

Laminated composite on the basis of plasma modified PTFE films and thin aluminum layers

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The treatment in low-temperature plasma is an effective method of the improvement of adhesive strength of the polymer/metal interface. It is well known what PTFE has unique chemical and physical properties: it neither swells nor dissolves in common solvents; is resistant toward oxidants, acids, and alkalis and exhibits good dielectric properties over wide temperature and frequency ranges. However, some applications concerning the use of PTFE as an engineering material demand the improvement of the contact properties. This task is highly important in practice. Earlier we showed that the modification of the PTFE films under conditions that ensure the separation of the discharge active species acting on the polymer materials make it possible to achieve substantially lower values for the contact angle and higher values for the surface energy than the case of other modes of discharge [1]. For example, θ value of water was 33° or 49° after modification at the anode or cathode, respectively, and the total surface energy increases from 13.18 to 61.5 or 50.7 mJ/m², respectively. These findings open the possibility for resolving the applied problem of manufacturing multilayer composite materials, including nanosized metal layers and thin PTFE films, which is important for electrical engineering and electronics.

PTFE films of 50 μm thickness (RF State Standard 24222-80) were used. The procedure for film modification in dc discharge is detailed in [2]. Film samples of 40 x 120 mm dimensions were mounted on the anode and treated on both sides in the alternating mode. The processing was run in the flow mode at a working gas

(air) pressure of ~ 20 Pa and a discharge current of 50 mA for 60 s. TO prepare a multilayer composite material, aluminum layers (of 100 nm thickness) were deposited by vacuum evaporation onto both sides of plasma-modified PTFE film in a VUP-4 device according to the scheme depicted in the figure. The thickness of the coating was controlled by varying the deposition time, and a calibration curve for determination of the Al layer thickness was obtained by the goniometric technique using a MII-4 microinterferometer.

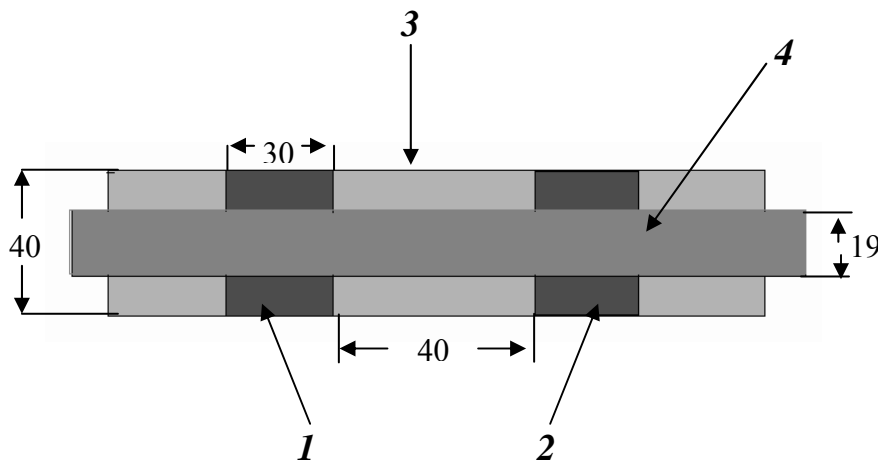


Figure. Schematic of the specimen for the measurement of adhesion (top view): (1, 2) Al layers deposited by vacuum evaporation, (3) PTFE film modified at the anode in dc discharge, and (4) Scotch®810 tape.

To appreciate the adhesion characteristics of the laminated composite material, we developed a peel resistance (A) measurement procedure, the T-peel test with the use of a Scotch® 810 adhesive tape (ASTM D3359-02) [3]. The T-peel testing of the obtained composite samples was performed on a Shimadzu Autograph AGS-10 KNG universal testing machine at a crosshead speed of 100 mm/min. As a result of the experiments, a curve reflecting a change in the peel resistance (A) along the sample length was obtained. Peeling was performed successively on one (layer 1/PTFE) and the other (PTFE/layer 2) side of the composite material. The experimental data were averaged over 3 sets of 5 specimens each; the results are given in the table.

Peel resistance (A) for specimens of the 100-nm Al (layer 1)/PTFE/100-nm Al (layer 2) multilayer composite material

Set	Joint measured	A , N/m		
		(1)-(4)*	(2)-(4)*	(3)-(4)*
I	Layer 1/PTFE	312±8	304±6	188±6
	PTFE/Layer 2	390±9	384±9	243±5
II	Layer 1/PTFE	315±5	321±8	190±5
	PTFE/Layer 2	380±6	370±11	208±5
III	Layer 1/PTFE	294±11	306±5	198±8
	PTFE/Layer 2	363±7	368±8	271±9

* The numbers refer to the joints as shown in the figure.

It was established that the A value for the first peel (layer 1/PTFE) is smaller than that for the second one (PTFE/layer 2), and the values of A averaged over all runs of the 3 sets are 308 ± 12 and 377 ± 13 N/m, respectively.

However, according to the concept of adhesive-layer failure mechanism [4], the peel resistance must be identical in the first and second cases despite the fact that the Scotch® 810 tape (55 μm thickness) is peeled off the PTFE/ Scotch® 810 composite (105 μm thickness) in the former case and from the PTFE films (50 μm thickness) in the latter case. The reason for the real resistance to be identical in both cases is that the thickness of the adhesive layer is the same. The results obtained in this study can be explained in terms of formation of charged states under the peeling of composite material [4]. Therefore the charge generation during the first peeling leads to the polarization of PTFE/layer 2 contact and to the increase of A value during the second peeling of layer 2 from PTFE film.

Thereby the DC discharge modification of PTFE film surface make it possible to obtain laminated composites on the basis of plasma modified PTFE films and thin aluminum layers with high interlaminar adhesion.

References

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