

Acceleration of Diels-Alder Reactions by Mechanical Distortion

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Mechanochemistry¹ involves the use of mechanical energy to activate chemical reactions. Specialized mechanochemical reactors, such as ball mills, planetary mills, or twin-screw extruders have been used to create diverse chemicals and materials, including pharmaceutical ingredients, polymers, nanoparticles. Many aspects of mechanochemical processes reduce usage of organic

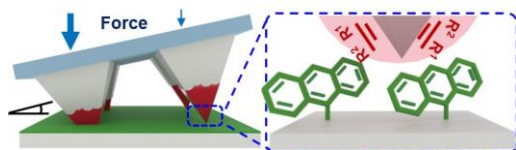


Figure 1. Tilted stage elastomeric tip array that transfers an ink mixture (red coating) consisting of a dienophile and PEG onto an anthracene-modified surface. Upon contact with the surface, the tips form nanoreactors, where forces are applied that accelerate the Diels-Alder cycloaddition reactions.

solvents and can provide regioisomers not obtained solvothermally. Mechanochemical synthesis, however, has not yet been adopted by the synthetic community because many mechanistic aspects of these reactions remain a mystery, and so the outcomes of reactions remain difficult to predict. Here we use arrays of nanoscopic tips to investigate experimentally and computationally the reaction kinetics of mechanically activated [4+2] Diels-Alder cycloaddition reactions between dienophiles and diene monolayers to measure how force affects reaction rates. The experiment (**Figure 1**) uses massively parallel elastomeric arrays containing

900 pyramidal tips² to bring fluorescently-labelled dienophiles into contact with monolayers of the tethered diene, anthracene, that is immobilized covalently onto the surface of a SiO₂ wafer. Fluorescence microscopy is used to track the Diels-Alder adduct formation as a function of force F and time t . The reaction rates of the anthracene monolayer with four different dienophiles were studied because their reactivity based on the electron-demand and the steric environment around the reactive alkene – the main factors that affect the reaction rates of Diels-Alder reactions. The fluorescence data are fit to a first order kinetic model to determine activation parameters, including the activation energy E_a , the free energy of activation, ΔG^\ddagger , and the activation volume, ΔV^\ddagger .

References:

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