Ceramatec NO_x Sensor and NO_x Catalyst Technologies

DEER Meeting, San Diego, CA

September 1, 2004

Ceramatec, Inc.

Advanced Ionic Technologies

Ceramatec Inc. - Company Information

- Founded in 1976 as a spin-off from the University of Utah
- R&D focused on commercializing advanced ceramic technologies
  - 70 patents generated
  - 110 personnel
  - Last 10 years: Over $80 million in R&D Programs
- 7 new businesses spun off & 2 business units sold: > 25 million sales/year
- Specialized expertise in ceramic electrochemical systems
  - Ionically conductive membranes
  - Solid oxide fuel cells
  - Electrochemical drug delivery systems
- New business programs: Diversification through SBIR/STTR
  - NO_x sensors, NOx removal, castable ceramics, hydrogen generation devices, ceramic coatings, fiber optic connectors, microchannel devices, ceramic armor.

Ceramatec NO_x Sensor Technology

Technology Briefs:

- US Environmental Protection Agency (EPA) funded Small Business Innovation and Research (SBIR) Phase I and Phase II awards.
- Patent pending technology - Intellectual property owned by Ceramatec.

Sensor Features:

- Low cost, small, robust, high-temperature design similar to automotive oxygen sensor.
- Sensor gives a total NO_x reading ($NO + NO_2$) irrespective of NO/NO_2 ratio
- Very high sensitivity to low NO_x.

Sensor Geometry

Ceramatec, Inc.
Advanced Ionic Technologies

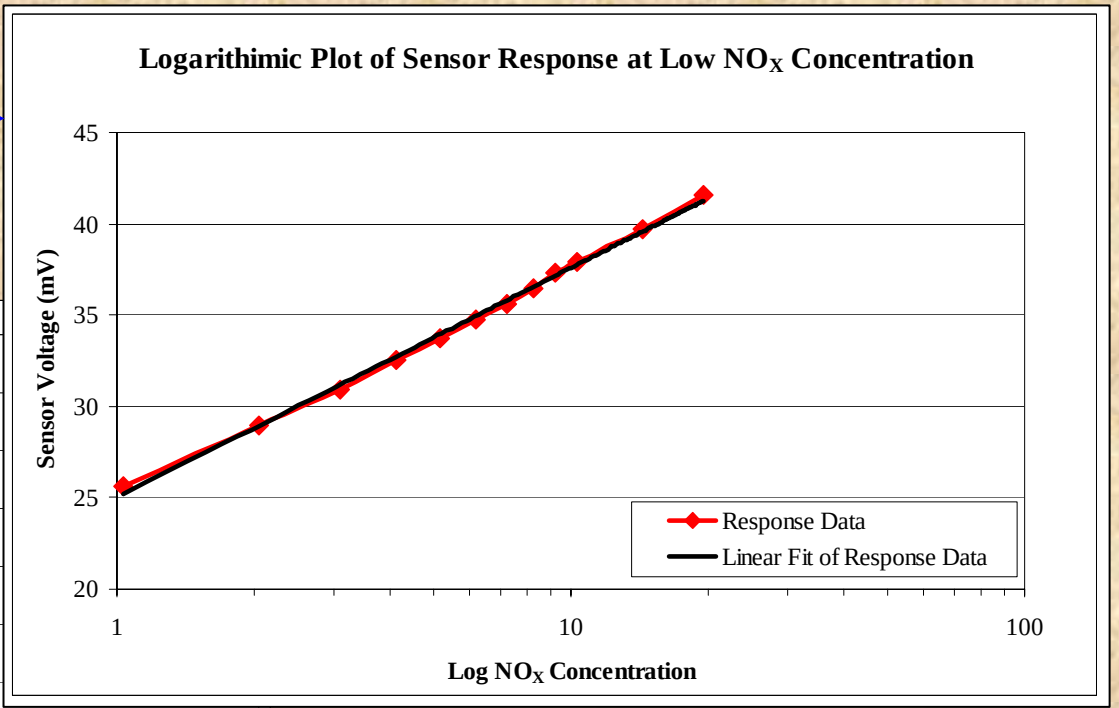
Sensor Specifications

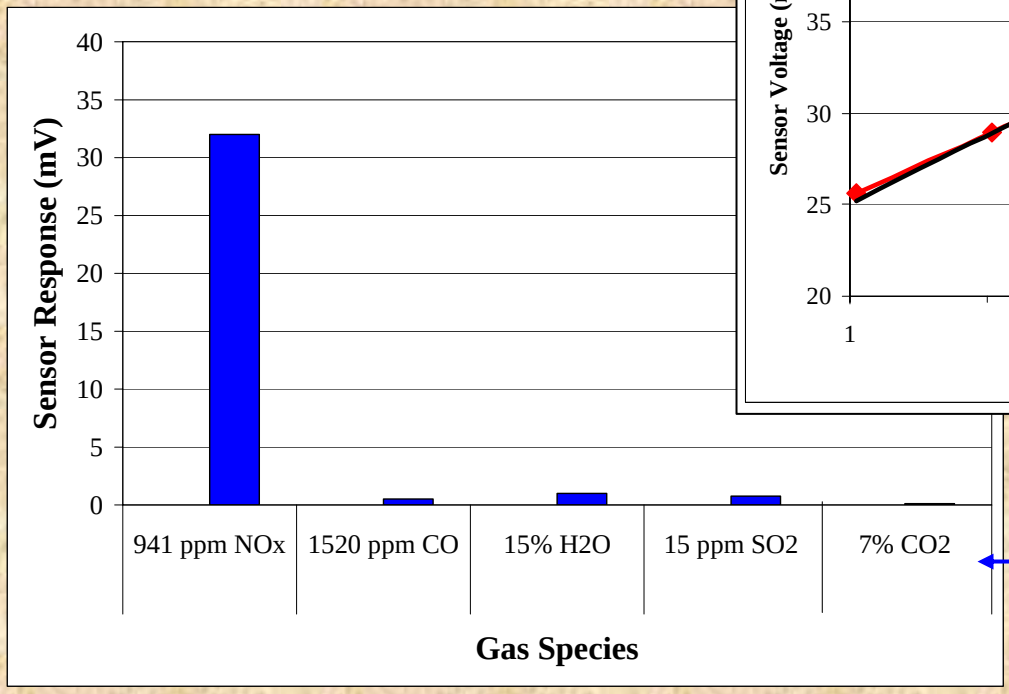
Specification	Units	Value Targeted at End of R&D	Value Obtained to Date
90% Response Time	Seconds	<1	1-3 s
Detection Range	ppm NO_x	1-1500	1-1500
Resolution	ppm NO_x	1	1
Use Temperature	^oC	500-600	500-600
Cross Sensitivity	N/A	Low cross-sensitivity to SO_2, H_2O, CO, CO_2	Very low cross-sensitivity to CO, CO_2, H_2O; SO_2 must be less than 15 ppm .
Oxygen Range	%	0 to 21%	0.01-21%

Ceramatec, Inc.
Advanced Ionic Technologies

Sensor Performance

Detection limit as low as 1 ppm





Minimal Cross-sensitivity to other gas species

Ceramatec, Inc.
Advanced Ionic Technologies

Advantages over Competing NO_x Sensor Technologies

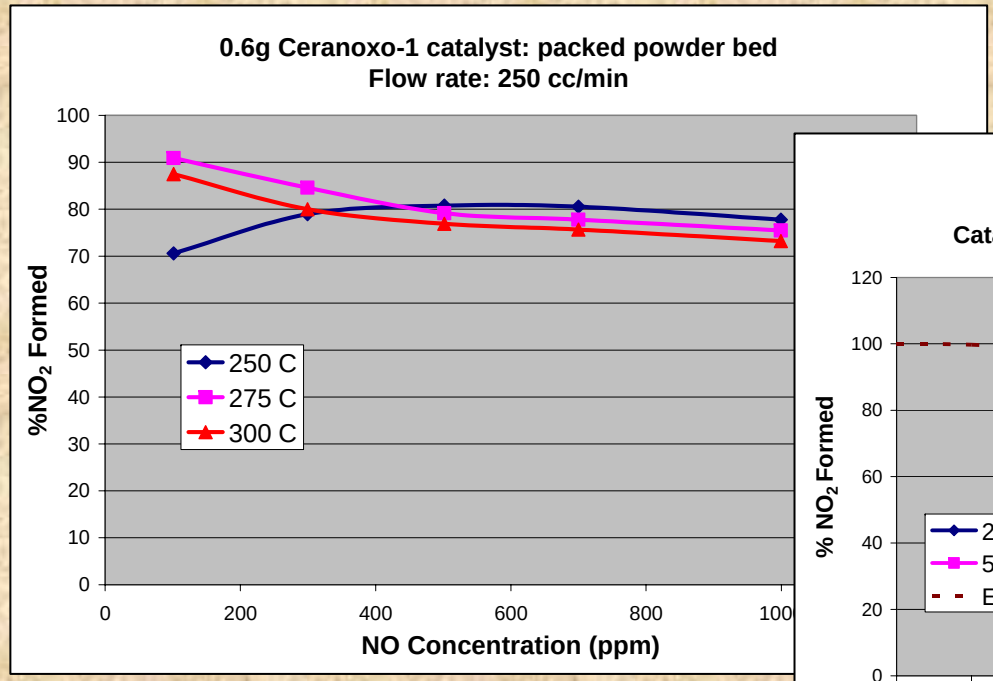
- **Advantages over commercial amperometric sensors:**
  - Very high sensitivity (1 ppm)
  - Substantially simpler design building on existing oxygen sensor technology (lower cost, improved reliability).
  - No oxygen pumping cell required (lower power requirements)
- **Advantages over competing mixed potential sensors:**
  - NO/NO_2 cross-sensitivity eliminated
  - CO cross-sensitivity eliminated
  - Design allows very fast response time
  - SO_x tolerance enhanced

Ceranoxo Catalyst Technology for NO_x Adsorbers

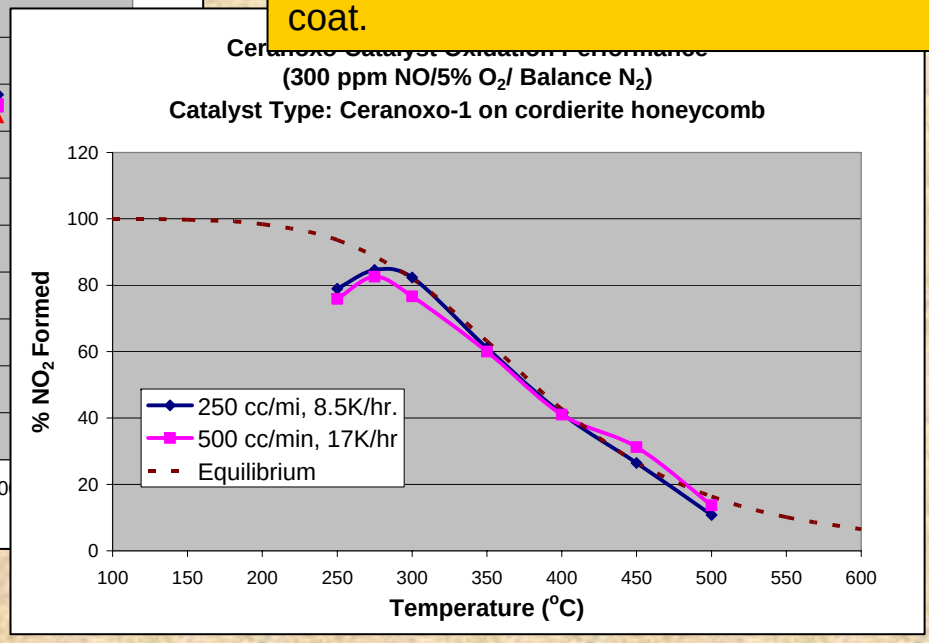
- Ceramic catalyst with **no noble metal** content
- > **90% cost reduction** over Pt-based catalysts
- > **85% NO oxidation** at 275°C
- **Successfully demonstrated** in conjuction with BaO type adsorbers for highly efficient NOx removal.

Ceramatec, Inc.
Advanced Ionic Technologies

Ceranoxo Catalyst Efficiencies for NO-to-NO_2 Oxidation



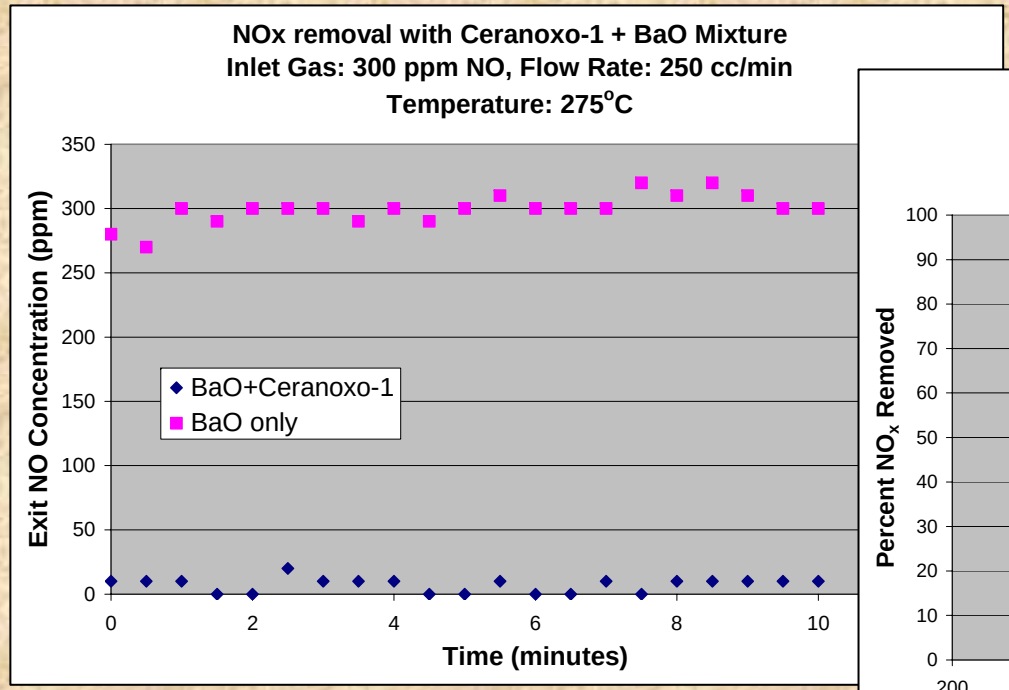
Cordierite honeycomb specs:
600 cells/in^2, No high surface area wash coat.

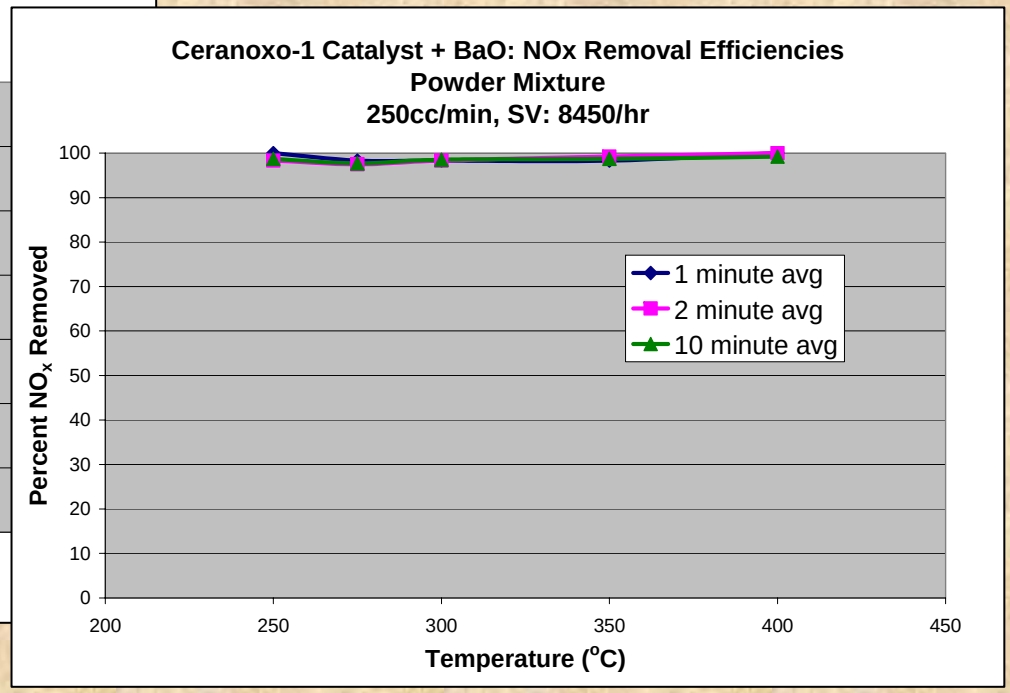


Ceranoxo-1 catalyst can achieve equilibrium at temperatures as low as 275°C (equivalent flow of ~420 SCFM through a 10” dia, 12” long honeycomb structure) with *no high surface area wash coat.*

Ceramatec, Inc.
Advanced Ionic Technologies

Combining Ceranoxo Catalysts with BaO-Type Adsorbers

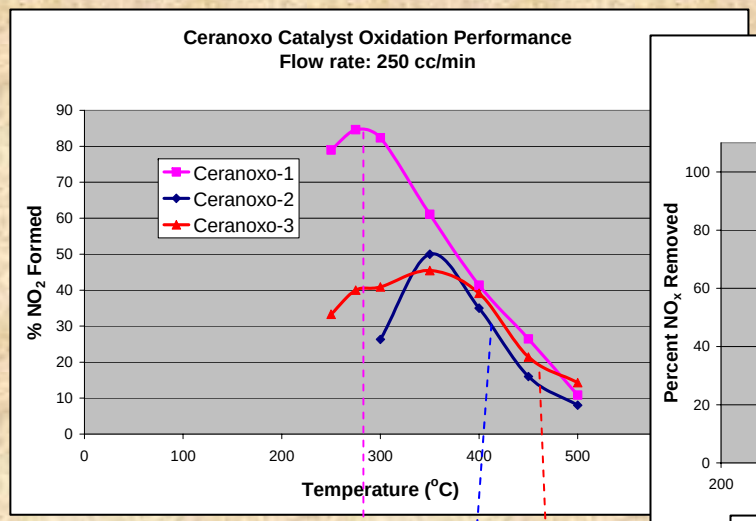


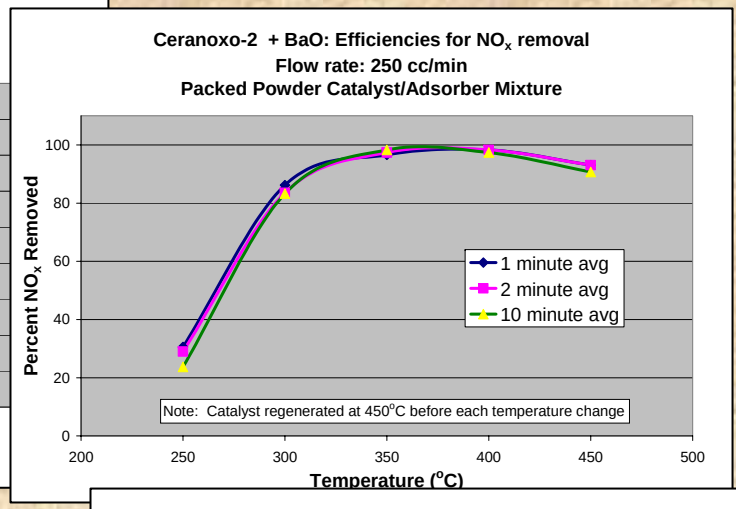


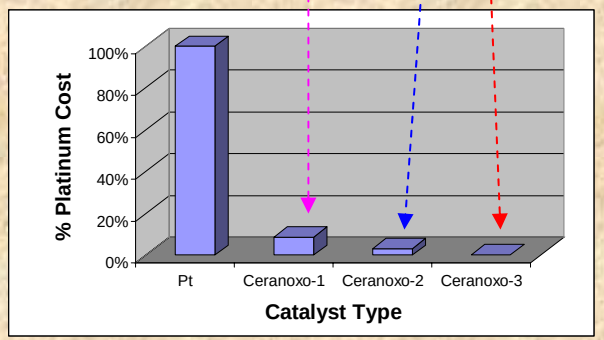
Very efficient NO_x removal demonstrated by combining Ceranoxo catalysts with BaO type NO_2 adsorbers.

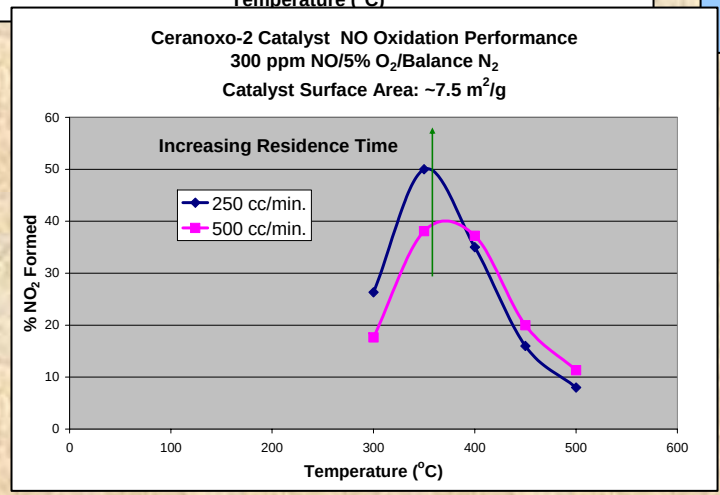
Ceramatec, Inc.
Advanced Ionic Technologies

Ultra Low Cost Catalysts Also Show Promise: Need Optimization



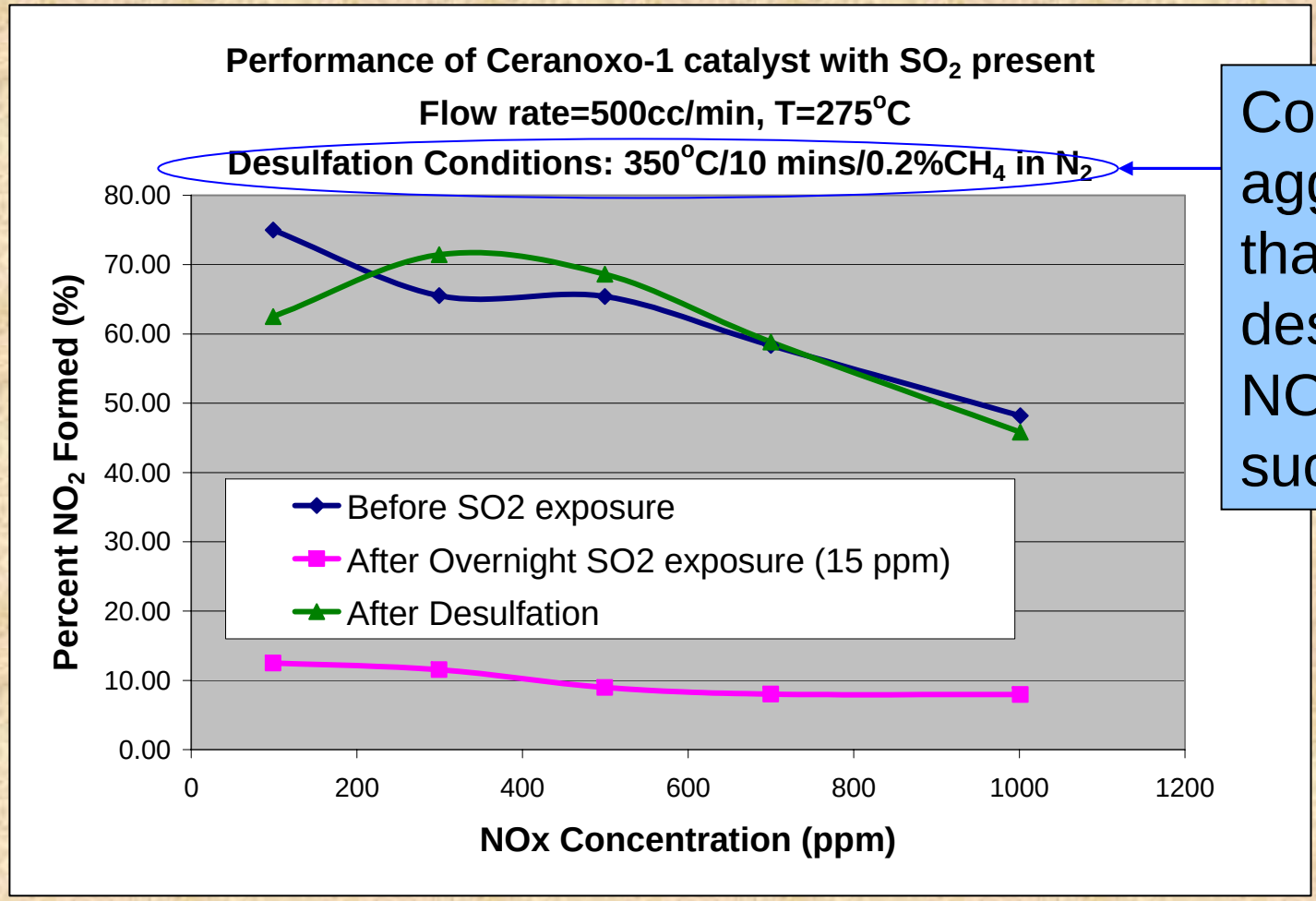






Ultra low-cost ceramic oxidation catalysts can potentially be developed and demonstrated through optimization

Sulfur is an Issue, But Not a Show-Stopper



Conditions less aggressive than that required for desulfation of NO_2 adsorbers such as BaO.

Ceramatec, Inc.
Advanced Ionic Technologies

Actively Seeking Partners ..

- Ceramatec is actively **seeking partners** for NO_x oxidation catalyst technology development and commercialization.
- We are looking to structure **win-win agreements** with:
  - Catalyst manufacturers/suppliers
  - System integrators/Tier I suppliers
  - Diesel engine manufacturers
  - Diesel truck manufacturers
- **Types of partnering** agreements
  - Joint development agreements
  - Technology Transfer Agreements
  - Licensing agreements

Acknowledgement

The work presented here was sponsored in part through Contract No. 68-D-03-061 from the U.S. **Environmental Protection Agency** (EPA).

Development Team:

Balky Nair (Program Manager)

Jesse Nachlas (Sr. Engineer)

Charles Lewinsohn (Sr. Scientist)

Sai Bhavaraju (Sr. Scientist)

Brandon Malman (Engineer)

Contact Information

Balky Nair

Ceramatec, Inc.

Tel: (801)-956-1000

Email: bnair@ceramatec.com

<u>Note:</u> Charles Lewinsohn from Ceramatec will be at the DEER meeting Sept. 1-2.