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Presentation to Clean Cities:

Toward the Carbon-Free Highway

John M. Guerra, P.E.
President and CEO
Nanoptek Corporation
Maynard, Massachusetts
www.nanoptek.com

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The Company

- Nanoptek Corp. is a Massachusetts clean-tech and renewable energy company developing highly efficient sunlight-activated catalysts that are used to generate hydrogen from water, as well as to clean water, air, and surfaces
- Pilot-production stage with first sales of SHG300's to Eni (Italy) and ARC International (India)
- Funding history includes NASA, Dept. of Energy, MassCEC, and private Series A raise in 2007
- 6 patents (1 international), 13 pending (4 international)

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Team

- The select multi-disciplinary group has been together 6 to 10 years:
  - John Guerra, Founder
  - Luke Thulin, Chief Scientist
  - Dr. Amol Chandekar, Senior Principal Scientist (chemist)
  - Dr. Andrei Ursache, Senior Principal Scientist (physicist)

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Are Hydrogen Highways Carbon-Free?
(and if not, what's the point?)

- Onsite hydrogen production
  - PEM and alkaline electrolyzers using grid
    - At least 8kg of CO2 released for every kg of H2 produced
  - Natural gas reforming
    - Cleaner, but still at least 3 kg of CO2 for every kg of H2
    - Carbon sequestration?
  - Electrolyzers powered by wind or PV electricity
    - Carbon-free, but higher cost
  - Photolysis
    - Direct sunlight to hydrogen
    - Carbon-free

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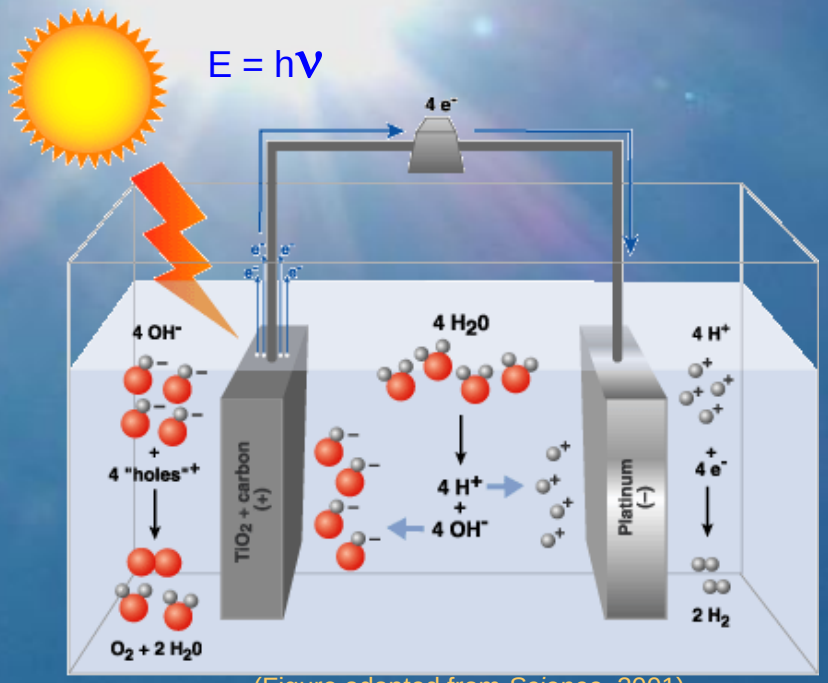
Photolysis



(Figure adapted from *Science*, 2001)

$4H_2O + 4e \rightarrow 2H_2 + 4OH$

- Basically an alkaline electrolyzer in which the anode is replaced with a photoanode
- The photoanode is Grade 1 titanium onto which a titanium dioxide (TiO_2) photocatalytic semiconductor layer is grown by thermal oxidation
  - Honda et al, Kafalas et al, 1970's discovered that it dissociates water into hydrogen and oxygen
  - Inert, low cost, long life
  - However, requires ultra-violet light, which is less than 5% of solar spectrum…
  - And also requires a bias voltage to align energetics for water spliting
- Nanoptek's proprietary band-gap engineering both eliminates the bias voltage, and reduces the band-gap for absorption of sunlight beyond the UV
  - Nanostructures cause highly localized stress during film growth
  - Inter-atomic spacing is increased, lowering potential
  - Bandgap is lowered, absorbs more of visible solar

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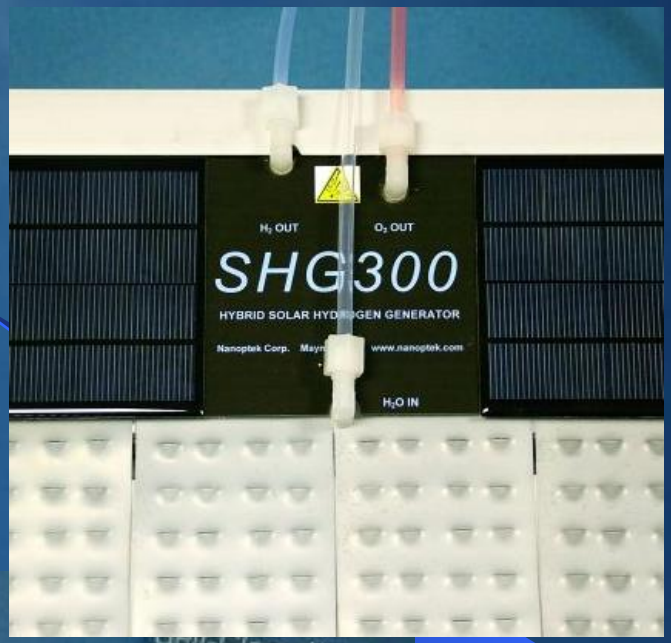
SHG 300

Hybrid Solar Hydrogen Generator



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Features

- No carbon in solar mode
- Silent
- Ultra-scalable modular design
- Distributable
- Can use lower water quality, even ocean
  - Titania photoanode is self-cleaning
  - No Nafion or platinum to foul
- No tracking or concentrator
- Low maintenance
- Projected 20 year life
  - Based on our accelerated testing
- Hybrid design

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Hybrid

- MMO anode behind photoanode can use renewable electricity to continue producing H2 without sun: conventional electrolysis
- MMO and photoanodes can operate simultaneously
- Greatly improves ROI and cost per kg
- SHG 300 as buffer between intermittant renewables (solar and wind) and, with fuel cell, on-demand power that utilities require
- Adds value to both sides of equation

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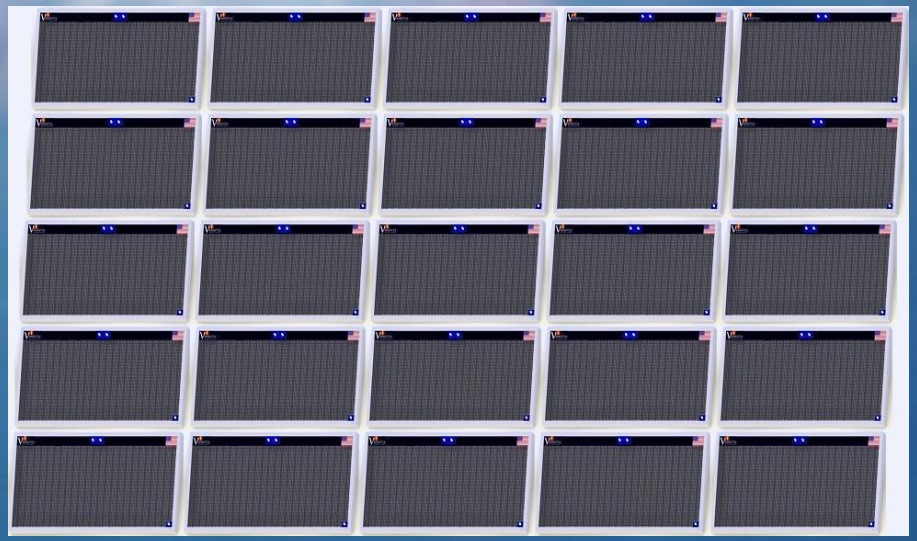
Footprint



- The cost of carbon-free solar H2 is a large footprint
  - even for conventional electrolyzers powered by PV and/or wind
  - In hybrid mode, 1 kg/day requires 25 panels —50m^2 or 15 ft. by 30 ft.
  - 30 kg per day (small forecourt) is less than 0.4 acres
- Can be linear, as along guardrail or other right-of-way
- Compare acre-year production:
  - 22,000 gge of H2 SHG in hybrid mode
  - 6,000 gge of H2 SHG in all-solar
  - 6,000 gge of ethanol algae
  - 800 gge ethanol from sugarcane
  - 400 gge ethanol from corn
- Can be installed on rooftops, brownfields; farmland NOT required

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CNG/H2

- CNG infrastructure and vehicles are much further developed than for H2
  - AVSG has stations throughout 10 states
- H2 can be added to NG up to 30% by volume and then compressed and dispensed with same CNG equipment
  - Hythane in Colorado, and also India, and of course Town gas
- CNG/H2 mixture
  - Reduces carbon and other emissions
  - Improves vehicle performance
- AVSG and Nanoptek are exploring co-locating SHG300 panels at AVSG CNG stations to provide a Solar Hydrogen additive
- Provides a transition to all-hydrogen vehicles

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Cost of Hydrogen

- Dept. of Energy goal is $4/kg (gge)
  - Cost to local distributors is over $16/kg
  - They charge their customers $23 to $75/kg depending on volume and purity
- SHG300 produces H2 at $7.50/kg
  - Not including value of O2 byproduct
  - Discounted cash flow NPV method, similar to DOE H2A program but more comprehensive
- Pathway to H2 at less than the DOE goal with SHG300
  - Scale-up to mass production and mill-lot material purchasing
  - Continued device STH efficiency improvement