Effect of molecular weight on friction of PolyStyrene

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Introduction

Single asperity friction measurements are an effective method to study the origin and phenomenology of friction and wear. Using well-defined micron-sized contacts one can probe friction and wear mechanisms that are relevant for macroscopic contacts [1]. Our aim is to relate microscopic features of polymers to their friction and wear behaviour. In this poster we present measurements on two grades of monodisperse PolyStyrene (PS). Mechanical properties of PS are well understood [5] which makes it a good model system.

Material and methods

PS samples with a molecular weight of 56 kg/mole and 966 kg/mole, and a polydispersity of 1.05 and 1.15 respectively, were used. Pressed samples of these materials were flattened by embossing with a silica wafer above Tg. The resulting surfaces can be considered smooth for our purpose. For the single asperity friction measurements the Lateral Force Apparatus described in [4] was used. This apparatus has recently been improved and is now capable of spanning 6 decades in velocity. A spherical diamond tip with a radius of 5 μm was mounted on a cantilever with a normal and lateral stiffness of 243 and 54 N/m respectively. "Start-stop" experiments were performed, in which the contact was prepared by bringing it into a reproducible sliding situation. Tip motion was then halted at time t=0 for a certain period, after which the motion was resumed. Lateral force and (vertical) z-displacement are measured continuously from t=0 onwards.

Results

At higher loads both materials showed an increase in friction in a certain sliding velocity range. The effect of molecular weight on the velocities at which this phenomenon occurred was consistent with trends in the work by Tanaka et al. [2] who found a shift of a friction peak to lower velocities with increasing molecular weight.

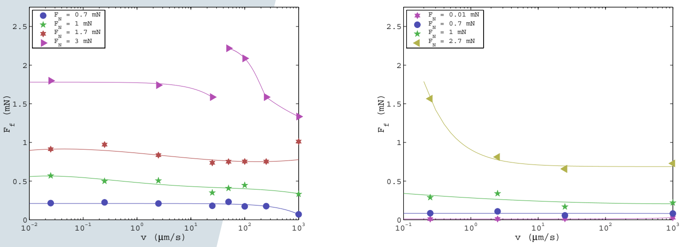

Figure 1 *Average kinetic friction force as a function of velocity on both the high (right) and low molecular weight material (left).*

The friction measured on the high molecular weight (MW) material was usually lower than on the low molecular weight material. It is reasonable to assume that a major cause of this difference is the size of the contact area.

The right graph of figure 2 shows the diamond tip sinks into the material when standing still. This process is slower for the high MW material (red) than for the low MW material (blue). After 10 seconds the tip had already sunken 3 μm into the low MW material. The high molecular weight material sank only 1 μm in the same amount of time at a higher load. From this it could be concluded the contact area was growing faster in the lower MW material.

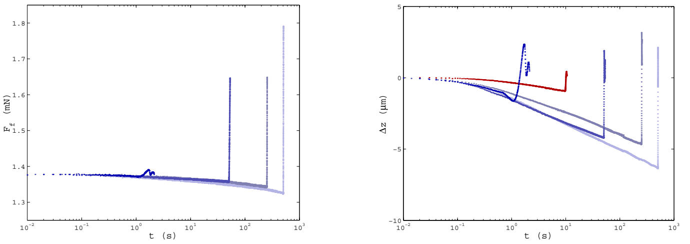

Figure 2 *Friction and horizontal displacement from t=0 till just beyond the friction peak. Δz=0 at t=0. v= 2.5 μm/s. Red line: high MW PS Fn = 2.5 mN. Blue lines: low MW PS, Fn = 2.2 mN.*

During the period the motion was stopped, the friction force relaxed. Upon the subsequent resumption of motion, the tip had to climb out of the pit it had just created, causing a peak in friction.

Discussion

The low MW PS has a reduced Tg. This reduction is about 5 K, calculated from a fit through values found in literature. The thermal mobility of the low MW chain is therefore higher than for the high MW chain, resulting in easier plastic deformation with decreasing Tg or MW. The easier plastic deformation will lead to a larger contact area.
The rise in friction can also be ascribed to the glass transition. The increase in the loss modulus causes an increase in friction. Nanofriction measurements by Wang et al. [3] show that the friction peak associated with Tg becomes more pronounced with increasing load. They explain the presence of the peak with the presence of a wedge in front of the tip. This could mean that the appearence of the friction peak in our experiments is associated with a transition from a ploughing deformation without, to one with wedge formation. Characterisation of the material used will have to be carried out to better understand the mechanisms leading to the observed phenomena.

References:

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