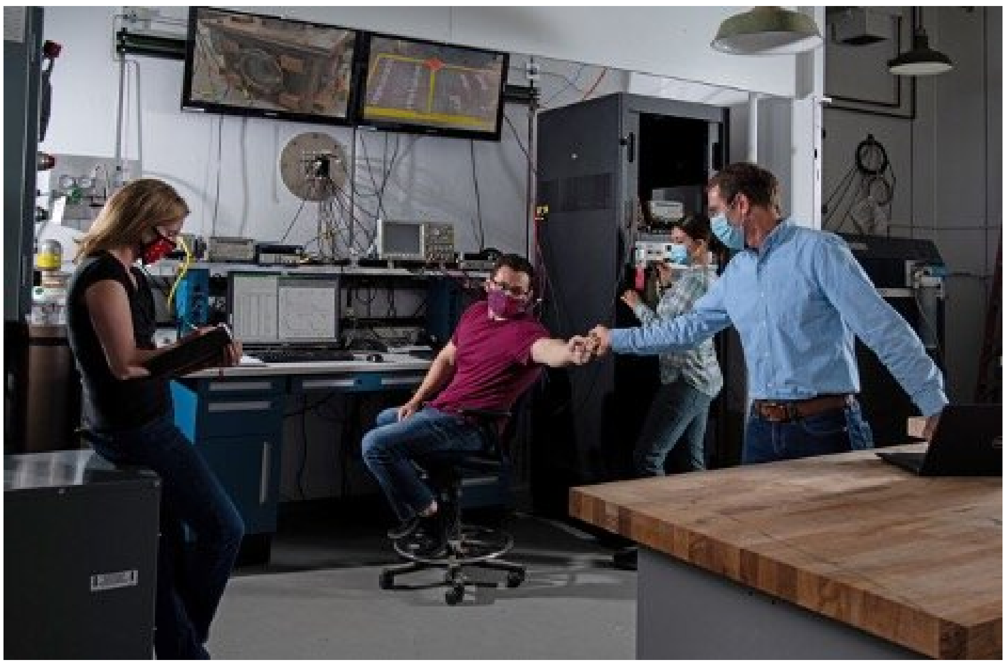
Study reveals robust performance in aged detonator explosive

October 29 2020



In the firing control room, postdoctoral researcher Nicholas Lease (right), hands Research and Development Engineer Nathan Burnside (center), a flash drive to transfer data for analysis, after Maria Campbell, an explosives technician, fires a shot. Explosives Scientist Virginia Manner, (left) takes notes. Lease, Campbell, and Manner are from the Laboratory's High Explosives Science and Technology Group, while Burnside is from the Detonation Science and Technology Group. Credit: Los Alamos National Laboratory

In a large, statistically significant, one-of-a-kind study, researchers at Los Alamos National Laboratory have confirmed that the explosive called PETN (Pentaerythritol tetranitrate), stabilized with a polysaccharide coating, is resistant to changes in particle shape, size, and structure that can degrade detonator performance over time. The benefits of polysaccharide coating have long been known and studied by Los Alamos energetic material scientists.

"PETN is a common initiating explosive used extensively in commercial detonators and in the U.S. nuclear stockpile, but batch-to-batch variability has made it difficult for us to definitively show how it responds to aging," said Virginia Manner, an energetic materials chemist at Los Alamos and the project lead for the study.

It all began with a simple conversation between Manner and Daniel Preston about three years ago. At the time, Preston was a research and development engineer in the Detonation Science and Technology group at the Laboratory and wrestling with how to create a comprehensive study that connects PETN aging with detonator performance.

"So we brought together several groups and divisions at Los Alamos to create a very large-scale study that would put to rest all the questions we and others have had about PETN stability," said Manner.

Detonators are small devices that are typically used to initiate large explosive charges. These stable explosive materials need a "kick" to initiate an explosion, a shock wave above a specific speed and energy. The job of a detonator is to convert an input signal, usually electrical or percussive, into a high-pressure shock output. They are required to do so with very high reliability, accuracy, and safety, even after years of fielded service in adverse environments. Detonator designers rely on explosive materials that can survive aging effects with minimal impact to performance.

High-speed video (39,000 frames per second) of the initiation of a detonator holding 40 milligrams of PETN, encased in an acrylic holder. Credit: Los Alamos National Laboratory

The research was published in the scientific journal *Propellants, Explosives, Pyrotechnics*. Many studies have been conducted on PETN stability during the aging process over the past 30 years at Los Alamos and other institutions, but challenges associated with production variability and the number of available detonators hampered the gathering of statistically significant testing data.

To solve this dilemma the research team treated a single source of PETN (enough to fill 2,000 detonators) with different stabilizers, thermally aged the resulting detonators, analyzed the powder characteristics and tested detonator function with a statistically significant sample size. The research highlighted in this particular paper included actual firing of about 400 of these detonators and other interrogations of the material to better understand its physical characteristics.

"We focused on four batches of PETN powder from the same stock using two stabilizers which have been applied for decades, polysaccharide and TriPEON," said Nick Lease, a scientist in the Laboratory's High Explosives Science and Technology group. A polysaccharide is a large molecule made of simple sugars, like glucose. TriPEON is the chemical tripentaerythritol octanitrate, a common explosive stabilizer.

According to Geoff Brown, another collaborator, "The PETN is aged as a free-flowing powder and in modified exploding bridge wire detonators for one month at 75°C. The powder is then analyzed chemically using high-resolution imaging as well as particle size and surface area analysis techniques."

Additionally, "detonator performance was evaluated at a range of voltages to determine the energy needed to light the detonators, also known as threshold voltages. The time to output was also measured," said Nathan Burnside, a research and development engineer in the Detonation Science and Technology group.

Findings from the study indicate that aging significantly changes the surface area and particle size of unstabilized PETN, leading to increases in detonator function time.

"We monitor detonator health through function time—the time it takes from the initial bridgewire burst in the detonator, which initiates the PETN, to ultimately generate a shock at the output end of the detonator. This event should be as prompt as possible, and increases in time indicate eroding detonator health," said Preston.

Powders stabilized with TriPEON displayed less significant increases in function time, while powder stabilized with polysaccharide exhibited no aging effects, despite the high temperature aging.

"We have shown that PETN stabilized with a polysaccharide coating exhibits little to no change in powder characteristics during aging at elevated temperatures, in both free-flowing powder as well as pressed into low density commercially prepared detonator pellets," said Manner. "Interestingly, measured threshold voltages do not appear to be affected by the coarsening that occurs in the powder during aging, even with the unstabilized powder. Longer term studies are underway to determine if this will continue to be a trend."

In a demonstration of the Laboratory's commitment to deliver on its core mission during the current pandemic, this project was completed under COVID-19 restrictions. Because the aging study was time sensitive, several members of the research team were given special approvals to be on site, and worked in labs using social distancing and masks, along with meticulous hygiene. They performed 25 to 50 explosive tests per day, disassembling approximately 30 detonators and imaging hundreds of parts.

Further work is underway to explore the effects of aging over various temperatures and longer timescales. The team at Los Alamos is composed of scientists and engineers from the Explosives Science and Technology, Detonation Science and Technology, Neutron Science and Technology, and Nuclear Security Production Integration groups.

More information: Nicholas Lease et al, The Role of Pentaerythritol Tetranitrate (PETN) Aging in Determining Detonator Firing Characteristics, *Propellants, Explosives, Pyrotechnics* (2020). DOI: 10.1002/prep.202000181

Provided by Los Alamos National Laboratory