ID: 144
SAND2018-10884C

Tamper-Indicating Enclosures with Visually Obvious Tamper Response

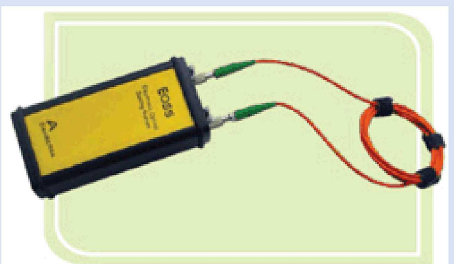
H.A. Smartt, P.L. Feng, W. Corbin, N. Myllenbeck, S. Patel
Sandia National Laboratories
hasmart@sandia.gov

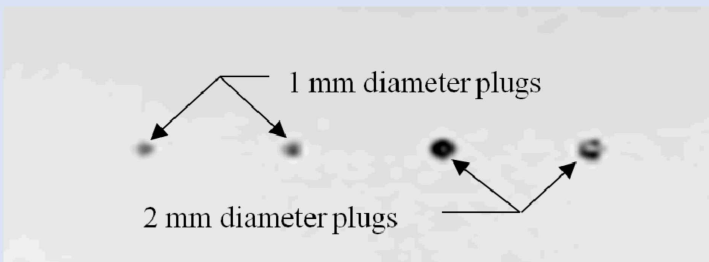
ABSTRACT

- Goal is to improve tamper-indicating enclosures (TIEs) by making response to tamper obvious through simple visual inspection
- Material dramatically changes color irreversibly upon tamper
- Adversary cannot repair or hide tamper-attempts on material
- Material is robust to environment and facility handling
- Material can be 3D printed, or applied by paint or spray coating to existing surfaces
- Material is low cost and deployable across wide range of applications
- Material facilitates rapid and objective inspection

BACKGROUND

- Current TIEs either need time consuming and subjective inspection, active monitoring technology, or external verification mechanisms. There are no approaches that upon tamper, result in obvious responses with only visual inspection needed.

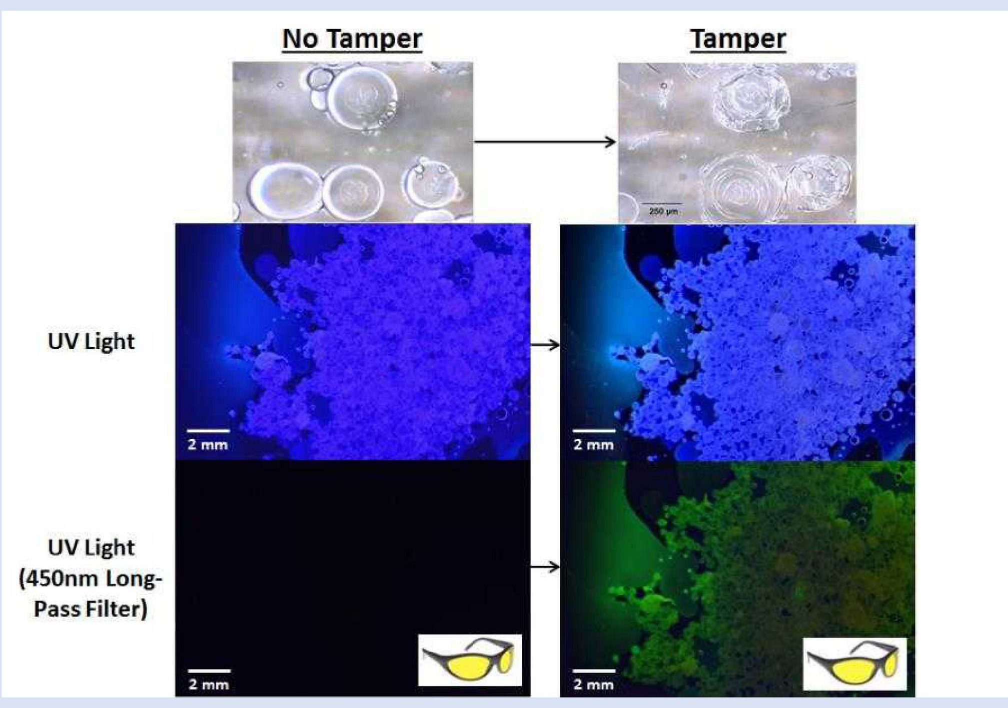




(Left) NGSS surveillance system uses both anodized aluminum, which is verified subjectively on both the outer and inner surfaces via visual inspection and touch, as well as active self-monitoring using conductive materials. (Middle) The EOSS fiber loop seal uses active self-monitoring using conductive foils. Active methods require power and are not applicable in some scenarios. (Right) Metal containers can be verified using eddy current – an external electronic instrument capable of finding disturbances in the metal, including drilled and plugged holes.

METHODS

- In previous work that provided the scientific basis for this concept, we used anthracene-based dyes that exhibit large changes in emission spectrum and intensity following the fracture of the outer microsphere. We explored Melamine-Urea-Formamide (MUF), Urea-Formamide (UF), PMMA, and silica microspheres based on water-in-oil emulsions. Our approach required use of a long-pass optical filter to visualize the tamper-response. In the current work, we continue to investigate and optimize sensor compounds that will dramatically and irreversibly change colors visibly.
- We will optimize microspheres in terms of wall thickness and force required for rupture, and integrate the microspheres into 3D printed and spray coated geometries.
- We will develop prototypes which will undergo testing and evaluation, including environmental and industrial handling.



Summary of the tamper-indicating material concept. Pressure-induced microcapsule breakage is visualized by the presence of green luminescence when viewed through a long-pass optical filter (bottom-right image). An example of such a filter is the yellow-tinted sunglasses shown in the inset. No luminescence is evident in the undamaged system when viewed through the same filter (bottom-left image).

RESULTS

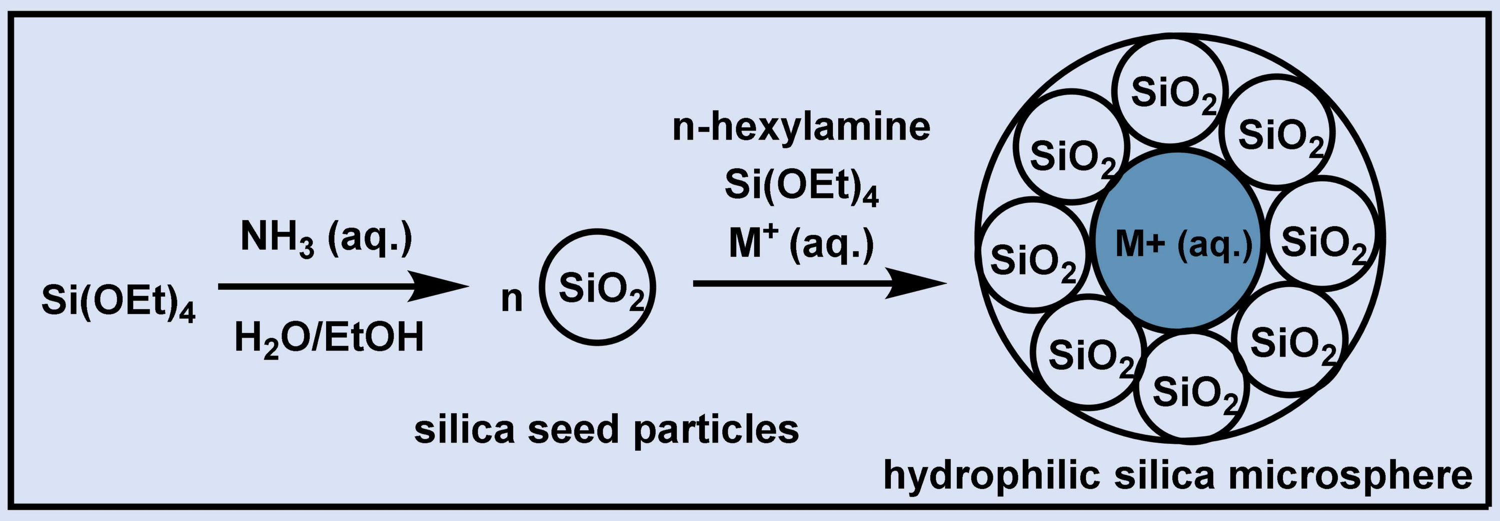
PRIOR RESEARCH RESULTS

- We used an exciplex turn-on fluorescence mechanism (anthracene-based dyes) that provided high environmental stability but reduced sensitivity (lower quantum efficiency of exciplex emission). Pressure-induced microsphere breakage is visualized by the presence of green luminescence when viewed through a long-pass optical filter. No luminescence is evident in the undamaged system when viewed through the same filter. While proving the scientific basis, further work is needed to increase the sensitivity of the response while still providing high environmental stability, as well as allowing the response to be viewed in the visible spectrum.

CURRENT SENSOR COMPOUND and MICROSPHERES

- We are investigating 3d transition metal ion solutions as the sensor compound. We have formulated eight metal ion solutions that exhibit dramatic color changes such as light yellow to purple.
- Silica microspheres are being synthesized using the well-known Stöber method.

Colorimetric sensor mechanism using transition metal solutions (TM) with sensing organic molecule (A) to irreversibly form molecular (TM-2A) complex.



Strategy employed for hydrophilic silica microsphere synthesis. First, silica seed particles are created through the Stöber method; next the seed particles are assembled into a microsphere using an inverse Pickering emulsion; and finally, the sphere is solidified using additional $Si(OEt)_4$.

CONCLUSION

- Tamper-indicating enclosures with visually obvious tamper response will ultimately lead to more rapid and objective inspections (improved efficiency and effectiveness). Other benefits include low cost, passive, flexible in application (from environmental standpoint, to being able to manufacturer custom enclosures or apply to existing enclosures).

ACKNOWLEDGEMENTS / REFERENCES

- The authors would like to thank the U.S. National Nuclear Security Administration (NNSA) Office of Defense Nuclear Nonproliferation R&D (NA-221) for funding this effort.
- Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2018-xxxC
- Subject matter of this poster is included in U.S. Patent Application No. 15898906 entitled "Fluorescent Compositions," filed February 19, 2018.