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Amorphous Hydrogenated carbon layers on Aluminum

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Introduction

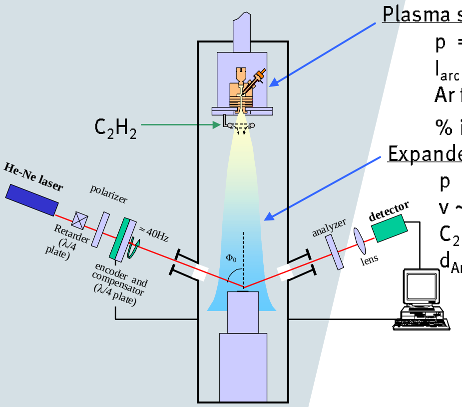
Hard chromium or anodised layers are often used to protect Aluminum surfaces. However, in high temperature applications (e.g. 150°C), these layers show a detrimental loss of hardness and tribological properties.

As a result, coatings that can keep their properties under such conditions are of high interest. We are presently focusing on amorphous hydrogenated carbon layers:

a-C:H

Deposition set-up

a:C-H layers are currently deposited via an expanding plasma technique: a sub-atmospheric argon (Ar) plasma is created in a cascaded arc source and expands into a chamber at low pressure where a hydrocarbon monomer (acetylene: C_2H_2) is added. See Figure1



Plasma source:
$p = 0.5$ bar $T_e \sim 1$ eV
$I_{arc} = 22$-61 A $P \sim 1$- 4 kW
Ar flow = 100 sccs
% ions ~ 10%

Expanded plasma:
$p = 0.3$ mbar $T_e \sim 0.3$ eV
$v \sim 750$ m/s
C_2H_2 flow = 0 -19 sccs
$d_{Arc\text{ - }Substr.} = 65$ cm

Figure 1 *Deposition Set-up*

Principle

In the expansion zone, the interaction of C_2H_2 with Ar^+ results in its ionization and subsequent dissociation/ recombination:

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

In order to form dense, hard coatings, $C_2H^\bullet$ radicals are needed [1]. The highest $C_2H^\bullet$ ratio is obtained when the plasma contains as much Ar^+ as C_2H_2 molecules. This situation is called: Critical-Loading. Under-Loading corresponds to a plasma with less C_2H_2 than Ar^+, thus further recombination can take place. With Over-Loading conditions, C2H2 are present in the layers.

Characterization

➪In-situ

Substrate temperature control [20-250°C] and ellipsometry measurements are performed during the deposition process. Ellipsometry is based on the measurement of the change in the state of polarization of a polarized light beam after reflection on a surface with a growing layer. See Figure1

This technique allow us to determine the refractive index (n), the extinction coefficient (k) and the thickness of the layer [0,5 - 1 μm].

➪Ex-situ

- Hardness and Young's modulus are retrieved from nano-indentation measurements at room temperature. A Berkovich indenter is used.

While uncoated Al mainly deforms plastically, a-C:H layers deform mostly elastically until cracks and delamination occur. See Figure 2

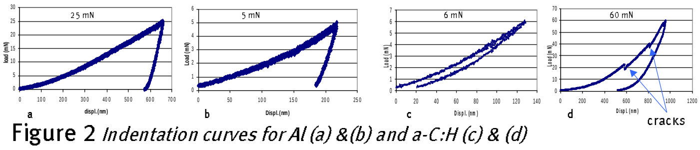


Figure 2 *Indentation curves for Al (a) &(b) and a-C:H (c) & (d)*

Results

	E(GPa)	Hard.(GPa)	n
Uncoated Al (Al 6063-T6)	90	1.5	1.4
Al/a-C:H (under loading)	40	2.5	1.95
Al/a-C:H (critical loading)	90	10	2.3
Al/a-C:H (over loading)	60	6	2

The refractive index (n) of the layer appears to be a good indicator of its hardness since there is a monotonic correlation between the two parameters [1].

- Tensile tests have been carried out on 2mm thick Al with and without a 1μm a-C:H layer. The layer drastically improves the load bearing from the system, see Figure 2 but shows, nevertheless, a poor adhesion. See Figure 3

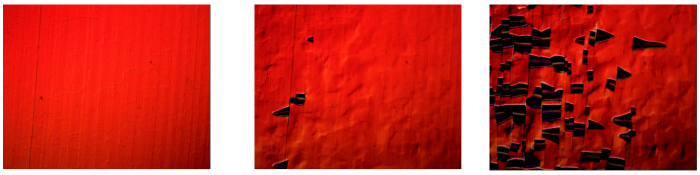


Figure 3 *Layer under tensile stress (⟵pulling direction⟶)*

Conclusions

Tuning of the deposition parameters allows to drastically modify the layers: from soft polymer-like (under-loading) to hard and more brittle ones (critical → over-loading).
Improvement of the layer adhesion is needed. NiP interlayers of various thicknesses will be investigated.

References:
[1] Plasma Beam Deposition of Amorphous Hydrogenated Carbon – J.W.A.M. Gielen PhD Thesis (ISBN 90-386-0099-2) – Chap2.3

/ department of mechanical engineering