Mechanistic insights into elastomer frictional wear using mechanophores to characterize sub-surface material damage.

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Understanding wear of soft elastomers following frictional sliding is a crucial topic in tribology, both from an applied and a fundamental point of view. However, our understanding of elastomer wear by fatigue is far from complete, due to the difficulty in accessing to the local damage field at the surface of the material following frictional solicitations. Here, we apply recently developed mechano-chemical strategies based on damage-reporting mechanophore molecules, to obtain novel quantitative information on the local damage field in elastomeric materials following frictional sliding, and to shed new lights on the underlying mechanisms of frictional wear in soft elastomeric materials.

Keywords : wear, elastomer, molecular damage, mechanophore

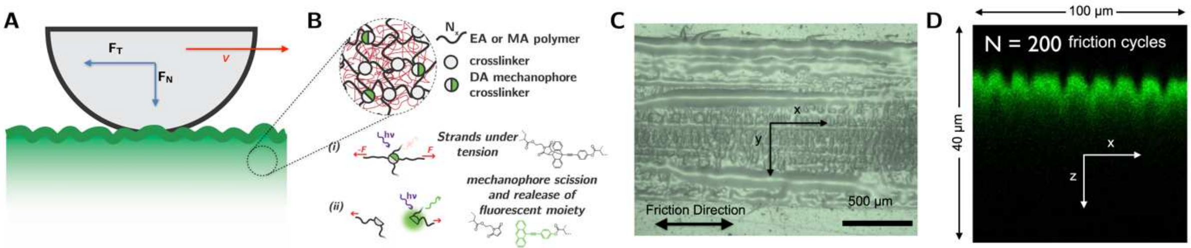

Figure 1. **(A)** A millimetric indenter slides with a reciprocal motion on a multiple network elastomer, leading to wear of the material. **(B)** Tagging of the sacrificial network with damage sensitive mechanophore molecules, reporting for chain scission. **(C)** White light image of a wear track showing ridges perpendicular to the friction direction and the presence of a liquid-like third body. **(D)** Confocal image of mechanophore activation in the sub-surface following 200 friction cycles.

1. Introduction

Understanding wear of soft elastomers following frictional sliding is a crucial topic in tribology, both from an applied (tyre wear in the automotive industry) and a fundamental point of view [1]. Elastomer fatigue wear is typically characterized by gravimetric measurements or post-mortem observations of the worn surfaces, giving poor insights on the underlying physical mechanisms at play. Here, we apply recently developed mechano-chemical strategies based on damage-reporting mechanophore molecules [2], to obtain novel quantitative information on the local damage field in elastomeric materials following frictional sliding.

2. Methods

We focus on multiple network poly(ethyl acrylate) elastomers, obtained by swelling of a prestretched sacrificial network in a soft extensible matrix. The sacrificial network is tagged by damage-reporting anthracene molecules introduced as a small fraction of cross-linkers (Fig. B). This anthracene mechanophore becomes fluorescent upon scission, working as a reporter for chain damage of the filler network. The full damage field in the material can accordingly be measured and quantified using confocal microscopy.

To study frictional fatigue wear, we submit the material to reciprocal sliding solicitations by a rough millimetric glass bead (Fig. A). We typically observe after several friction cycles the appearance of ridges, perpendicular to the friction direction, as a well as the creation of a liquid-like third body of ultra-large viscosity, reminiscent of the phenomenology associated with fatigue wear [3] (Fig. C). By performing confocal mapping of mechanophore activation in the sub-surface, we obtain quantitative measurements of the damage gradient in the material in these conditions (Fig. D). We probe specifically the effect of the number of friction cycles, the normal load applied to the slider, as well as the structure of the material, characterized by the prestretch of the sacrificial network.

3. Discussion

Our measurements of the local damage profile evidence that damage is maximal at the surface and decays in the material with characteristic distances of tens of µm. Elastomers with larger prestretch of the first network have enhanced fracture energies, but we observe that these materials have poorer resistance in fatigue wear, due to extended sub-surface damage. Analyzing the dependence of damage on the number of frictional cycles, we further evidence a 2-step damage mechanism with damage accumulation in the sub-surface, followed by erosion of the material. Our observations shed new lights on the underlying mechanisms of frictional wear in soft elastomeric materials.

4. References

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