	92±10	10±2

While, Al mainly deforms plastically, a-C:H layers deform mostly elastically until cracks and delamination occur.

We are presently trying to retrieve mechanical parameters, such as E modulus and critical loading conditions, from the failure behaviour of layers.
Tensile tests are performed under optical microscope.
Initiation and interaction of cracks, delamination and buckling can then be followed. See Figure 3

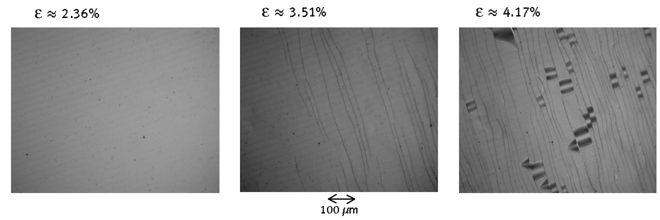

Figure 3 *Layer under tensile stress (←pulling direction→)*

A correlation length (required distance for the stress to build up in the coating) can be defined that will influence the crack interaction: $\xi=[E_i/h_i*(1/(h_cE_c)+1/(h_sE_s))]^{(-1/2)}$
with h: height of surface(s), interface(i) and coating (c).
⇒Mean length between cracks against strain plots give us an insight in ξ as well as an idea of the order in the coating. See Figure 4

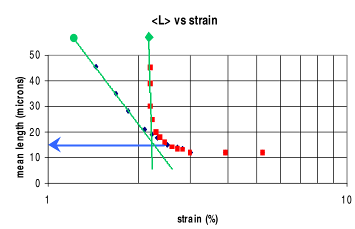

Figure 4 *<L> vs strain*
low disorder
higher disorder
$\xi \approx L$ for L

Thus allowing to compare coatings. See Figure 5.

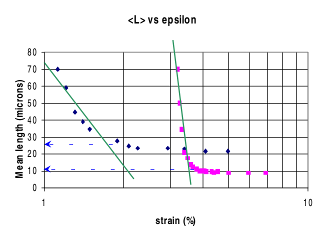

Figure 5 *Coatings with the same thickness and deposition temperature.*
♦ Diamor layers (kindly provided by FhG-IWS, Dresden, D) have a higher correlation length and more disorder than ■ layers from the expanding thermal plasma set-up.

The critical external load when buckle will start can be estimated using the Euler column shape model [2]:
$\sigma_c=(\pi^2E_ch_c^2)/(3l_d^2[1-\nu])$ with l_d:delaminated length

Conclusions

⇒ a-C:H layers show a pronounced elastic behavior.
⇒ Important parameters such as E and critical buckling load can be estimated from ‹L› vs strain plots.

This study is financially supported by the Dutch ministry of economic affairs (project IOT 97002)

/ department of mechanical engineering

References:
[1] Plasma Beam Deposition of Amorphous Hydrogenated Carbon – J.W.A.M. Gielen PhD Thesis (ISBN 90-386-0099-2) – Chap2.3
[2] B. Audoly, *Stability of straight delamination blisters*, Physical review letters , vol. 83, number 20, November 1999