Corrosive Drywall and other Imported Concerns



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Presentation Outline

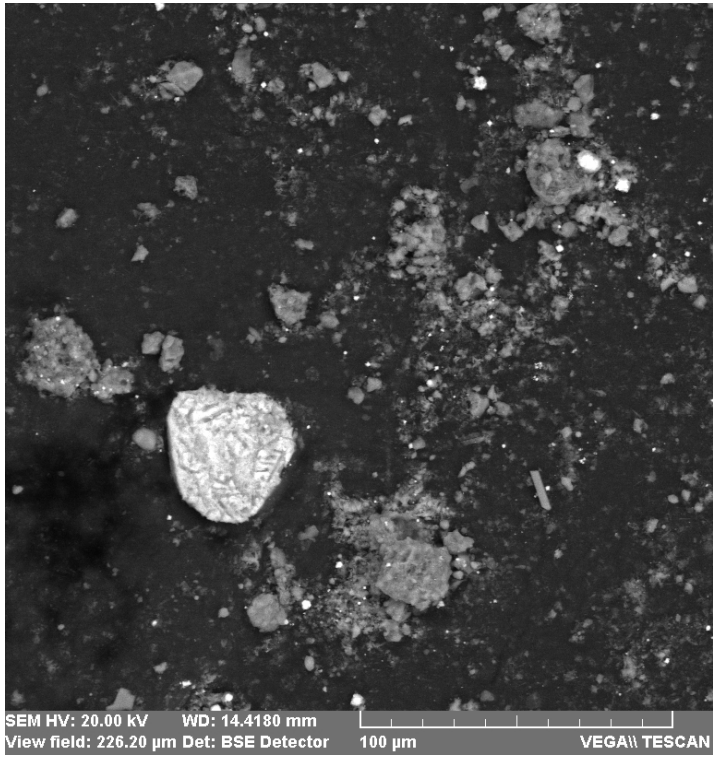
- Elemental sulfur is the distinguishing characteristic of corrosive wallboard.
- Sulfur in the wallboard reacts slowly to release reduced sulfur gases.
- Reduced sulfur gases corrode copper plumbing and electrical components in the home.
- Samples collected from repaired Lucaya residences contained elemental sulfur in wallboard.
- Remediation was required to stop the ongoing corrosion.

Elemental Sulfur is the Distinguishing Characteristic of Corrosive Wallboard

- Elemental sulfur is a "sensitive and specific marker of problematic drywall" (EH&E, 2010).
  - Strongly associated with hydrogen sulfide emissions and copper corrosion in chamber experiments.
  - Also associated with hydrogen sulfide levels in indoor air and corrosion of silver and copper coupons as part of the CPSC 51-Home study.
- Present as individual particles in the gypsum matrix.
- Likely originated as sulfur inclusions in mined gypsum.

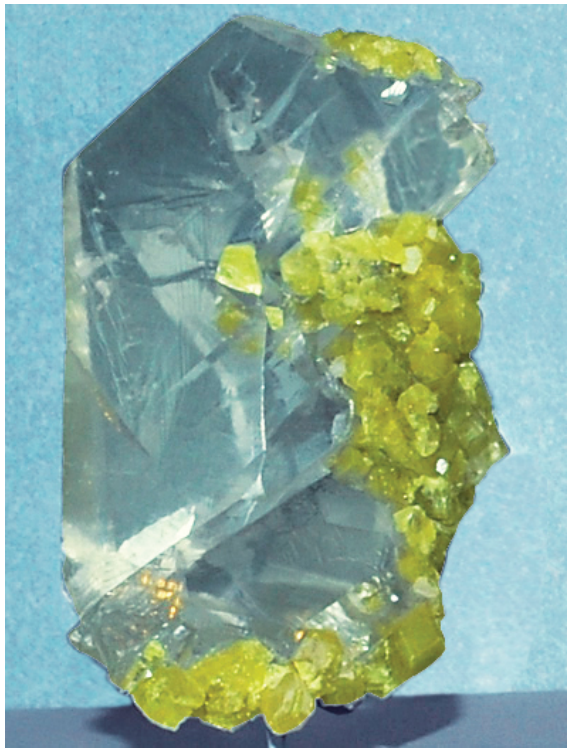
Environmental Health and Engineering, Inc. (EH&E). 2010. Identification of Problematic Drywall: Source Markers and Detection Methods. Prepared for U.S. Consumer Product Safety Commission. EH&E Report 16512. May 28.

Elemental Sulfur in Gypsum



Scanning electron microscope image of elemental sulfur particle in gypsum wallboard sample.

Source: Materials Analysis Group, Inc. Norcross, GA.



Gypsum with sulfur. Agrigento, Sicilia, Italy

Source: Smithsonian Institute

Proposed Reaction Mechanism for Generating Reduced Sulfur Gases

- Carbon monoxide reacts with sulfur to form carbonyl sulfide.

Kcal/mole

$$CO_{(g)} + \frac{1}{2}S_{2(g)} \leftrightarrow OCS_{(g)} \qquad -34.2$$

- Carbonyl sulfide hydrolyzes to form hydrogen sulfide.

$$OCS_{(g)} + H_2O_{(g)} \leftrightarrow H_2S_{(g)} + CO_{2(g)} \qquad -7.1$$

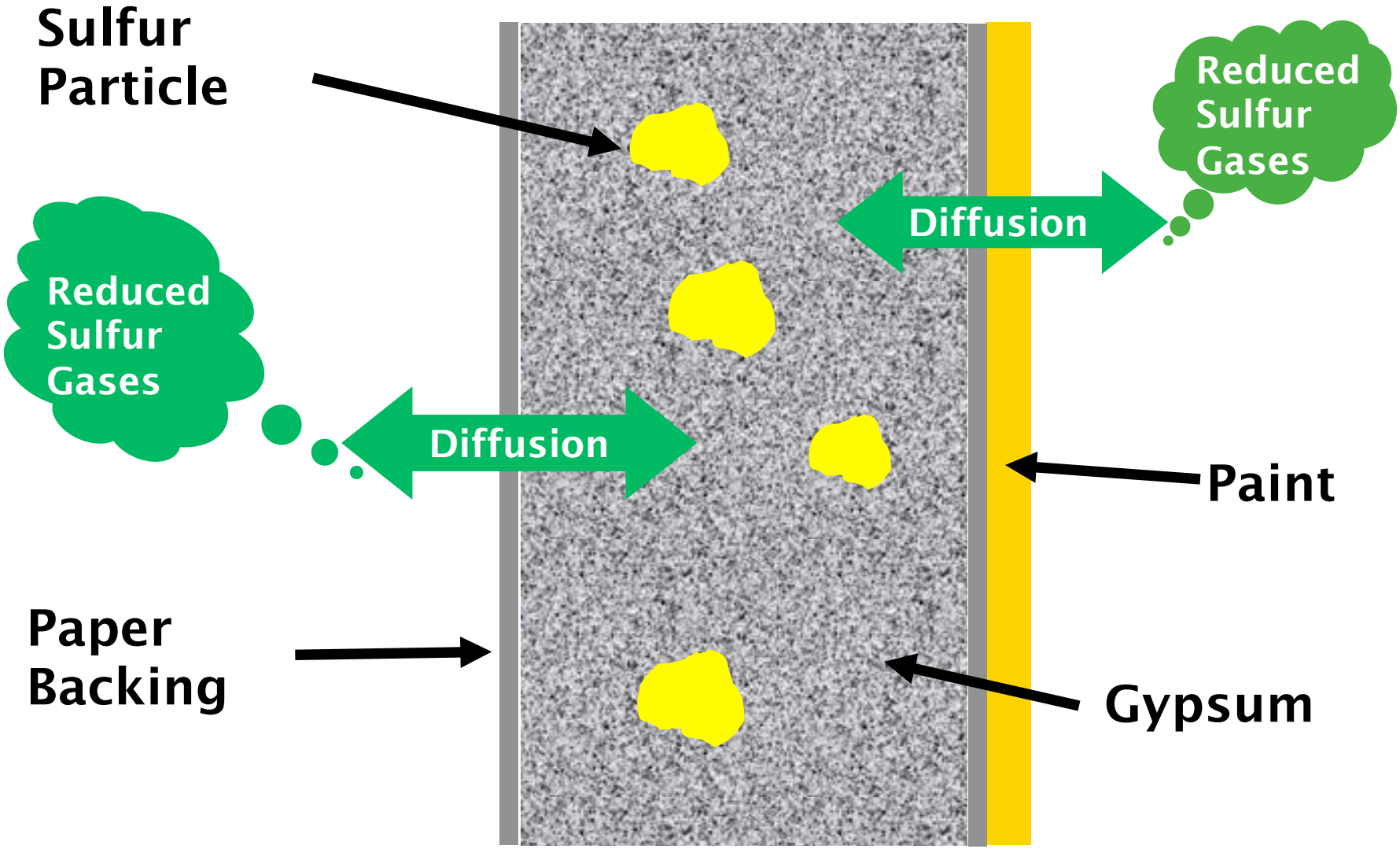
- Competing reaction generates carbon disulfide.

$$2CO_{(g)} + S_{2(g)} \leftrightarrow CS_{2(g)} + CO_{2(g)} \qquad -32.0$$

Proposed Mechanism (cont.)

- Thermodynamically favored.
- Supported by experimental data showing increased OCS with added CO
  - Performed in experimental chambers containing corrosive wallboard.
- Consistent with empirical evidence showing effect of moisture (humidity) on corrosion.
- **Reaction will proceed until sulfur is depleted.**
  - Projected to be on the order of tens to hundreds of years depending on site conditions and level of sulfur in the wallboard.

Drywall Schematic Illustrating Release of Reduced Sulfur Gases



Reduced Sulfur Gases Corrode Copper Plumbing and Electrical Components in the Home

- Number of studies have shown that both OCS and H_2S are corrosive in humid air (e.g. Graedel et al., 1981; Tran et al., 2003).
- **Rate of corrosion is approximately linear with total exposure** (i.e. the product of exposure time and sulfide concentration)(Graedel et al., 1981).
  - Thus, 10 years exposure to 1 ppm produces the same effect as 1 year exposure at 10 ppm.
- Experiments show **corrosion continues even after corrosive wallboard is removed.** (Freeman et al., 2011).

Graedel, T.E., G.W. Kammlott and J.P. Franey. 1981. *Science* 212:663-665.

Tran, T.T.M, C. Fiaud, E.M.M. Sutter, and A. Villanova. 2003. *Corrosion Science* 45: 2787-2802.

Freeman, G.B., R. DeMott, T. Gauthier, M. Stevenson and J. Hubbard. 2011. *J. Fail Anal. And Preven.* 11:265-273

Rate of Corrosion is Linear with Total Exposure

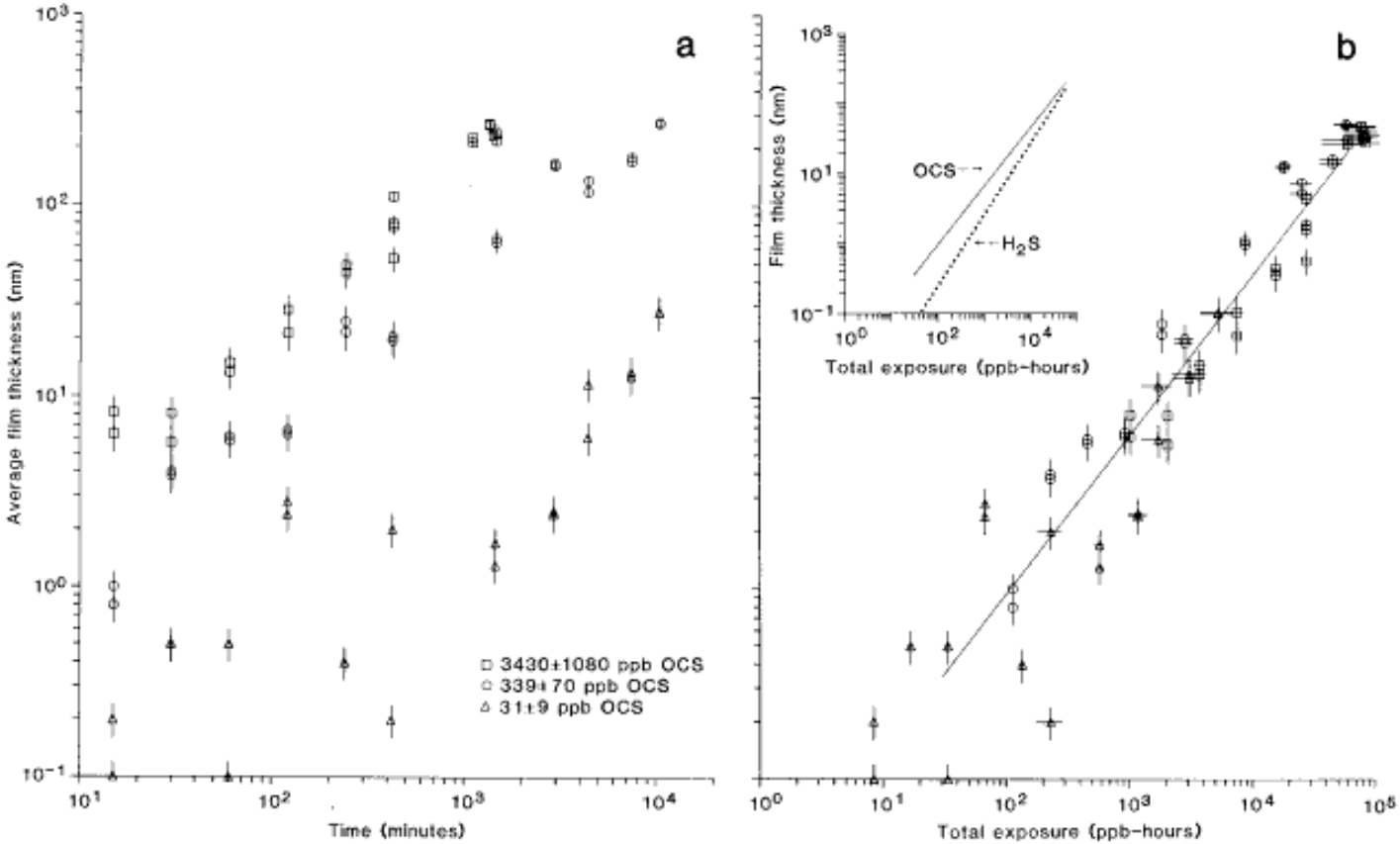


Fig. 1. (a) Sulfide film thickness as a function of exposure time for different OCS concentrations. All exposures were made within the experimental ranges temperature = 20° ± 2°C and relative humidity = 80 ± 4 percent. (b) Sulfide film thickness as a function of total exposure to OCS. The solid line is a least-squares fit to the data points. The inset compares the rate of copper corrosion by OCS to that produced by H_2S exposure, as determined under the same experimental conditions (9).

SCIENCE, VOL. 212, 8 MAY 1981 0036-8075/81/0508-0663$00.50/0

Graedel, T.E., G.W. Kammlott and J.P. Franey. 1981. *Science* 212:663-665.

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Visible Corrosion Observed in Most Homes

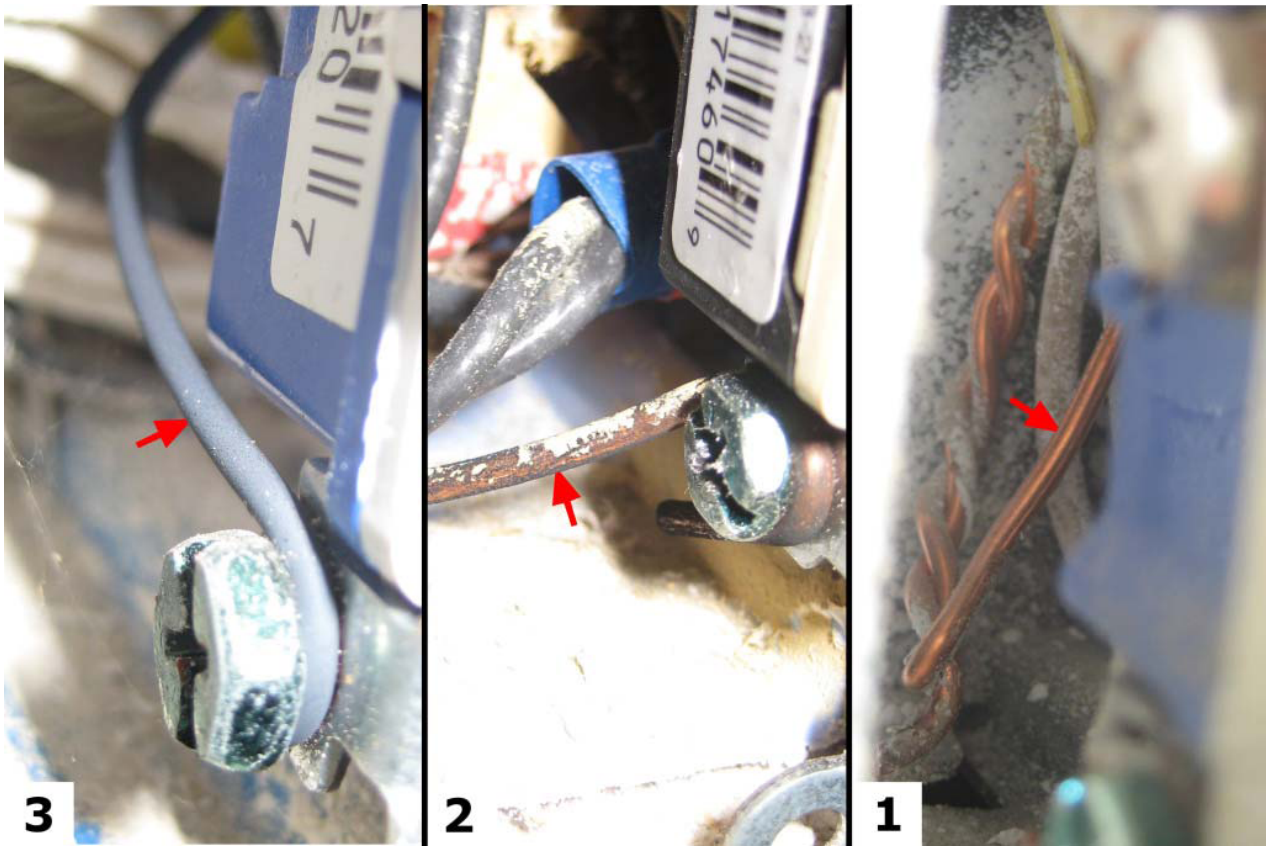
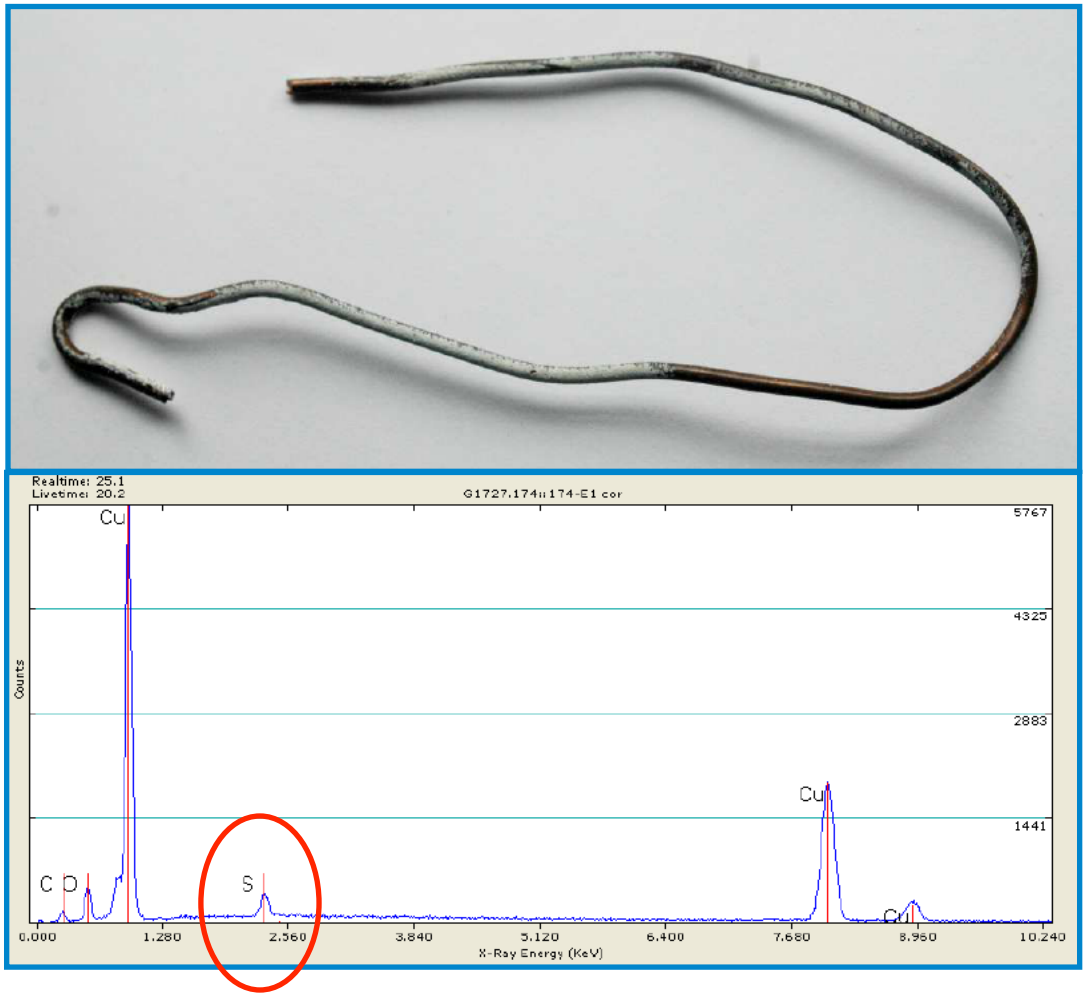


Figure 4.1 Example of Visual Corrosion Ratings, Electrical Ground Wire
(3—Significant Visible Corrosion, 2—Moderate Visible Corrosion, 1—No Visible Corrosion)

(Source: EH&E, 2010. Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall)

Sulfur Corrosion Detected on Copper Wire Collected from Residence



"In addition to the paint residue, areas of oxidation and copper oxide/sulfide were present on the surface of this sample. Sulfur was identified as a significant component of some areas of corrosion seen on this sample."

Materials Analysis Group Inc., Project No. G1727.174, August 3, 2010

IMT Gypsum detected at 1.5 to 2.5 ppm

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Corrosive Effects Depend on Multiple Factors

- The severity of corrosive effects observed depends upon a number of factors including:
  - Level of sulfur in the wallboard.
  - Percentage of defective wallboard in the home.
  - Ventilation conditions.
    - Air exchange rate in the home.
  - Environmental conditions.
    - Temperature.
    - Humidity.
  - **Exposure Time.**

Drywall Conclusions (cont.)

- Emissions of reduced sulfur gases will continue until elemental sulfur is depleted.
  - Projected to take tens of years.
- Experiments suggest corrosion of copper will continue even after corrosive drywall is removed.
- Even homes with low sulfur Chinese Drywall (i.e. < 10 ppm) need to be remediated to prevent longer-term corrosion observed in homes built with higher sulfur (> 10ppm) Chinese drywall.

So Why are We Here and What Have We Learned?

- Between 5-8k homes structures were affected
- Billions spent for repair, litigation and settlement
- Millions of pounds of waste generated
- Not all responsible parties held accountable

Another example of an imported material with unforeseen consequences.

Other Imported "Mistakes"

- "Samsonite Pulls Luggage Amid Cancer Claims"
  - Elevated PAH's
- "Rubber on Violin Cases"
  - Tetrachloroethylene
- "The Gingerbread Man"
  - 1,2-Dichloroethane (DCA)
  - http://www.sciencenews.org/view/generic/id/49897/description/Case_of_the_toxic_gingerbread_man

Areas of Concern

- Asbestos – 1973 vs. 2013
- Lead
- Mercury – rubber soles of children's shoes
- Melamine – food stuffs for humans and pets
- Chromate – children's toys
- Formaldehyde – engineered building materials, household products
- Antifreeze – toothpaste
- Tires – absent tread separation features
- Seafood – drugs banned by the FDA

China – Increasing Influence in the Global Marketplace

- 80% of toys sold in US are from China
- Top producer of tires
- Top supplier of seafood worldwide
- More than half of all CPSC recalls are for Chinese manufactured products and nearly all toy recalls are for Chinese manf. toys

Thoughts for the Future

- What tradeoffs or concessions are we willing to accept for the influx of inexpensive goods?
- The global economy will continue to expand

"Those who cannot remember the past are condemned to repeat it" George Santayana 1863-1952