Image Analysis of the Cavitation Process in Pressure Sensitive Adhesives

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Pressure sensitive adhesives (PSAs) are viscoelastic or viscoplastic materials that adhere to a substrate upon the application of light pressure[1]. A well known example of a PSA is the sticky layer on Scotch® tape. A good PSA is obtained when the material has a liquid-like behavior to create easily a molecular contact and dissipate energy upon debonding, and an elastic behavior to resist shear forces over long times. This dual property is especially important on rough surfaces and low energy surfaces.

Although recent advances in mesoscale modeling of the rheological properties of PSAs have greatly improved our knowledge about the bulk behavior of such materials[2], the debonding mechanism is essentially an interfacial process and it is still poorly understood. In fact, the detaching of PSAs is due to different phenomena, such as the creation of cavities and fibrils, the propagation of interfacial cracks and the lateral invasion of air fingers into the sample.

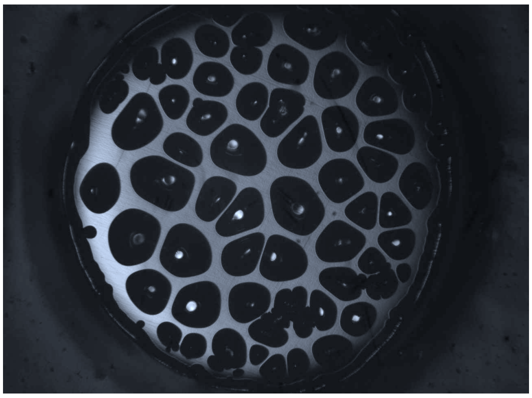

FIG. 1. Top view of the probe tack experiment. The PSA material is transparent and the black regions are the interface of the cavities.

The studies of adhesive performances of these materials are efficiently carried out through the so-called probe tack tester. In this test a flat ended probe (of a diameter of 10 mm) is brought in contact with a thin adhesive layer and is then removed at a controlled velocity[3]. Typically, force versus displacement curves are measured and the adhesion energy is calculated as integral of these curves in the debonding phase. Besides, taking advantage of the transparency of the PSA, additional information regarding the interfacial events occurring during the debonding phase can be obtained by inspecting the sample with a standard optical microscope and a digital video camera, see Figure 1. This imaging technique allows one to detect curved interfaces between trapped gas in cavities (or air in fingers) and the PSA from a top view perspective (a two-dimensional projection of the real three-dimensional space).

Here we have developed a boundary recognition algorithm in order to analyze the digitalized frames from probe tack experiments. This methodology allowed us to detect the nucleation of cavities, track their growth during the detachment process and measure various geometrical quantities, such as the equivalent area, the eccentricity, and so on. We have verified the reproducibility of our measurements over different experiments under the same conditions. From the data of the projected cavities we can obtain the load bearing area and estimate the magnitude of the shear stress from the nominal force measured during the experiment and the knowledge of the uniaxial tensile stress.

We have analyzed the images from the probe tack test of three PSAs with different viscoelastic features, ranging from a more liquid to a more elastic behavior, at two pulling velocities (1 and $10\,\mu m s^{-1}$). For each material we have characterized the growth law of the radius of individual cavities as function of time. Moreover, we have been able to test the validity of the assumption of spherical cavities after the onset of each nucleation events by comparing the overall probe displacement (i.e. a change in the total volume of the PSA) with the growth of the projected area of each cavity.

To conclude, we have shown that the probe tack experiment combined with our image analysis technique can provide valuable data for the understanding of the interfacial processes that lead to the debonding of pressure sensitive adhesives.

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