Acoustic emissions from organic martensite analogues

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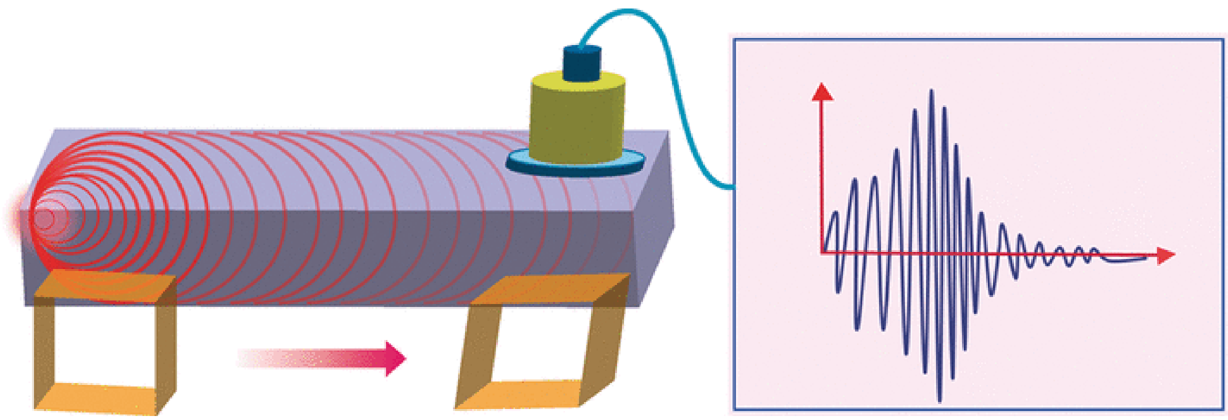

Credit: Wiley

Some organic crystals jump around when heated up. This happens because of an extremely fast change in their crystal structure. In the journal *Angewandte Chemie*, scientists have now demonstrated that the crystals send out acoustic signals during this process, which may be useful in analyzing the characteristics of this phenomenon. The researchers demonstrated that this process is analogous to martensitic transitions observed in steel and some alloys.

Martensite is a form of steel made by quenching austenite, and gives its name to a particular type of phase transition. The rapid cooling of the austenite does not allow the atoms to adopt their preferred structure at the lower temperature. Instead, they move in unison to form the martensite lattice. In jumping crystals, a large number of atoms also change their lattice positions in concert. The high speed of this phenomenon and the fact that the crystals often explode have previously made it impossible to prove this theory, understand the details, and make use of this thermosalient effect, as it is known. The ability of the hopping crystals to very rapidly transform heat into movement or work is potentially useful for the development of artificial muscles or microscale robotic arms.

Starting from the assumption that the sudden release of the accumulated elastic tension in jumping crystals results in relatively strong acoustic waves, similar to seismic waves from an earthquake, the team from New York University Abu Dhabi, the German Electron Synchrotron (DESY) in Hamburg, and the Max Planck Institute for Solid State Research in Stuttgart got down to work. Led by Panče Naumov, the researchers chose to study crystals of the vegetable amino acid L-pyroglutamic acid (L-PGA). These jumping crystals change their crystal structure when heated to between 65 and 67 °C; they return to their starting structure upon cooling between 55.6 and 53.8 °C, as demonstrated by X-ray crystallography with synchrotron radiation.

As postulated, the crystals give off clear acoustic signals during the transition. These signals can be registered with a piezoelectric sensor. The number, amplitude, frequency, and form of the signals gave the researchers information about the dynamics and mechanism of the effect. The intensity and energy of the initial acoustic wave were significantly higher and the rise time shorter than for subsequent waves. The reason for this is the more efficient propagation of the elastic wave through the defect-free medium at the beginning of the phase transition. As the transition progresses, the number of microfissures increases, which decreases the elastic stress.

The phase boundary between the different crystal structures progresses at 2.8 m/s in L-PGA, which is several thousand times faster than other phase transitions. However, the two crystal structures are more similar to each other than expected. The transition involves expansions in two dimensions and a contraction in the third, all in the range of only 0.5-1.7 percent.

"Our study shows that the jumping crystals are a class of materials analogous to inorganic martensite, and this could be of a tremendous significance for applications such as all-organic electronics" says Naumov. "Acoustic emission techniques finally deliver direct insight into these rapid transitions. Our results indicate that organic matter which is normally perceived as soft and brittle, and much harder materials, such as metals and metal alloys are, at least at the molecular level, not that different. The research into the organic solid state could allow us to gain a better understanding of the related macroscopic effects."

More information: Manas K. Panda et al. Acoustic Emission from Organic Martensites, *Angewandte Chemie International Edition* (2017). DOI: 10.1002/anie.201702359

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