Color Changing Hydrogen Sensors

NASA Kennedy Space Center: Dr. Luke Roberson, Dr. Martha Williams, Dr. Janine Captain
HySense Technology: Dr. Nahid Mohajeri
University of Central Florida: Dr. Ali Raissi

THE MISSION

During the Space Shuttle Program, one of the most hazardous operation that occurred was the loading of liquid hydrogen (LH_2) during fueling operations of the spacecraft. Due to hydrogen's low explosive limit, any amount leaked could lead to catastrophic event. Hydrogen's chemical properties make it ideal as a rocket fuel; however, the fuel is deemed unsafe for most commercial use because of the inability to easily detect the gas leaking. The increased use of hydrogen over traditional fossil fuels would reduce greenhouse gases and America's dependency on foreign oil. Therefore a technology that would improve safety at NASA and in the commercial sector while creating a new economic sector would have a huge impact to NASA's mission.

The Chemochromic Detector for sensing hydrogen gas leakage is a color-changing detector that is useful in any application where it is important to know not only the presence but also the location of the hydrogen gas leak. This technology utilizes a chemochromic pigment and polymer matrix that can be molded or spun into rigid or pliable shapes useable in variable temperature environments including atmospheres of inert gas, hydrogen gas, or mixtures of gases. A change in color of the detector material indicates where gaseous hydrogen leaks are occurring. The irreversible sensor has a dramatic color change from beige to dark grey and remains dark grey after exposure. A reversible pigment changes from white to blue in the presence of hydrogen and reverts back to white in the presence of oxygen. Both versions of the sensor's pigments were comprised of a mixture of a metal oxide substrate and a hydro-chromic compound (i.e., the compound that changed color in the presence of hydrogen) and immediately notified the operator of the presence of low levels of hydrogen. The detector can be used in a variety of formats including paint, tape, caulking, injection molded parts, textiles and fabrics, composites, and films. This technology brings numerous benefits over the traditional hydrogen sensors: The technology has excellent temperature stability (4 K to 373 K), it can be used in cryogenic fluid applications, it is easy to apply and remove; it requires no power to operate; it has a quick response time; the leak points can be detected visually or electronically; it is nonhazardous, thus environmentally friendly; it can be reversible or irreversible; it does not require on-site monitoring; has a long shelf life; the detector is very durable; and the technology is inexpensive to manufacture.

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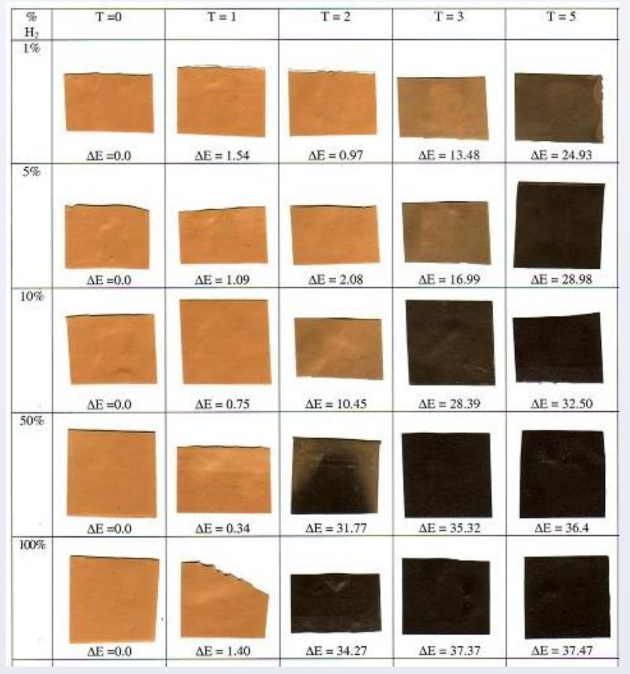
THE TECHNOLOGY

Color change of the irreversible sensor over time.



The principal advantage of these tapes over other hydrogen sensing technologies is that they do not require power for operation, which is desirable since hydrogen is flammable and electronics represents a potential ignition source. One of two different pigments can be incorporated into the tapes, one that changes color only once (i.e., irreversible) upon exposure to a threshold dose of hydrogen and one that changes colors multiple times (i.e., reversible) upon cycling between hydrogen and oxygen containing environments. This technology is significant, because it provides a breadth of possible applications for safe operations when using gaseous or liquid hydrogen. The technology in supporting NASA 's highest priority in safety could also have a significant benefit in helping protect the surrounding environment , like the Kennedy Space Center 's National Wildlife Refuge or surrounding areas of Stennis Space Center in helping decrease chances of large scale fires. As (1) the hydrogen economy becomes more prevalent, (2) the cost of gasoline rises, and (3) carbon dioxide emissions are further regulated, technologies like the Chemochromic Detector would be regularly used to improve public safety, awareness, and confidence.

Products include tape, paint, injection and blow molded parts, fibers, and textiles.

AWARDS AND RECOGNITION

R&D Magazine's 2014 R&D 100 Award
NASA 2014 Spinoff Magazine Feature
2009 NASA Environmental and Energy Award

4 US Patents Issued, 2 Pending

Chemochromic Hydrogen Leak Detectors. **L. B. Roberson**, J. E. Captain, et. al. *NASA Tech Briefs*. **2009**, V33, No. 6, pp 54.

DEPLOYMENT AND OPERATIONS

Deployment of tape for cross country lines during STS-130.

Testing on hydrogen pressurization lines during tanker loading.

Deployment of tape on hydrogen fuel cell lines during STS-120.

TEAMWORK LEADS TO SUCCESS

The team that invented and commercialized the Chemochromic Detector consists of 12 people. Dr. Luke Roberson, a KSC chemical research scientist and principal investigator, Dr. Martha Williams, a KSC NASA chemist and lab lead, and Dr. Janine Captain, a KSC NASA environmental chemist, all located within the Materials Science Division of the Engineering Directorate at KSC. Trent Smith, now with the KSC Space Station Directorate, and Dr. LaNetra Tate, now with NASA HQ, supported article manufacture of tapes and fabrics. Dr. Ali T-Raissi, Dr. Nahid Mohajeri. Dr. Gary Bookerman and Dr. Nazim Muradov, all employed by the Florida Solar Energy Center at UCF invented, synthesized, and patented the reversible and irreversible pigments. This broad team with unique expertise worked to come up with a solution that would provide a safe, effective, and economical way to locate a hydrogen leak. New Walsh, CEO of DeWAL Industries, was a collaborator through a NASA SAA. Shelley Ford and Jim Nichols assisted in the patenting and technology transfer. Dr. Nahid Mohajeri, founder and CEO of HySense Technology, LLC, is the licensee of the technology portfolio.

The Chemochromic Detectors project is formally a Joint Ownership Agreement (JOA) between NASA's Kennedy Space Center and the University of Central Florida's Florida Solar Energy Center. Research was initially funded through a NASA grant to Florida universities for FSEC to invent chemochromic pigments that would detect leaking hazardous gasses. Co-development of the technology was performed at FSEC to improve and advance the pigment's response rate and capabilities, while NASA incorporated the pigments into articles manufacturable for launch and commercial applications. NASA deployed these test articles for Shuttle and ground operations and provided feedback to the professors to enhance their pigments. Our collaboration with NASA Engineering operations provided successful technology infusion into NASA operations at the launch pad, at WSTF engine operations, and in the MSFC safety courses. After a successful product was created in the lab and deployed on the field, commercial companies DeWAL and HySense were approached for large scale manufacturing and license opportunities. Through teamwork with the NASA KSC Patent and Technology Transfer Offices at UCF and NASA, the team filed 6 patents, a NASA Space Act Agreement, and a joint license agreement to transfer the technology into industry through HySense Technology. External customers were also a big influence on the development of this invention. Companies such as BMW, Chevron, and Air Products provided helpful feedback when developing this technology portfolio for a wide range of commercial applications.

This project was an ideal case for how leadership and teamwork came together to take a high-impact environmental technology from concept to commercialization.

2014 R&D Magazine – R&D100 Award Presentation.

POINTS of CONTACT

For questions regarding research and technology development, please contact Dr. Luke Roberson (Luke.B.Roberson@nasa.gov).

For licensing and purchasing of products, please contact Dr. Nahid Mohajeri (Nahid@hysensetechnology.com