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# Adhesion measurement of Cu thin films on polyamide and polypropylene substrates

A. L. Gasparin[(1)*], I. J. R. Baumvol[(1,2)], A. P. Umpierre[(1)], A. E. Crespi[(1)], F. Cemin[(1)], R. C. R. Nunes[(1)] and C. Giacomelli[(1)],

[(1)]UCS, Universidade de Caxias do Sul, e-mail: algaspa1@ucs.br
Programa de Pós-Graduação de Materiais, Universidade de Caxias do Sul, Caxias do Sul, Rio Grande do Sul 95097-470, Brazil
[(2)]UFRGS, Universidade Federal do Rio Grande do Sul, e-mail: israel@if.ufrgs.br
Instituto de Física, Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul 91501-970, Brazil
* Corresponding author.

**Abstract** – Thin solid copper films were evaporated on polymer surfaces by ion plating process. The polymers chosen as substrates in this work were polyamide – PA (polar) and polypropylene PP (non polar), and the adhesion measurement was done by pull strength. The film thickness was found to dictate the adhesion strength of surface films, with thick films being released more easily than thin counterparts. It is also demonstrated that the use of glues to connect surface film to the pull-off pin may well produce artifacts, potentially leading to overestimated adhesion strengths. For the pull strength test, a device was especially constructed for this work. The higher adhesion forces were observed for Cu/PA systems.

Thin solid copper films were deposited on polypropylene homopolymer (PP) and polyamide 6 (PA 6) substrates by physical vapor deposition method (PVD) using an electron gun under $10^{-5}$ mbar pressure. Whilst metallic films have been usually deposited on polyethylene terephthalate (PET) [1] and polyimide (PI) [2], polyamide (PA) and polypropylene (PP) were chosen in the present case in order to highlight the effect of surface chemical composition on the adhesion strength. In fact, such a comparison is not usually made, and one single polymer only is used. Concerning the measurement methods, adhesion tests can be carried out by Peel strength, which is an indirect method [3]. The pull off strength method, on the contrary, is a direct approach that allows for the establishment of normal stress and substrates polarity relationship.

Within this context, a device was constructed for the pull strength determination as showed in Figure 1. The pull off pin was joined to the thin film surface using two different adhesives: liquid glue (acrylic based) and solid tape (TRANSFER TAPE 9469 – 3M). The stress obtained using the solid tape for Cu/PP system was 0.54 MPa while using the liquid glue a value of 0.97 MPa was recorded for the same film and substrate. These apparently discrepant results may have strong implications for the design and application of such composite films. It is worth noting that both adhesive methods have been regularly used in laboratory and in industry, but this subject has not been carefully discussed so far.

Metallic depositions of different thicknesses were also studied in order to investigate whether liquid glue affects the mechanical characterization. Experiments were performed by comparing the attenuated total reflection infrared spectrum (ATR-IR) of each polymer with that characteristic of glue material and the area where the thin film of each polymer was pulled off. It was observed that the glue could pass through the 85 nm-thick film barrier, whereas for 495 nm-thick films the spectra did not show the presence of the adhesive material on the polymer. The remaining copper concentration on the substrates which were pulled off, and the films thicknesses, was measured by Rutherford Backscattering (RBS) technique.

Furthermore, the area pulled off during the tests is of utmost importance, since the stress can be dictated by such parameter. Whenever there is a circular area with the same diameter of the pull off pin or the pin is adhered to a rectangular film larger than the pin contact area, some non-negligible differences are likely to appear. This behavior is shown in Figure 1. The stress analysis in both cases showed a lower stress of approximately 40% when the film has the same area as the pull off pin, compared to the rectangular film.

Polymer-metal film adhesion was determined by pull strength to obtain normal stress data that can be used as a parameter to evaluate the interface energy through the area below the stress *versus* strain curve. Low surface polarity of polymers like PP provides poor adhesion to most coatings [4]. Figure 2 shows the results of uniaxial load *versus* displacement, which proves that the polar polymer (PA) has higher adhesion to copper than the non-polar polymer PP.

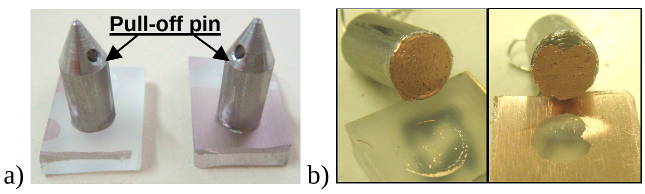


**Figure 1:** Illustration of the device used in pull strength determination, before (a) and after (b) test.

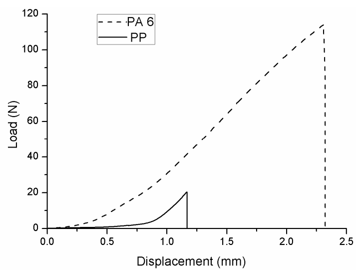


**Figure 2:** Pull strength of copper films evaporated onto polypropylene and polyamide,

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