Measuring Friction at a Single Interface with Two Independent Microtribometers: A Model Study with Alumina Spheres on Gold or Single-Crystal MoS_2

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Fundamental studies of micro/nanoscale friction often employ scanning probes operating at relatively low speeds (< 1 mm/s). These approaches typically rely on compliant spring-based mechanisms whose deflections are sensed electrically or optically. Over the last decade, several groups have developed an alternative approach using quartz crystal microbalances (QCM) to quantify frictional forces at solid-on-solid contacts [1-4]. QCM-based techniques achieve high sliding speeds (~1 m/s) that are relevant to most practical devices. By reciprocating a probe-on-flat interface at MHz frequencies, the QCM detects lateral forces in a regime where the probe can be considered infinitely rigid. We have integrated spring-based and QCM-based measurements into a single system in order to perform well-controlled comparisons of these two distinct techniques. The interfaces examined use two model materials, polycrystaline gold and single-crystal MoS_2, against alumina microspheres. The alumina-gold tribosystem produced kinetic friction coefficients of 0.28 ± 0.03 and 0.25 ± 0.01 during QCM (~0.5 m/s) and spring-based (~25 μm/s) measurements, respectively. The alumina-MoS_2 tribosystem produced kinetic friction coefficients of 0.086 ± 0.009 and 0.041 ± 0.001 during QCM and spring-based measurements, respectively. We show how integrating these complementary approaches can help bridge the gap between fundamental and practical micro/nanotribology studies.

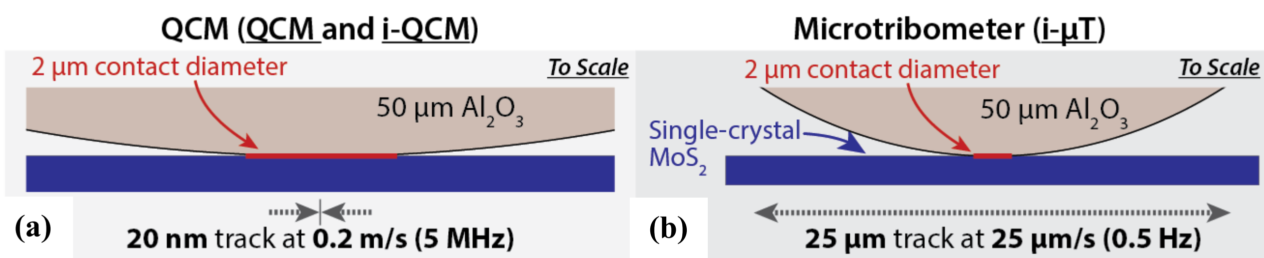

Figure 1. Schematic comparison of test conditions for alumina microspheres on substrates prepared with single-crystal MoS_2. (a) The QCM reciprocates laterally at ~5 MHz with a track length up to 50 nm and sliding velocity up to 0.5 m/s. (b) The track length in the spring-based tribometer is 25 μm, with sliding speeds 5 orders of magnitude smaller than the QCM.

REFERENCES

[1] Inoue, D., Machida, S., Taniguchi, J., Suzuki, M., Ishikawa, M., Miura, K.: *Dynamical frictional force of nanoscale sliding*. Phys. Rev. B **86**, 115411 (2012).
[2] Hanke, S., Petri, J., Johannsmann, D.: *Partial slip in mesoscale contacts: Dependence on contact size*. Phys. Rev. E **88**, 032408 (2013).
[3] Leopoldes, J.L., Conrad, G., Jia, X.: *Perturbation of the yield-stress rheology of polymer thin films by nonlinear shear ultrasound*. Phys. Rev. E **91**, 012405 (2015).
[4] Borovsky, B.P., Bouxsein, C., O'Neill, C. et al., *An Integrated Force Probe and Quartz Crystal Microbalance for High-Speed Microtribology*. Tribol. Lett. **65**, 148 (2017).