Spontaneous Combustion of Hydrogen/Oxygen Mixtures in Nanobubbles

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Loyal to the scaling law, we would expect combustion to be impossible at nanoscale because heat loss would profoundly dominate chemical reactions. Svetovoy et al. [1, 2], though an accidental discovery, however, claimed that the hydrogen and oxygen gases (generated by water electrolysis) could be ignited spontaneously in nanobubbles with sizes smaller than 150 nm. If this is true, the nanobubbles would the first nanoscale device in which combustion took place. Motivated by this, we developed an experiment similar to that of Svetovoy to see if we could get same results. Moreover, a microfabricated thermal sensor was employed to measure the change in the temperature (and the amount of heat produced), which would provide important insights on whether combustion of H_2 and O_2 in nanobubbles took place or not. A chip consisting of several pairs of micro-electrodes was fabricated. Bubbles were generated by electrolysis of a 1M solution of Na_2SO_4 in deionized water. In addition to the experiment, we also performed reactive molecular dynamic simulations to understand the mechanism that contributes towards the spontaneous combustion of H_2/O_2. The simulations were based on the first-principles derived reactive force field, ReaxFF, which includes both the physical changes such as thermal transport and the chemical changes such as bond breaking and forming. The combined experiment and simulations provided important insights on the chemistry and dynamics of hydrogen/oxygen mixtures inside nanobubbles. Potential application of the newly found reactive nanobubble phenomenon could be used to design and create nanoscale sensors, actuators, heaters, etc.

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