CMCC Mechanochemistry Discussions

Online Seminar Series

The Stress-Controlled Mechanochemical Reactor: A Novel Tool to Determine Which Stress Components Drive Mechanochemistry

Livestreaming at
10:00 AM (CT)

THURS., March 23, 2023

on the CMCC YouTube Channel:
https://www.youtube.com/channel/UC7eCYPKbGTKpgO7W2bNABxg

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https://carpick.seas.upenn.edu/group-members/robert-carpick/

ABSTRACT:

Mechanochemistry is used in a wide array of novel syntheses, but is also important in many other domains. This includes in the interdisciplinary field of tribology – the study of friction, adhesion, lubrication, and wear. Specifically, chemical reactions driven by both compression and shear at sliding interfaces can dramatically alter – for better or for worse – the amount of friction and the long-term durability of materials and components. Combining concepts and tools from the fields of mechanochemistry and tribology can produce new insights beneficial to both fields. We study the mechanochemical synthesis of zinc dialkyldithiophosphate (ZDDP) tribofilms. ZDDP, the most widely used antiwear chemical additive in lubricants, forms glassy phosphate-based tribofilms on surfaces sliding in ZDDP-containing oils through mechanochemical reactions. These tribofilms are critical to prevent or reduce wear. Recent work showed that a combination of compressive and shear stresses can form the tribofilms, but the individual effects of shear and compression were unexamined. Here, shear and compression are studied separately in addition to temperature, all while monitoring the volume of reacted product in situ using a novel instrumentation approach we call a stress-controlled mechanochemical reactor. From this we confirm the reaction kinetics follow stress-assisted thermal activation, but reveal contrasting roles of compressive and shear stress. Specifically, shear promotes the reaction while compression inhibits it. This points toward a bond-breaking reaction being the rate-limiting step in ZDDP-derived tribofilm growth. We will discuss the broader mechanochemistry implications of these findings, and suggest how this approach can be used more generally for fundamental studies.

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