

Life Saving Light: Triboluminescence as a Sensor

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Purpose:

- Develop a novel, quick, and effective tool for detecting cracks in structures.
- Current systems (i.e. acoustic tests, electro-imaging, and fiber optic tests) can't monitor in real-time and require structures to be closed off.

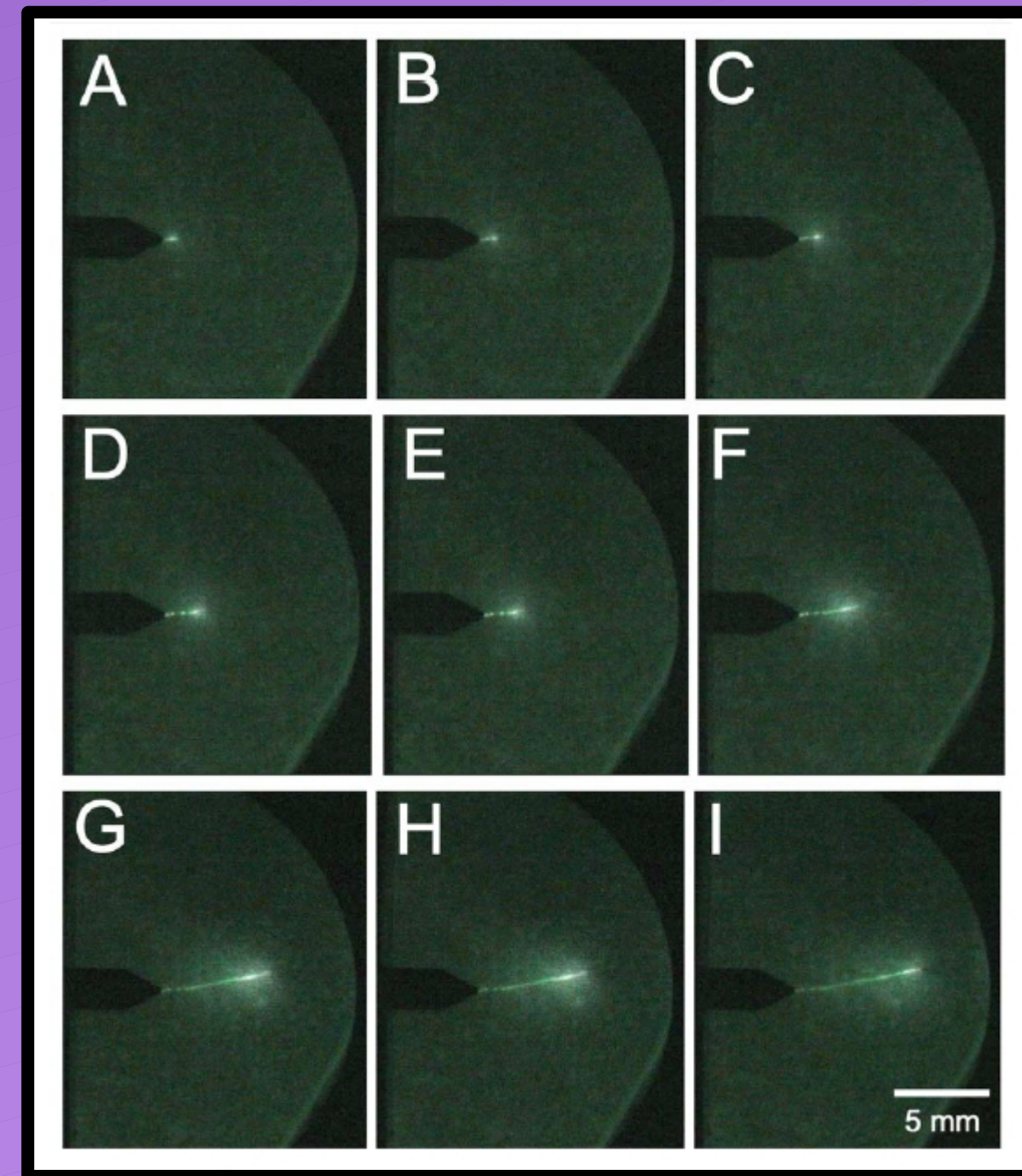


Figure 1: 0.3 second time-lapse of light emission of a triboluminescent solid. [3]

Triboluminescence:

- Meaning "light from friction", triboluminescence occurs in some crystals when molecular bonds crack, creating a charge separation.

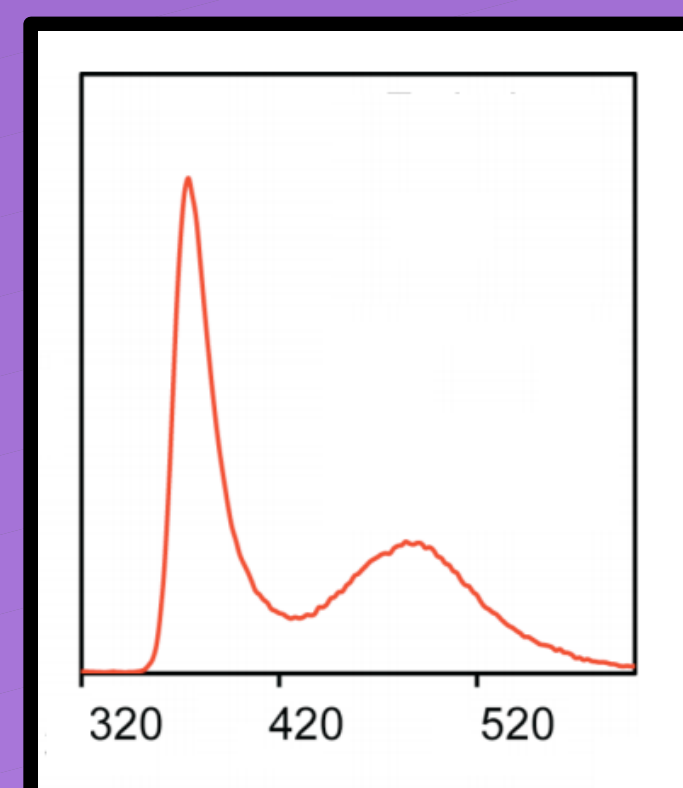


Figure 2: Light emission spectrum of BAS powder. [1]

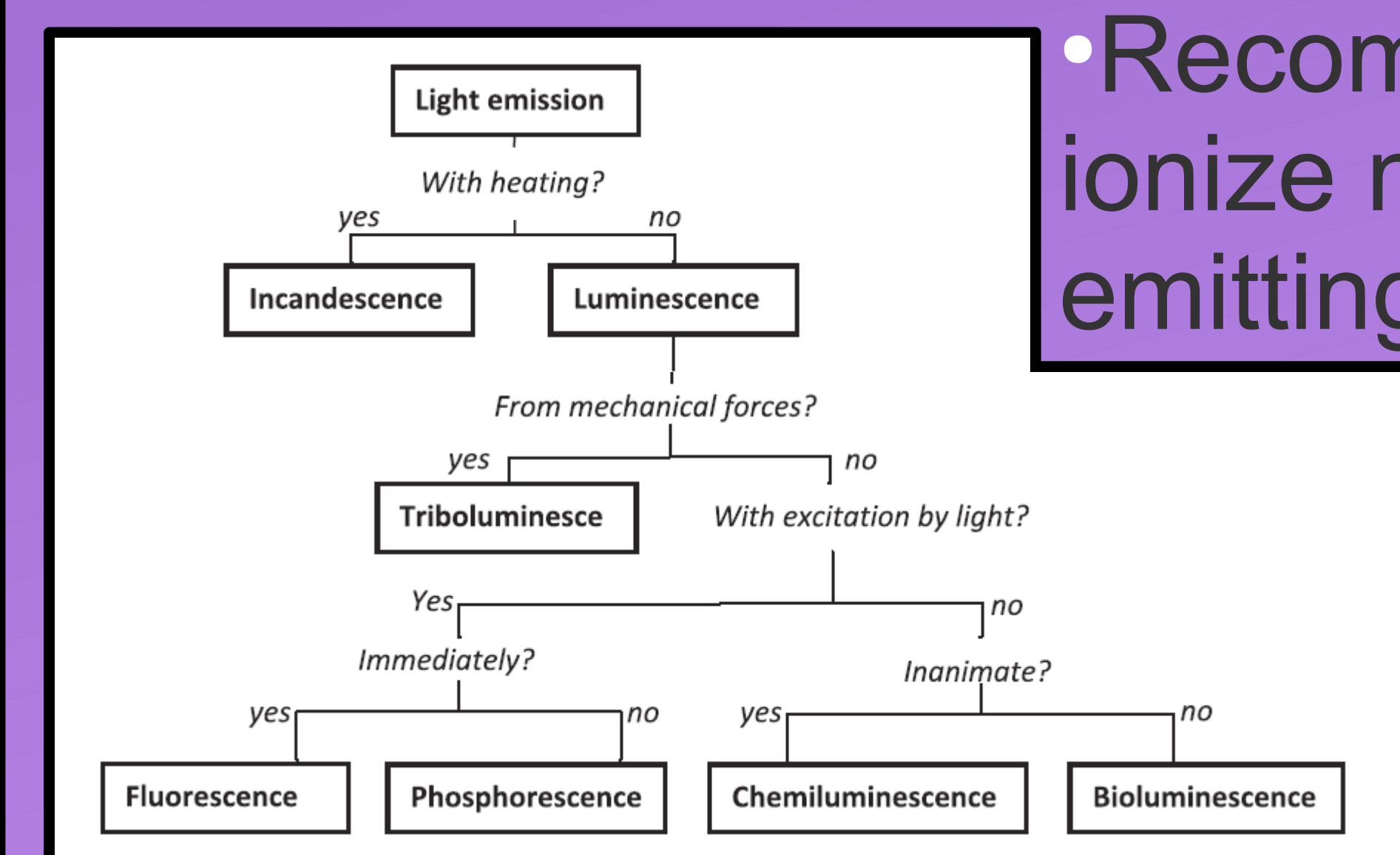


Figure 3: Handy flowchart of luminescence vocabulary. [2]

- Recombining electrons ionize nearby particles, emitting mainly UV light.
- UV photons strike photoluminescent material, creating a visible glow, much like a black light.

Household Examples:



Figure 4: Any sucrose-based candy will triboluminesce, but the wintergreen oils in these mints are photoluminescent, making the flash brighter and colored blue.

- Famously, Wint-O-Green® Life Saver mints emit a brief glow when cracked in a dark room.
- Duct tape displays this property with two pieces, taped sticky-side together, are ripped apart.

Electronics:

- Wint-O-Green® mints used for calibration.
- Initial tests with a Photron Fastcam MC2 Camera.
- iPhone 5 camera at 60 frames per second produced successful images, though flash only captured in 1 frame.
- GoPro considered for high frame rate, low light capabilities, ease of control and WiFi compatibility, allowing for a large array of cameras to be activated all at once.



Figure 5: Photron Fastcam MC2 high-speed camera set up uses a modular computer system which internally saves 4,000 frames. The camera is capable of 2,000 fps, though in low-light setting can only do up to 20 fps, making it impractical for our quick flash.

Paint Testing:

- Various kinds of paints tested, mixed with crushed mints and barium hexacelsian (BAS) powder.
- Needed to adhere well to steel and have a practical curing time.



Figure 6: Specimen of BAS powder mixed with metal epoxy. Crack was induced in a dark room, but no discernible emission of light could be detected.



Figure 7: WildFire UV paint at rest in dim room (left) and glowing under an ultraviolet light source (right). This is the same effect that makes things glow under a black light.

- UV paint included in the mixture to amplify the dim flash.
- Triboluminescent UV photons would activate the paint, causing it to glow in the visible spectrum.

Issues:

- Triboluminescence emits a dim, usually UV flash making it difficult to capture
- Paint would need to adhere to powder with a stronger bond than the crystal's inner molecular bonds to actually split along propagating crack.
- Powder needs to be coarse to produce light.
- Detection requires complete darkness.



Figure 8: Powder changes the properties of the paint, making it significantly more rough and less cohesive.

Conclusions:

- We were unsuccessful in observing triboluminescence within a paint mixed with BAS powder, due to issues listed above.
- Testing will continue, to attempt to find a good recipe that balances practicality with the desired chemical effects.
- Other methods of damage detection are being investigated (i.e. digital image correlation).
- Triboluminescence is still not well researched, which may lead to brighter, practical materials

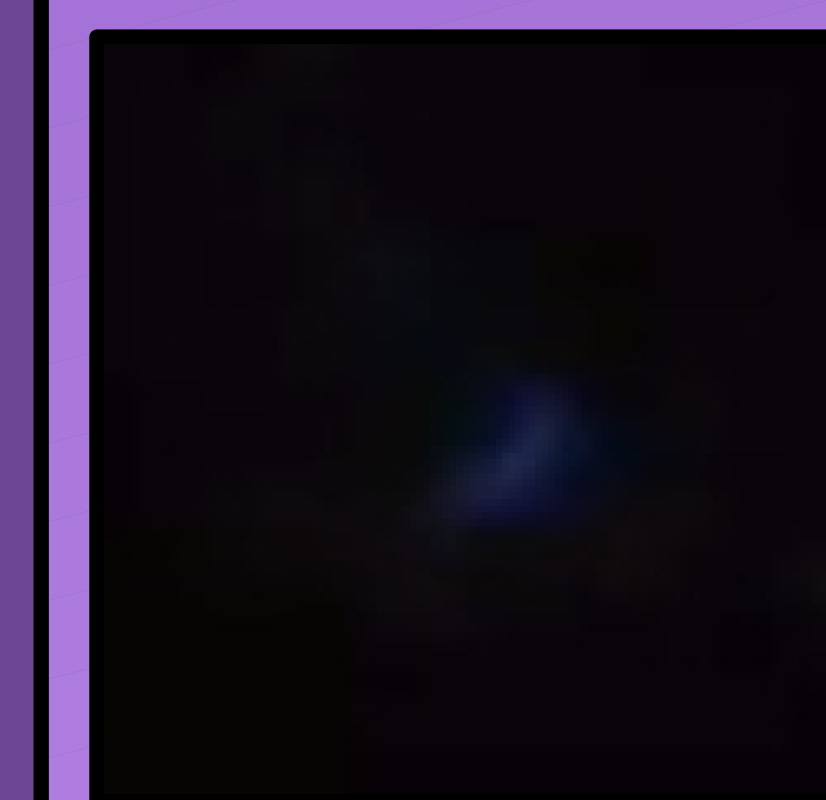


Figure 9: A hopeful image of triboluminescence from a Wint-O-Green® mint, captured in one frame of 60 fps video.

Acknowledgments:

[1] Sinha, K., Pearson, B., Casolco, S.R., Garay, J.E., and Graeve, O.A. (2009). "Synthesis and Consolidation of BaAl₂Si₂O₈:Eu. Development of an Integrated Process for Luminescent Smart Ceramic Materials," *Journal of the American Ceramic Society*, 92 (11), 2504-2511.
[2] Olawale, D.O., Dickens, T., Sullivan W.G., Okoli, O.I., Sobanjo, J.O., and Wang, B. (2010). "Progress in triboluminescence-based smart optical sensor system," *Journal of Luminescence*, 131, 1407-1418.
[3] Kim, J.S., Kwon, Y., and Sohn, K. (2003). "Dynamic visualization of crack propagation and bridging stress using the mechano-luminescence of SrAl₂O₄: (Eu,Dy,Nd)," *Acta Materialia*, 51, 6437-6442.
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