NONCONVENTIONAL TRIBOCHEMICAL ACTIVATION: FACING THE CHALLENGES IN NON-TRIBOLOGICAL APPLICATIONS

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ABSTRACT
Over the past years, enormous efforts have been made in order to find new paths of chemical reactions, that could lead to the highly desirable thermodynamic and kinetic targets in various applied chemical processes. The nonconventional approaches involve non-thermal ways of activation of chemical reactions, many of which can have unusual reaction trajectories and products. Recently, the concept of a new technology for processing polychlorinated biphenyls waste through mechanically activated chemical treatment was proved (triboREMEDY project).

Our studies were focused on deep understanding of fundamental mechanisms underlying tribochemical activation for different classes of materials including metals, ceramics, polymers, surface coatings and liquids using a combination of advanced and original techniques including Mechanically Induced Gas Emission Mass Spectrometry. Then, we explored the potential of tribochemical approach to solving challenging problems in such areas as decontamination of dredged sediments, and extraction of hydrogen from solid-state storage materials.

The basic conception relies on the fact that at the tribological interface mechanical energy is transformed into heat not directly and not completely but through a numerous physical and chemical processes, which are activated sequentially and in parallel forming dissipation cascades. Therefore, the thermal chemical reactions are enhanced due to coupling mechanical stress to the reaction energy landscape, and also new reactions can be triggered.

Experimental investigation of a series of solid hydrides being potential candidates for matured technology of hydrogen storage was carried out to explore their susceptibility to release hydrogen under tribological solicitation at room temperature. Notably, ionic hydrides such as MgH_2 released hydrogen with good kinetics under mild loading conditions. Contrary to the expectations, hydrogen release from less stable $NaAlH_3$ and ammonium borane adducts was much less intensive than from MgH_2. It was suggested that for ionic solids the activation of chemical reactions can be produced not via diminishing the activation potential of an intermediate state due to application of tensile stress, but due mutual approaching of chemical groups during shear plastic flow. The flow promotes mutual approaching of normally distant chemical groups and chemical reaction between them.

The second potential application of tribochemical activation studied was decontamination of dredged sediments polluted both with organic matter (persistent organic contaminants, microplastics, etc.) and metals. The existing technologies of soil decontamination are not effective for sediments with such a complex pollution. We explored the effectiveness of tribochemical method using a model system consisting of a quartz sand as the main mineral component of sediments and various polycyclic aromatic hydrocarbons and aniline, which simulated the contaminants. The contaminants were transformed during dry tribochemical treatment. Furthermore, the synergistic effect of combining tribochemical treatment with other forms of activation of chemical reactions such as photocatalysis and electrodynamics have been explored for real dredged sediments collected at Atlantic and Mediterranean harbors.

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