Cyclic wear behaviour of 2D materials

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Abstract

Wear, an important factor which determines lifetime and reliability of a mechanical system, can occur due to friction in almost every machine with moving parts. Because of complicated nature of nanoscale wear, the behaviour of two-dimensional materials under high cyclic wear and their surface damage mechanism is yet unknown[2]. That is why, Understanding this phenomenon at nanoscale is of great importance for applications such as nanolithography and nanomanufacturing[1]. In this study, we used atomic force microscopy-based scratch testing to examine the cyclic wear behaviour of single-layer graphene, MoS_2, and WSe_2. The test involved using a sharp diamond tip to scratch a single nano-regime line in a reciprocating manner. Results showed that graphene displayed exceptional lubricity, lasting over 3000 cycles at 85% of the applied critical normal load, the minimum load at which the material fails under a single cycle, before failure. MoS_2 and WSe_2, on the other hand, failed on average after 500 cycles. Based on the findings of this study, graphene fails catastrophically, and, in most cases, graphene tends to fold over on itself just after failure exposing substrate underneath (As shown in figure 1.b). It is found that the reason for graphene's failure is linked to the concentrated stress that occurs when nano wrinkles form due to puckering effect. On the contrary, MoS_2 and WSe_2 shows a completely different behaviour compared to graphene after failure. For these TMDs, the damage usually starts from one edge of the wear track and propagates through the entire line. Due to their high out-of-plane stiffness, MoS_2 and WSe_2 are less affected by puckering, which results in intermittent failure. This research not only has implications for the MEMs and NEMs industry, but it also has the potential to optimize the use of 2D materials as lubricant additives on a macroscopic level.

References

1. Liu, Y. *et al. Nano Lett.* **22**, 6018–6025 (2022).
2. Marian, M., Berman, D., Rota, A., Jackson, R. L. & Rosenkranz, A. *Advanced Materials Interfaces* vol. 9 at https://doi.org/10.1002/admi.202101622 (2022).

Figures

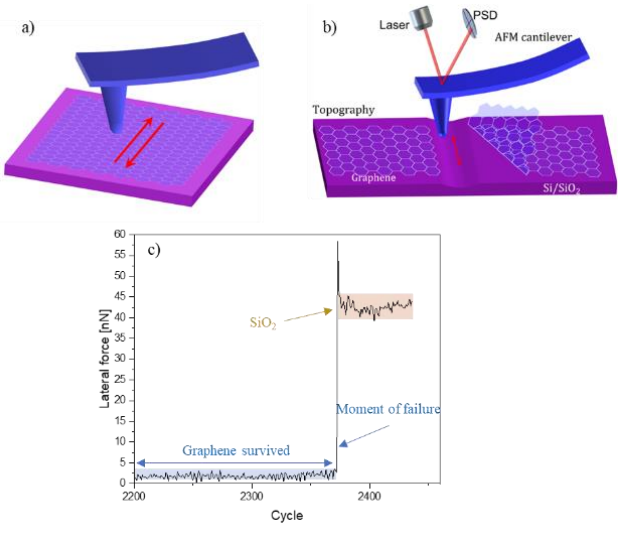

Figure 1: Schematic of wear test using friction force microscopy before starting the test (a) and after failure of graphene (b), cycle number versus lateral force for a single experiment on graphene (c).