

Characterization of a-C:H layers on aluminum

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Characterization of a-C:H layers on aluminum

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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

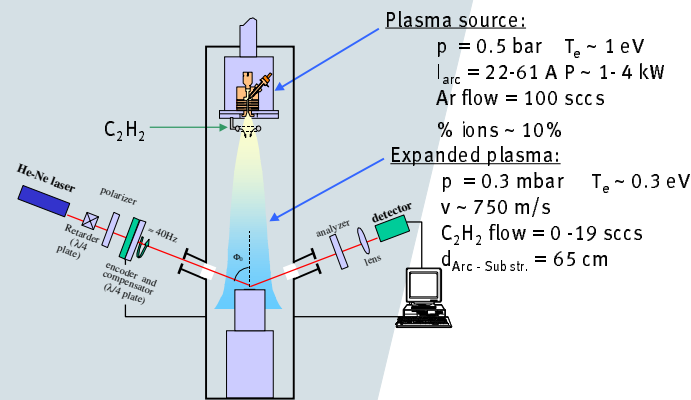
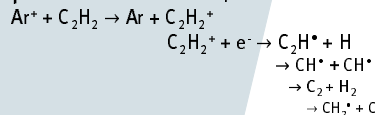


Figure 1 Deposition Set-up

Principle

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



Dense, hard coatings are obtained with the highest C_2H^+ 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.

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/ department of mechanical engineering

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

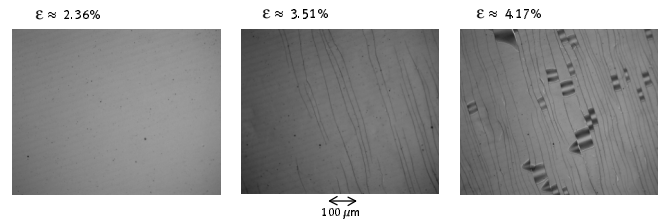


Figure 3 Layer under tensile stress (←pulling direction→)

A **correlation length** (required distance for the stress to build up in the coating) can be defined that will influence the crack interaction: $\xi = [E_i/h_i^*(1/(h_c E_c) + 1/(h_s E_s))]^{(1/2)}$ 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

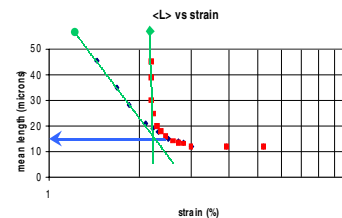


Figure 4 <L> vs strain
 ◆ low disorder
 ◆ higher disorder
 $\xi \approx L$ for L

thus allowing to compare coatings. See Figure 5.

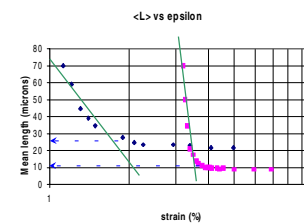


Figure 5 Coatings with the same thickness and deposition temperature.
 ◆ Diam or layers (kindly provided by FhG-IWS, Dresden, D) have a higher correlation length and more disorder than ■ layers from the expanding thermal plasma set-up.

The critical external load when buckle will start can be estimated using the Euler column shape model [2]:

$$\sigma_c = (\pi^2 E_c h_c^2) / (3l_d^2 [1-\nu]) \quad \text{with } l_d: \text{delaminated length}$$

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.

References:

- [1] Plasma Beam Deposition of Amorphous Hydrogenated Carbon – J.W.A.M. Gielen PhD Thesis (ISBN 90-386-0099-2) – Chap.2.3
- [2] B. Audoly, *Stability of straight delamination blisters*, Physical review letters, vol. 83, number 20, November 1999