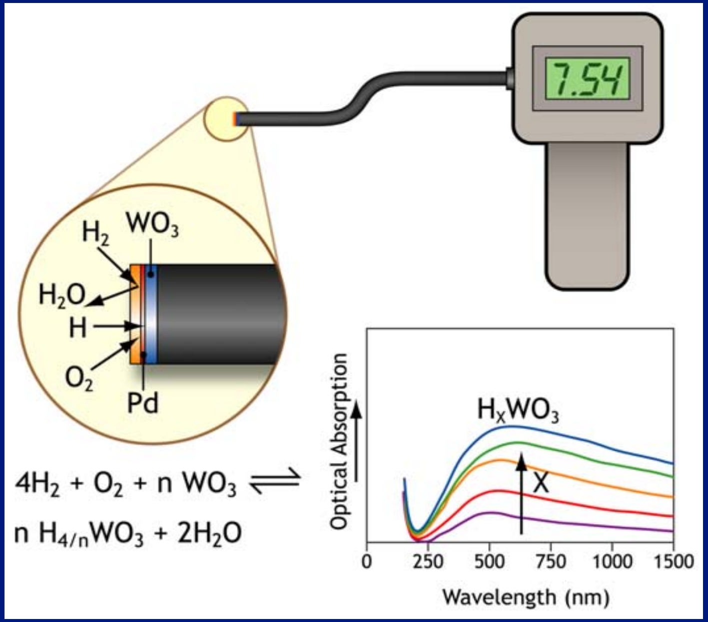
National Renewable Energy Laboratory

Hydrogen Safety Sensor Development

Interfacial Stability of Thin Film Sensors



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May 22, 2003

Program Relevance

- **Hydrogen Safety:** "**A catastrophic failure in a Program-funded project could cause irreparable damage to the entire transition strategy**. The Safety Plan delineates the steps that the Program is taking (including the use of safety sensors) to ensure that its projects are performed in a safe manner. … **Safety devices, including sensors**, fail-safes, and interlocks, are an integral part of any hydrogen process and must be included in all system designs."

- **Hydrogen Delivery (Pipelines):** "Develop lower cost material, seals, components, **sensors**, and controls."

- **Fuel Cells:** "Program objectives will be accomplished through R&D on materials and components as well as on high-volume manufacturing processes for fuel cells, fuel processors, and balance-of-plant components such as air compressors, and **sensors** and controls."

Safety Sensor Performance Goals

- Measurement range: 0.1–10% H_2 in air
- Operating temperature: -30–80 °C
- Response time: <1 s
- Accuracy: 5%
- Gas environment: ambient air, 10–98% RH range
- Lifetime: 5 y
- Interference resistant (e.g., hydrocarbons)

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Approach

1. Use thin film materials that change color in the presence of hydrogen.
2. Optimize film structure to be selectively sensitive to hydrogen.
3. Probe optical state of films remotely with light beam.
4. Use design criteria to provide:
    - Stable, repeatable signal
    - Long service lifetime
    - Easy servicing (replacement)
    - Low cost optical elements

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Why Thin Film/Fiber-Optic Sensor

- Inherently safe for detecting hydrogen leaks in air (no ignition energy source at the leak site).
- Immunity to electromagnetic interference.
- Can be fabricated in high volumes at low-cost (one control, many sensor heads).

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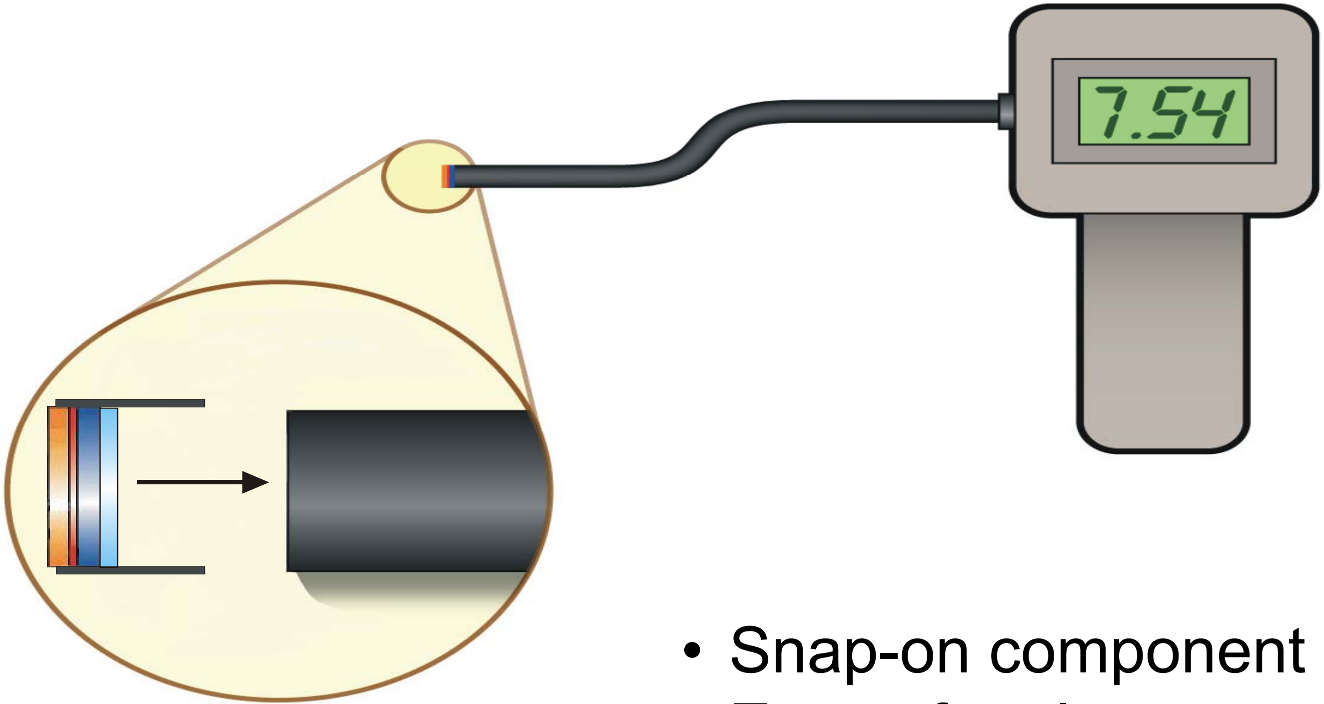
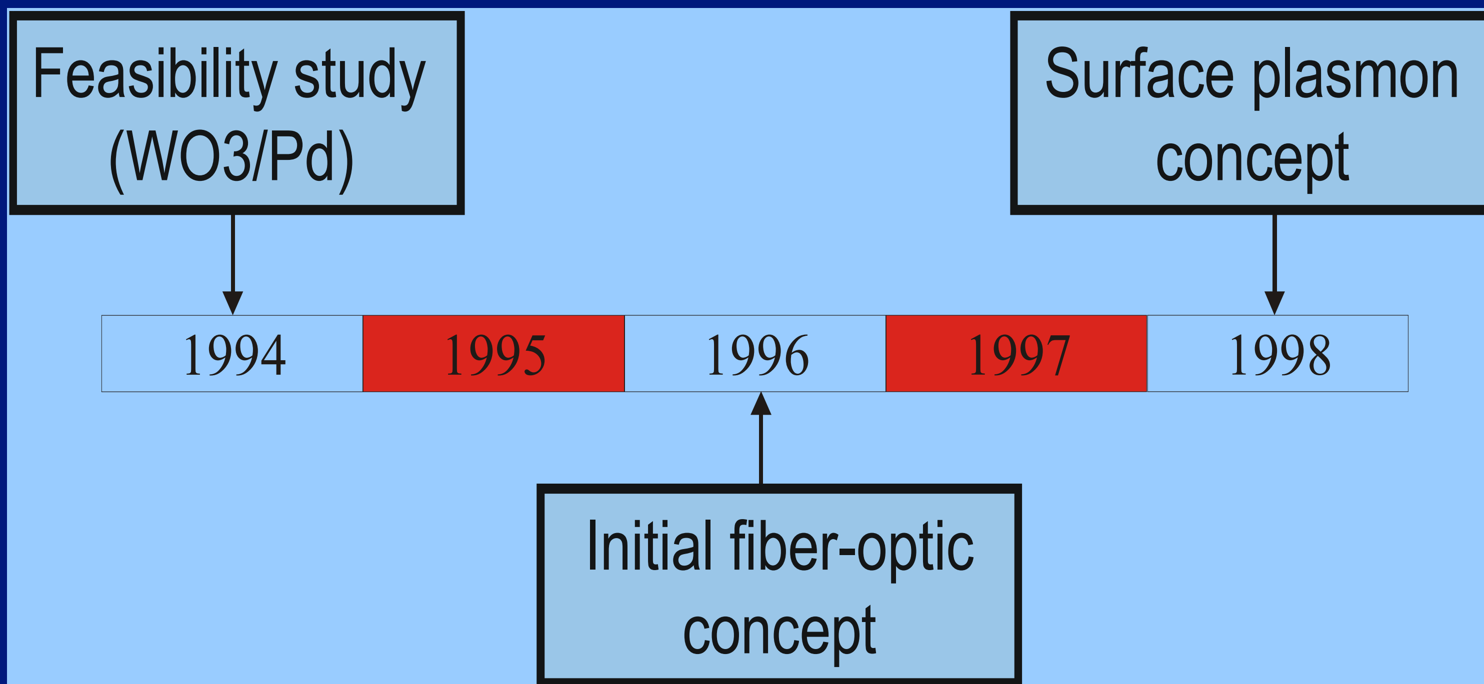
Quick-connect Sensor Head

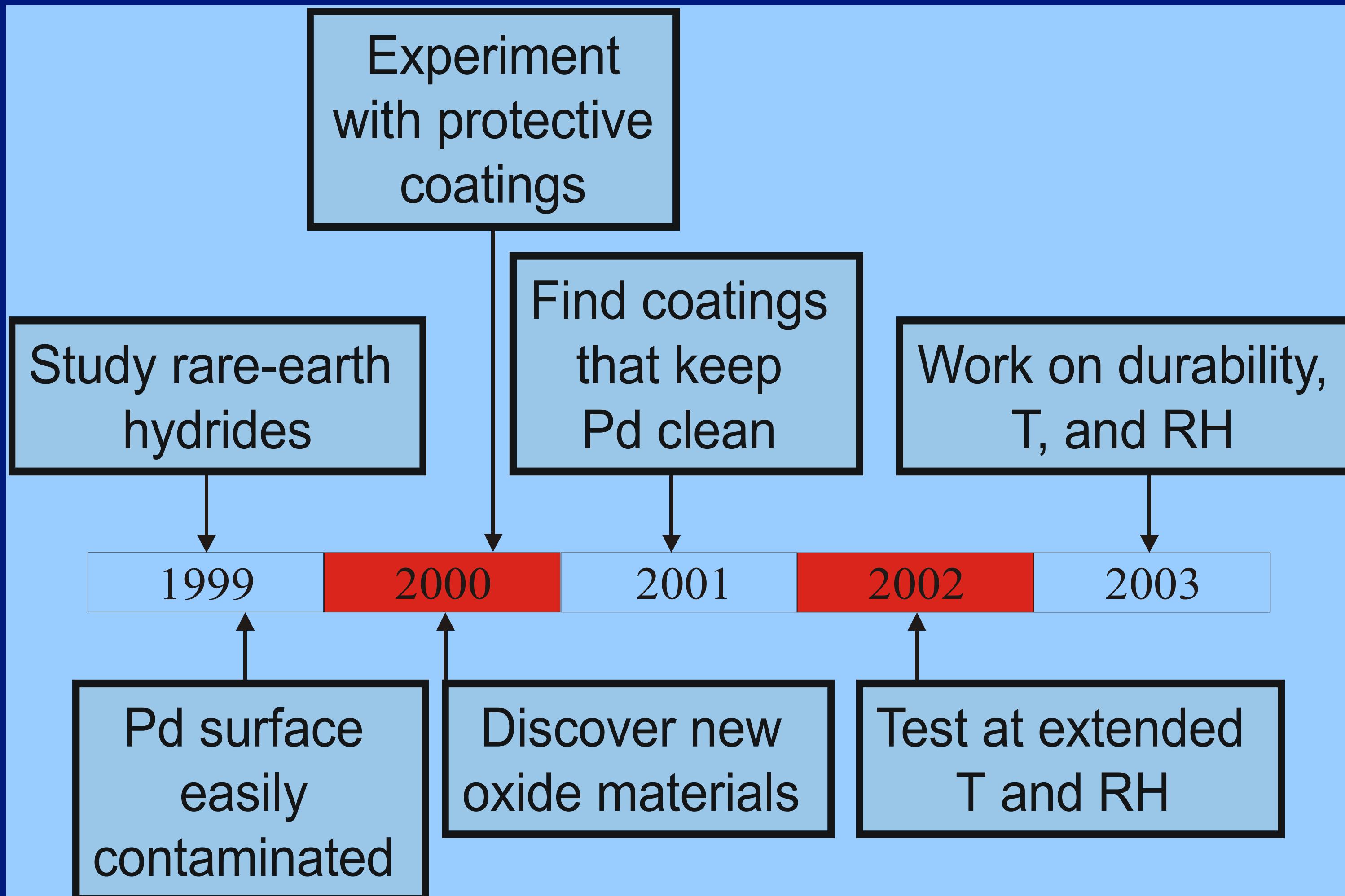


- Snap-on component
- Ease of replacement
- Low cost

Project Time-line



Time-line (continued)



Accomplishments

- **Milestone 1 (Feb. 2003):** Test thermal and relative humidity response in an interim target range of -10 to +60 ºC. This was done, reported, and extended to a range of -20 to +80 ºC by 4/03.

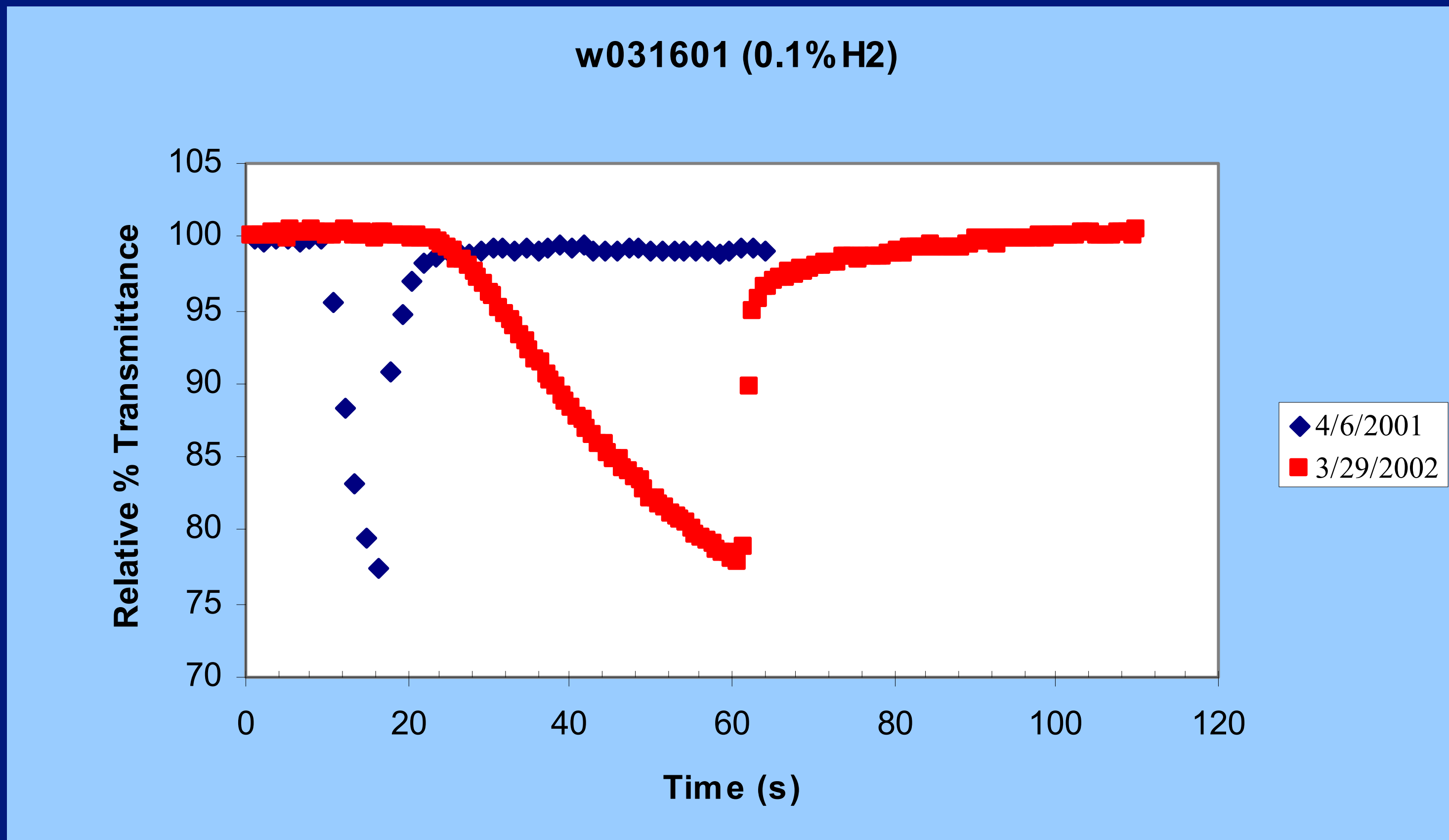
- **Milestone 2 (Aug. 2003):** Modify proprietary inorganic coating for the Pd catalyst to improve performance and increase sensor longevity (interim target lifetime 2 years). Test performance with accelerated as well as real time tests. This cannot be done on time, due to unanticipated technical (scientific) issues as well as funding issues.

Accomplishments

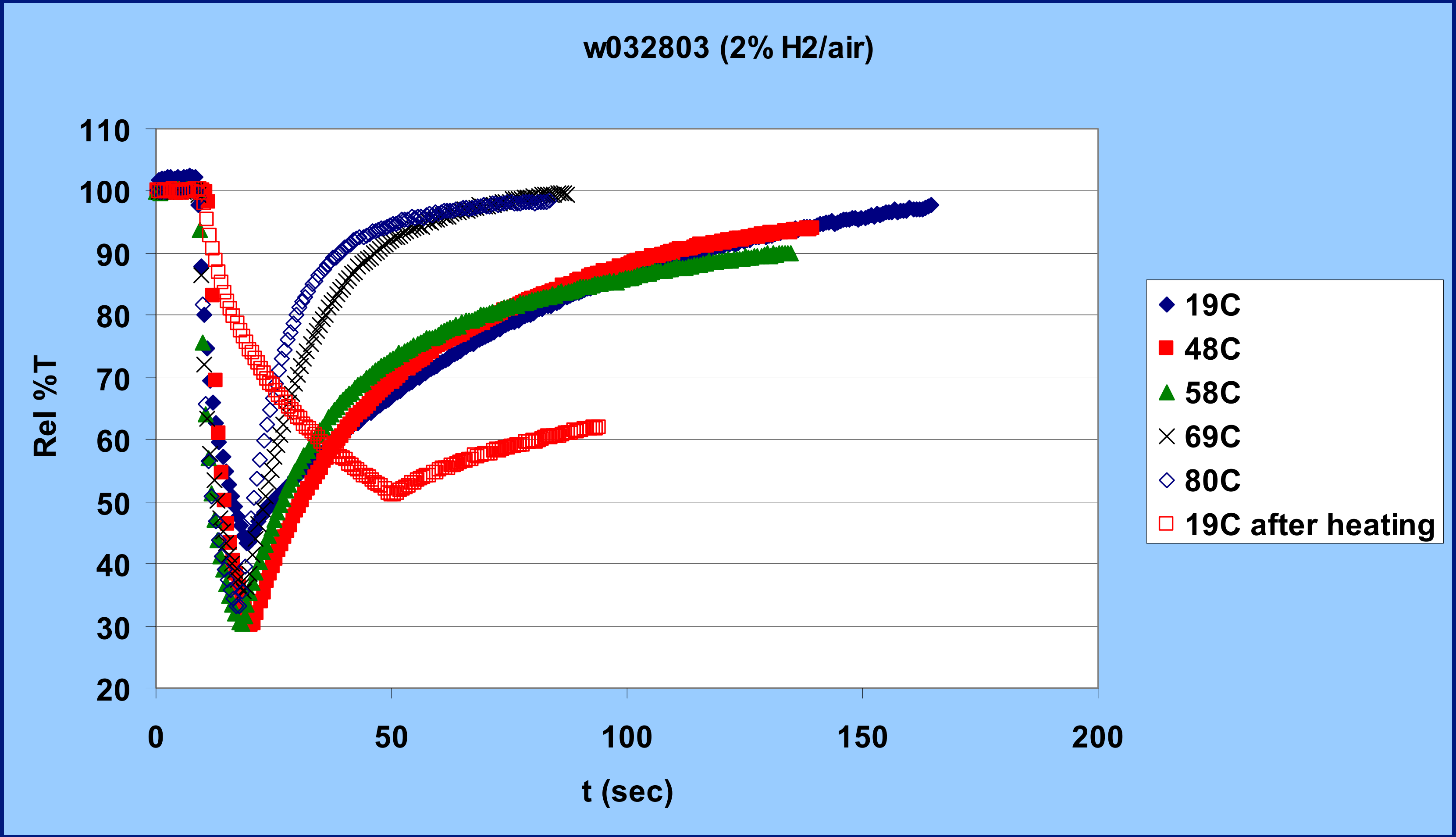
- **Milestone 3 (May 2003):** Perform experiments with new polymeric, CVD coatings to determine the level of protection from liquid water. Target flat plate sensor lifetime of 2 weeks in aqueous media. Also determine if these coatings can be used to expand the sensor measurement range below 0 ºC. This milestone was delayed due to funding issues.

- **Milestone 4 (Aug. 2003):** Provide support for the bio-hydrogen production project by making large area sensor plates. Begin negotiations for technology transfer by end of year. The first element has been done, but the second element has been delayed by funding issues.

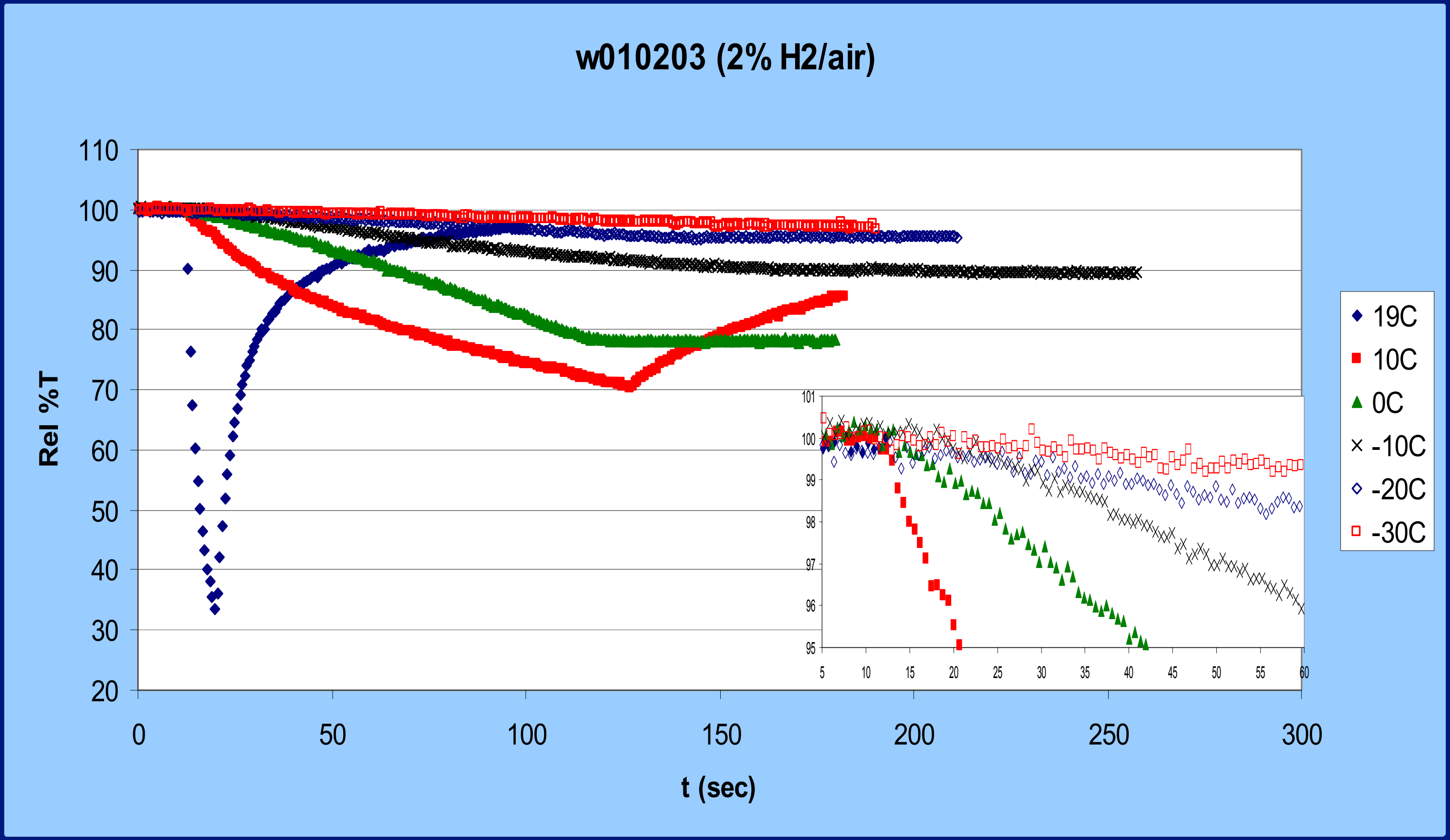
Response after 1 Year



Response at Elevated Temperature



Response at Low Temperatures



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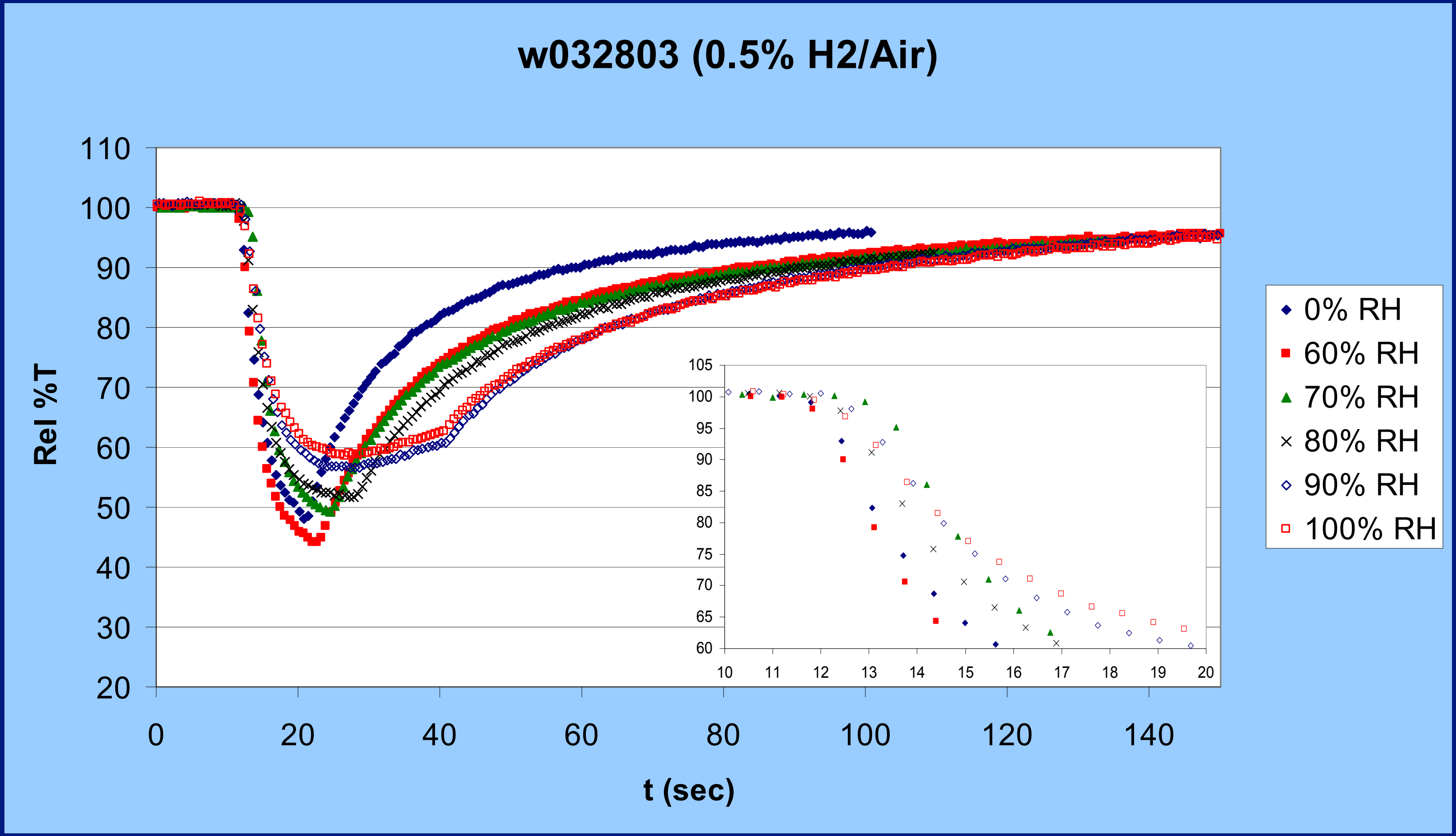
Response at Various Relative Humidities



Safety Sensor Status

- Measurement range: 0.02 – 10% H_2 in air
- Operating temperature: -20 – +80 °C
- Response time: <1 s
- Accuracy: needs to be determined
- Gas environment: ambient air, 0 – 100% RH range
- Lifetime: 1 y
- Interference resistant (e.g., all other gases)

Significant Interactions

- 3 year CRADA with DCH Technologies for sensor development terminated at the end of FY01.
- Interaction with GVD Corporation on protective polymer films for bio-sensors.
- Responded to requests to provide measurement services for a small business.
- Interaction with Element 1 on potential collaborative work in related area.
- Interaction with Davidson Instruments on fiber-optic based sensors.

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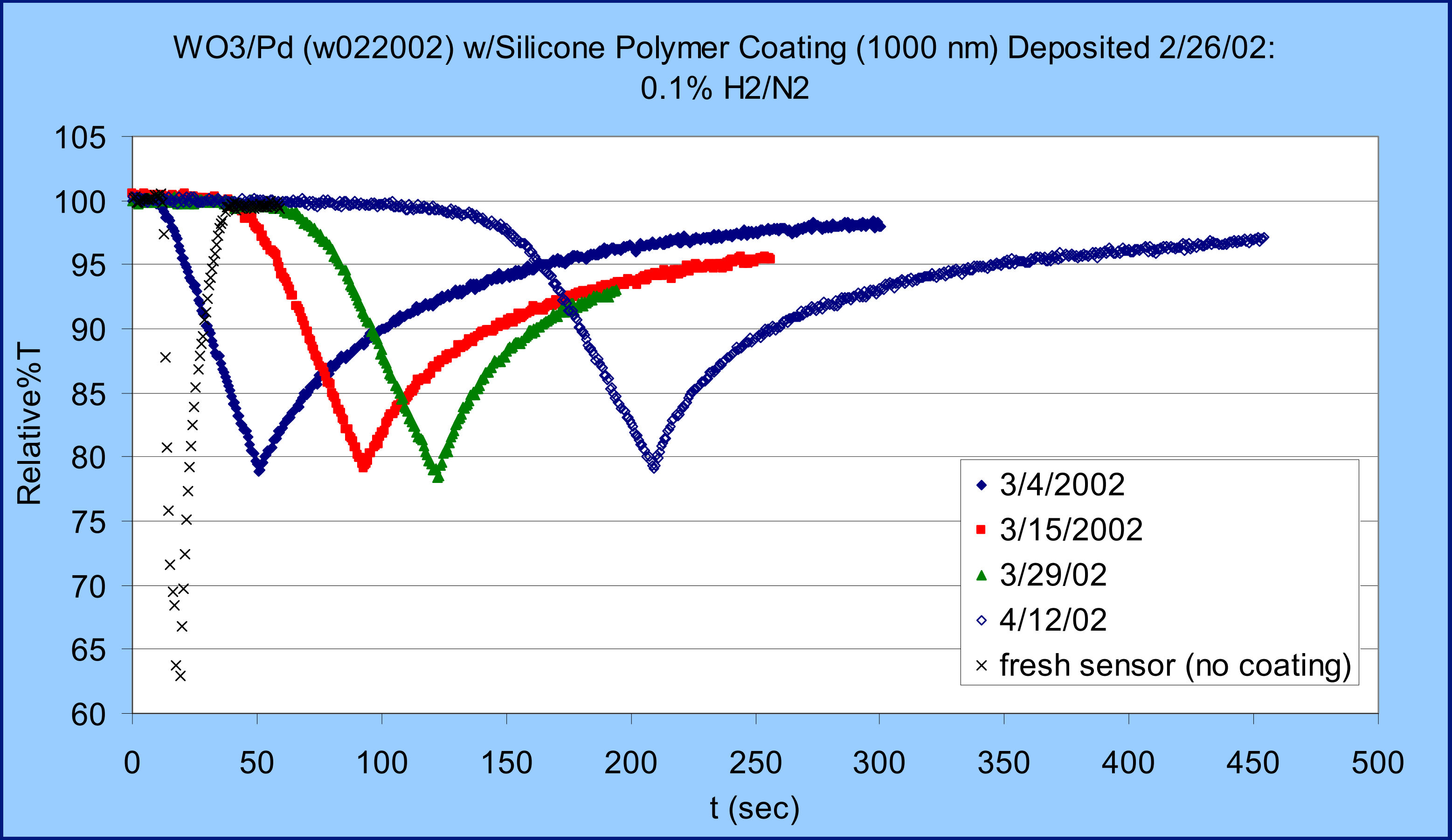
CVD Polymer Coating (GVD)



Response to Reviewers Comments

- Review workshop report for sensor design targets. (Done, targets modified beginning Qtr. 3, 2002)
- Resolve adverse effects of humidity and temperature. (Progress demonstrated, more work needed)
- Projected cost of sensors and control package still questioned. (Design study planned FY03, but delayed by funding issues)

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Plans for FY 2004

- Continue fundamental study of best protective coating.
- Investigate ability of polymeric coatings to improve low temperature and high humidity response.
- Expand collaboration with private sector to design complete sensor package and perform cost analysis.
- Fabricate prototype.

Conclusions

- Fiber-optic H_2 sensors based upon chromogenic materials are sensitive, durable, and potentially low-cost.
- Performance is close to DOE goals for safety sensors. Durability is the primary issue.
- Fouling of the hydrogen dissociation catalyst can be controlled. However, fundamental work is needed to fully understand the material science aspects of the protective coating.
- Hotwire polymeric films with controlled morphology and surface properties hold promise for superior protection in wet environments.
- Technology transfer is on the horizon.

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