Nano-Enabled Catalysts for the Commercially Viable Production of H_2O_2

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Headwaters Technology Development Principle

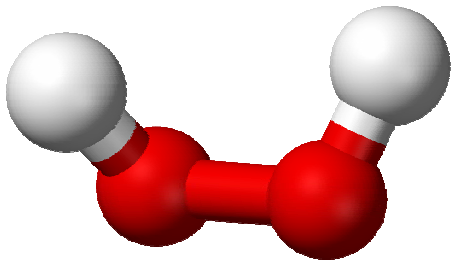
- **Develop future generation technology not only creates value for industry, but also benefits the environment and human health.**

Green Projects at Headwaters

- Waste coal conversion into solid alternative fuel
- Waste pyrolysis oil from ethylene cracking to value-added chemicals – BTX, gasoline and diesel
- NOx removal
- Sulfur removal
- Mercury removal
- **Direct synthesis of hydrogen peroxide**

Hydrogen Peroxide

- A environmental friendly molecule H_2O_2

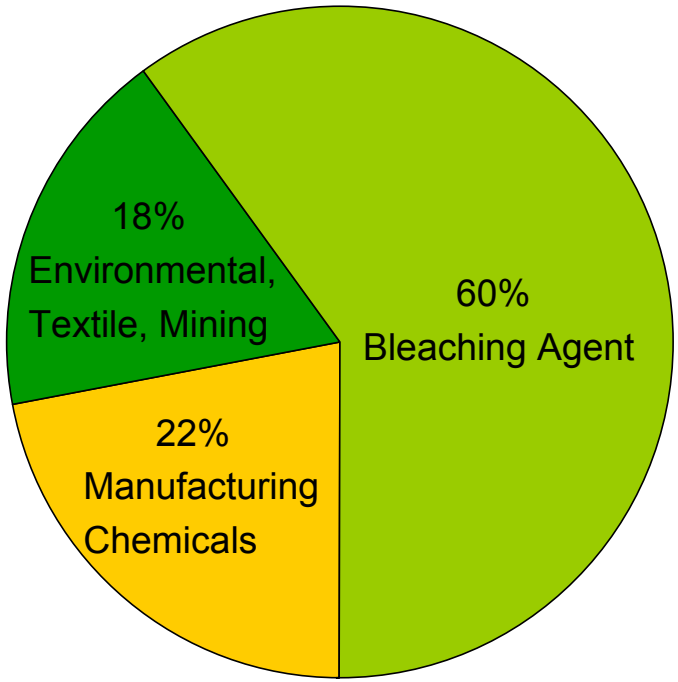


- Upon decomposition, it releases water and oxygen

$$H_2O_2 = H_2O + \frac{1}{2} O_2$$

Current Hydrogen Peroxide Applications

- 2006 global hydrogen peroxide use as oxidant ~ 2 million tons
- 2005 global hydrogen peroxide production ~ 3.5 million tons



- Demand for H_2O_2 has grown significantly in recent years. But high cost slowed down its replacement of chlorinated oxidants which have serious environmental impacts.

Chemical Industry Efforts Since 1970s

- A new process to make H_2O_2

$$H_2 + O_2 = H_2O_2$$

  - Clean process
  - Water or Alcohol as working solution
  - No waste generated
  - Water is the only by-product

- Hundreds of million dollars invested by chemical companies like Dupont, BASF, Dow, Mitsubishi, Solvey, Degussa, etc.

Direct Synthesis of H_2O_2

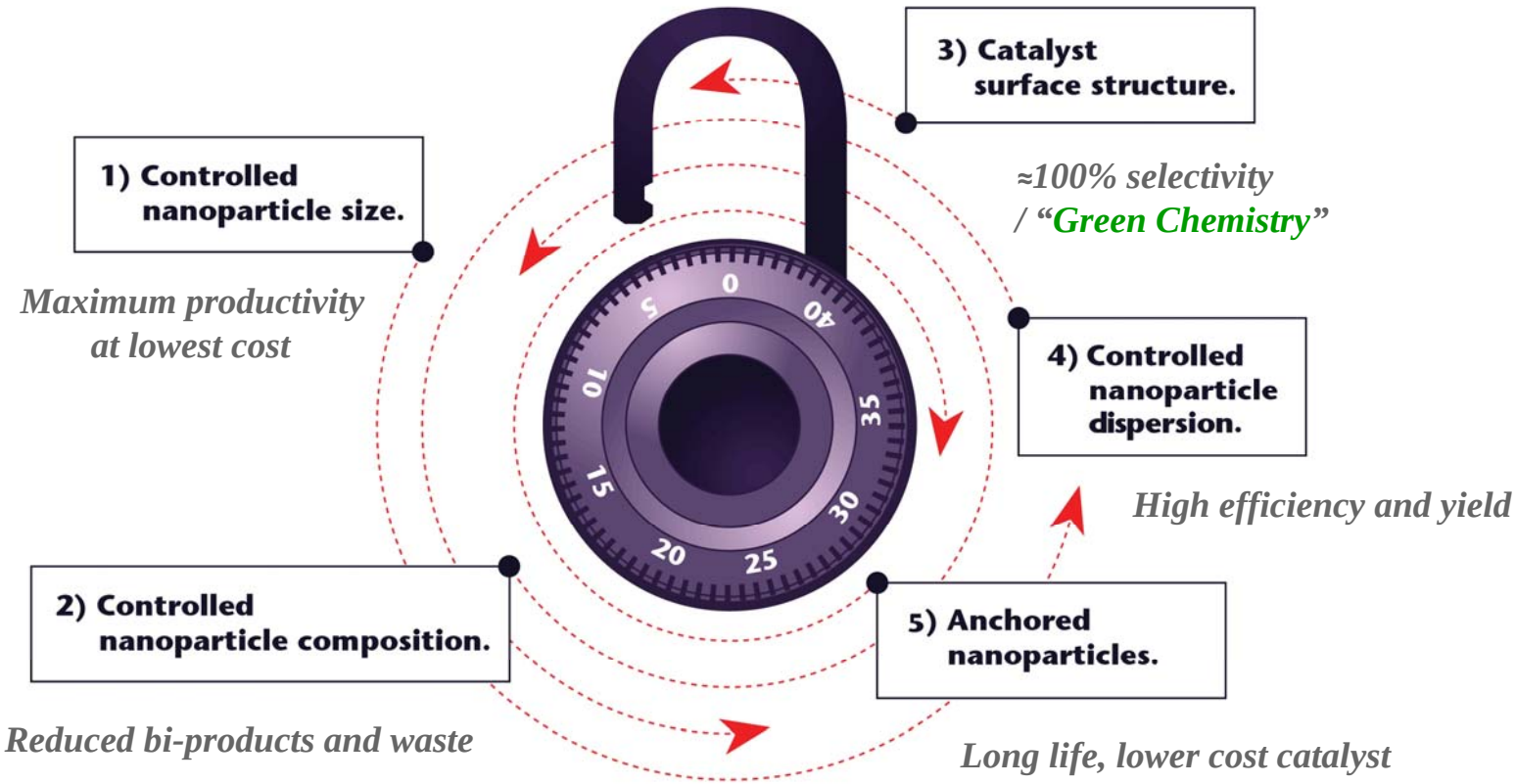
> 100 patents between 1980s and 1990s

Company	Number of Patent
Air Products	11
BASF	5
Dow Chemical	1
DuPont	11
ENI	14
Eka Nobel	1
FMC	3
Solvay Interox	6
Mitsubishi Gas Chemical	21
Shell	1

HTI's Results vs. Patented Data

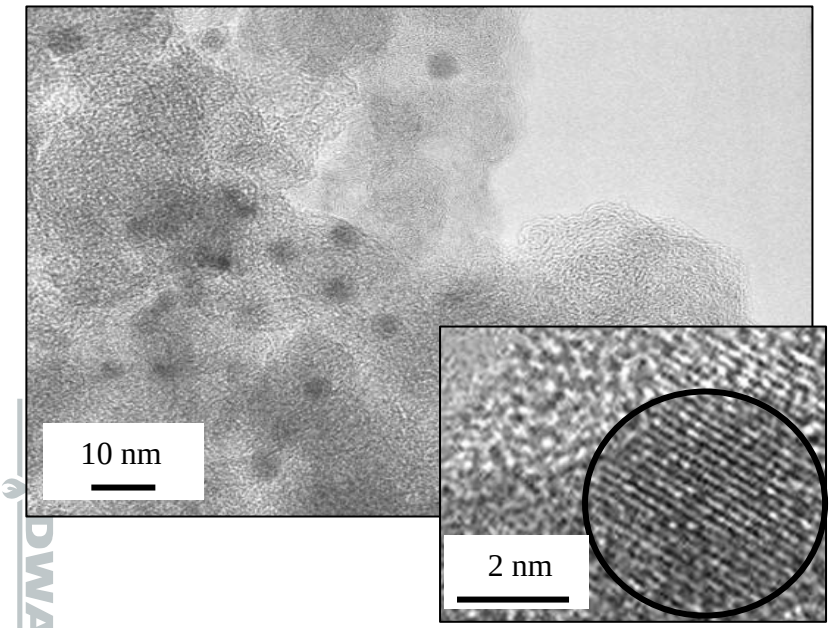
Patent Number	Assignee	H2 in Feed (vol.%)	H_2O_2 Concentration (wt%)	H_2O_2 Selectivity (%)
US 4,832,938	DuPont	18	8.0	74
US 2002 0025293	ENI	3.6	7.3	74
US 6,375,920	BASF	10	7	82
WO 02/28527	BASF	10	5.5	90
US 6,168,775	HTI	3.0	5.2	100
	HTI	3.0	9.0	99
Continuous Production	HTI	3.5	11.0	95
	HTI	3.0	7.0	98*

NxCat Nanotechnology is the Key to HTI's Process



NxCat Nanotechnology is the Key to HTI's Process

DSHP Catalyst

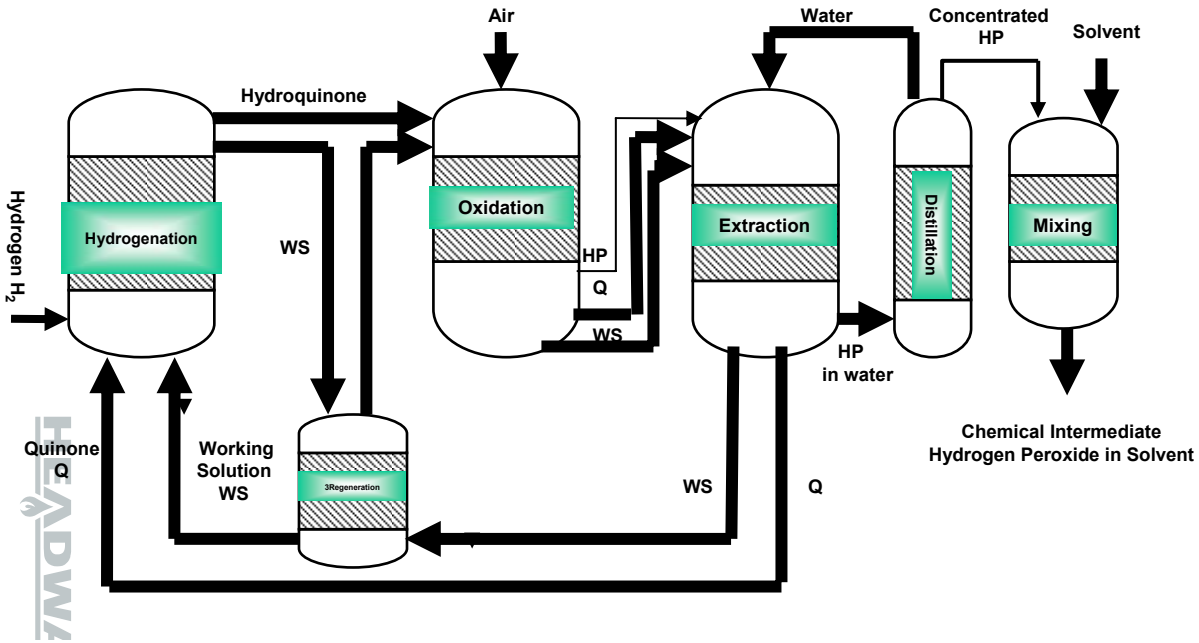


NxCat Catalyst Features

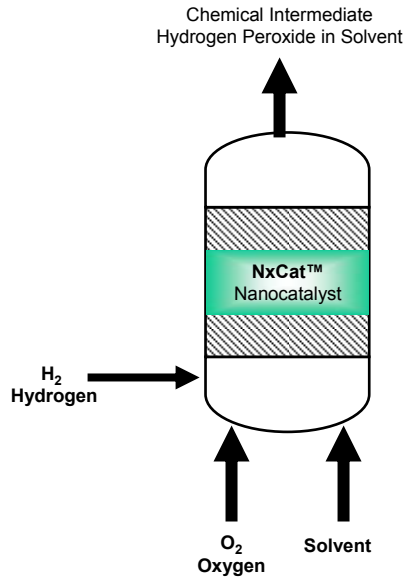
1. 4 nm particles -- *2 nm makes water!!*
2. Uniform metal alloy particles -- *50 :1*
3. 110 crystal structure *≈100% selectivity*
4. Highly dispersed low metal loading
   -- *10x more productive than competition*
5. Anchored particles *>3 year life*

Conventional vs. Direct Synthesis Process

Conventional H_2O_2 Process



Direct Synthesis H_2O_2



NxCat nanotechnology enables simple manufacturing process with up to 50% lower capital cost and 20% lower H_2O_2 cost.

Direct Synthesis of Hydrogen Peroxide Milestones

- Sept. 2004: Joint venture with Degussa
- Mar. 2005: Pilot plant operation
- Oct. 2005: Commercial demonstration plant contraction started
- Oct. 2006: Commercial demonstration plant operation
- 2007: Data collection for design of 200,000-ton commercial plant
- 2008: Commercial plant construction scheduled to start
- 2010 and beyond: every other year a new 200,000-ton plant to be built

DegussaHeadwaters

Commercial Demonstration Plant
Hanau Wolfgang, Germany

HEADWATERS INCORPORATED

Conclusions

- Direct Synthesis is an environmental friendly process
  - Reduce energy consumption by a simple and more efficient process.
  - Low cost H_2O_2 has potential to replace chlorinated oxidants that have serious environmental impacts.
- Nanotechnology is the key to enable the new cutting edge process for commercially viable production

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Direct Synthesis of Hydrogen Peroxide Team

Presidential Green Chemistry Challenge Award