Ultrasonic hammer sets off tiny explosions

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Ken Suslick led a team of Illinois chemists who developed an ultrasonic hammer to help explore how impact generates hotspots that trigger explosive materials. Credit: L. Brian Stauffer

Giving new meaning to the term "sonic boom," University of Illinois chemists have used sound to trigger microscopic explosions.

Using an "ultrasonic hammer," the researchers triggered tiny but intensely hot explosions in volatile materials, giving insight into how explosives work and how to control them. Led by chemistry professors Ken Suslick and Dana Dlott, the researchers published their findings in the journal *Nature Communications*.

Explosive materials often are shock-sensitive, meaning they can be triggered by hitting or dropping them. Scientists have long thought that the impact triggers the explosion by creating hot spots in the material, but these hot spots have never been directly observed, making it difficult for researchers to understand the dynamics of such explosions or how to control them.

"Many explosives go 'boom' when dropped. Nobody really knows why," said Suslick, the Schmidt Professor Emeritus of Chemistry. "The problem with controlling explosions lies in the difficulty of seeing where hot spots are formed and how they grow. A mechanical impact strong enough to produce intense hot spots also destroys the structure of the energetic material too quickly, in a millionth of a second, so we cannot really track their location and dynamics."

The Illinois researchers used the ultrasonic hammer to bombard the material with ultrasound waves, watching with a fast infrared camera to detect any hot spots. They saw that the ultrasound triggered local hot spots and tiny explosions within the material, without destroying the material completely.

"Instead of one big bang, we had 20,000 little bangs per second," Suslick said.

Thanks to the infrared camera, the researchers were able to see where the hot spots formed and how hot they got. They were able to produce hot spots at targeted locations with temperatures soaring at rates of 40,000 degrees F per second.

The experimental setup allowed researchers to explore some of the mysteries surrounding the nature of explosive materials, such as how defects in composite materials contribute to explosiveness.

To simulate defects in polymer-composite explosives, the researchers used sugar crystals as a stand-in to more volatile explosives and covered them in a thin liquid coating, then embedded them in a flexible polymer. When hit with the ultrasonic hammer, intense hot spots formed only on the crystal surfaces, while the rest of the material, including uncoated sugar crystals, stayed cool.

"The liquid coating around the embedded crystals keeps the crystal from sticking to the polymer," Dlott said, "then the ultrasound rubs the polymer against the crystal, and this causes friction leading to hot spots."

This finding gives insight into the properties of composites loaded with high-explosive crystals, as well as the explosion between an oxidizer and a fuel – the typical ingredients of homemade or improvised explosive devices.

Next, the researchers will use ultrasound to control the thermal reaction of real polymer-bonded explosives, which have a high density of explosive crystals.

"Astronomers are interested in the Big Bang, but to understand what starts explosions, we want to understand these little bangs," Suslick said.

More information: "Ultrasonic hammer produces hot spots in solids." *Nature Communications* 6, Article number: 6581 DOI: 10.1038/ncomms7581