Oxidation Resistant Coatings Via Combustion Chemical Vapor Deposition (CCVD) Process

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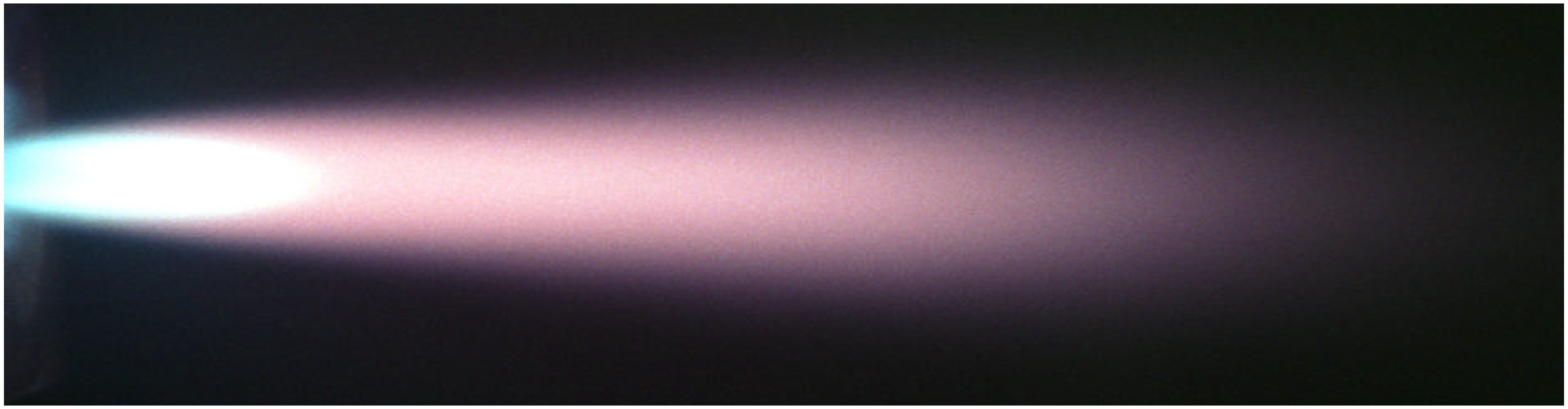
Outline

- **Introduction to MCT**
- **The CCVD technology**
- **Oxidation resistant coatings development**
- **Representative examples**
- **Summary**



Company History

- Founded in 1994 to advance CCVD process to commercialization
- Graduate member of Georgia Tech’s Advanced Technology Development Center
- Grew from government & customer R&D funding - “Bootstrap model”
- Equity investments started in mid-1999
- 37 patents issued and over 150 patents pending worldwide

A Unique Flame Based Technology

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- Combustion Chemical Vapor Deposition-CCVD
  - patented
  - open-atmosphere
  - flame-based technique
  - thin films of advanced materials

CCVD Process → **Unique Materials** → **Products in Target Markets**

Target Products

RF Wireless

- Components for cellular phones
- Components for wireless devices

Nano

- Novel nanopowders
- Catalysts and fuel cell layers
- Fuel injector

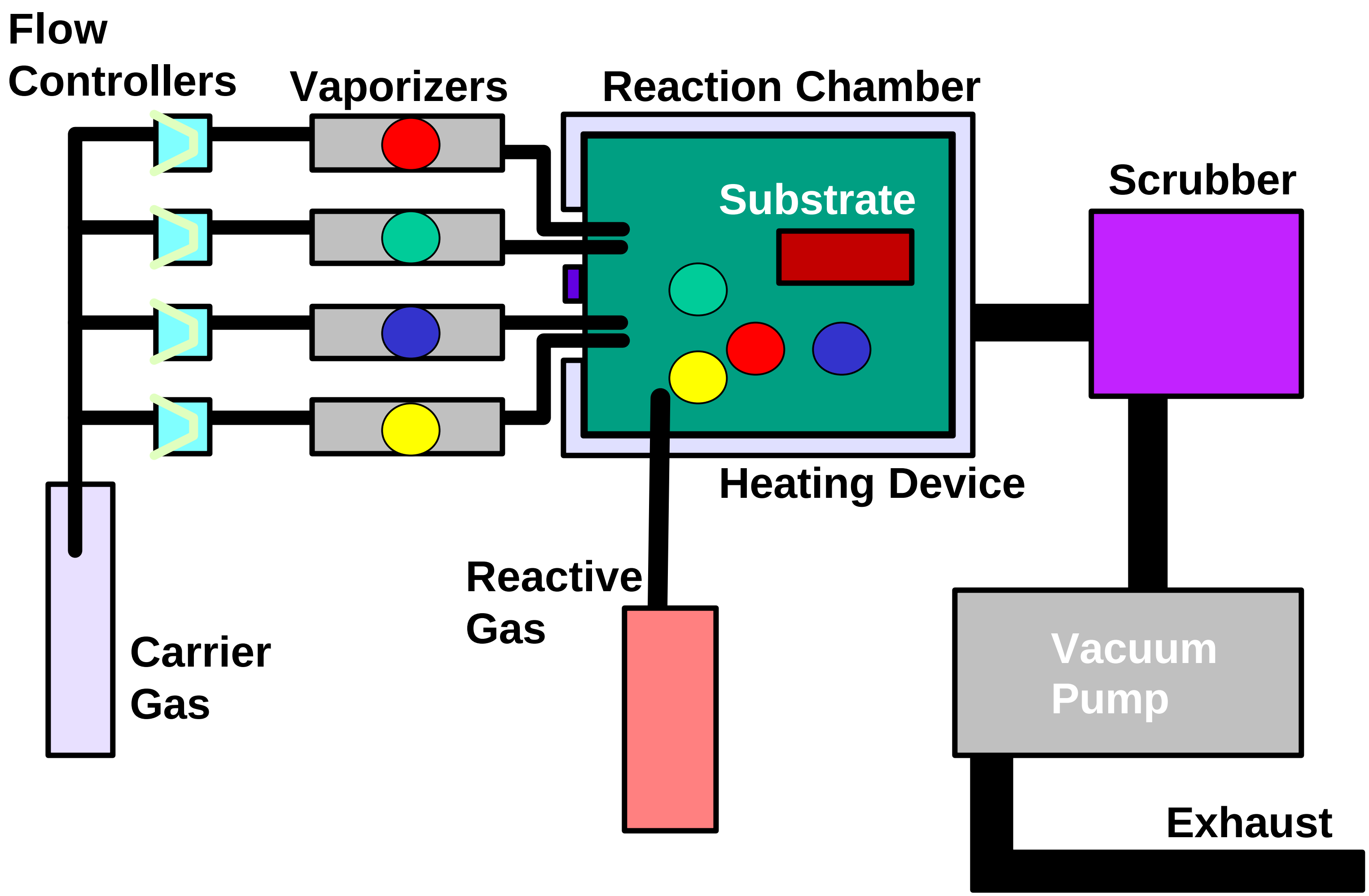
Barriers

- Food and beverage packaging
- Superconducting tapes
- Gas / Moisture / Anti-corrosion

Electronics and Optics

- Next generation circuit boards
- Photonic devices and sensors
- Light emitters and detectors
- Advanced dielectrics
- Solar cell – transparent conductive oxides

Traditional CVD System



Open Atmosphere CCVD Process

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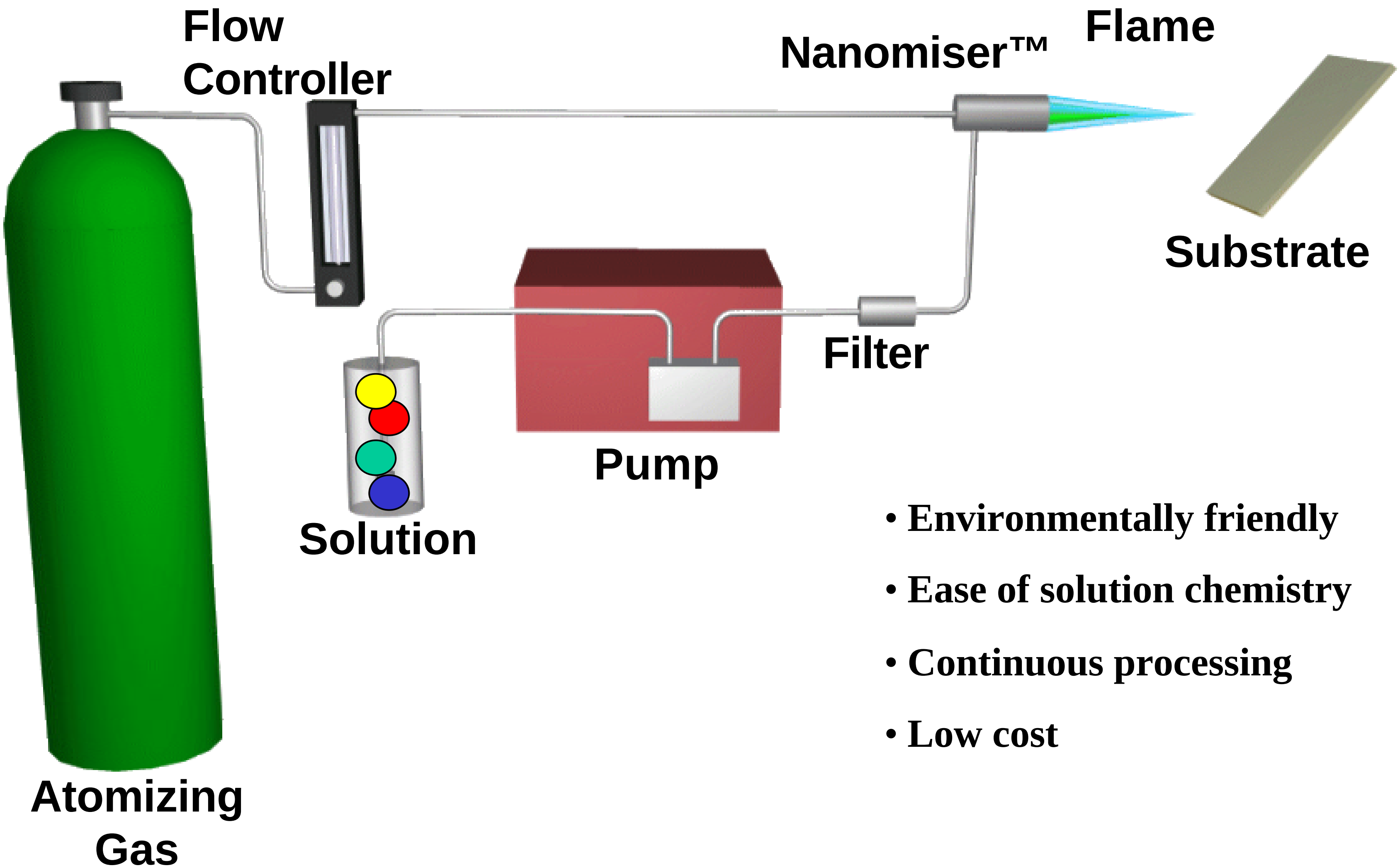

- Environmentally friendly
- Ease of solution chemistry
- Continuous processing
- Low cost

Examples of Deposited Materials

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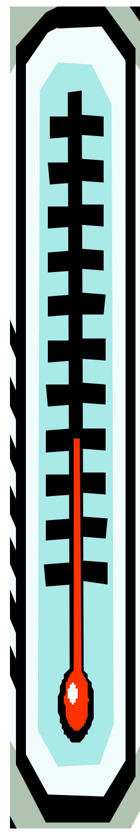
<u>Coatings</u>

- **Oxides**
  - Simple (silica, alumina)
  - Complex (PZT, YBCO)
  - Multilayers
- **Metals**
  - Au, Pt
- Polymer composites
- **Over 90 Different Materials**



<u>Substrates</u>

Oxides

Metals and superalloys

Glass

Polymers

CCVD Technical Advantages:
Top Ten List

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- **Deposits very thin films, 10 nm to thick films > 60 µm**
- **Controls density/porosity**
- **Enables high compositional control and multi-layering**
- **Deposits onto complex/large substrates**
  - Not line of sight
- **Allows substrate temperatures less than 100°C**
- **Offers *in situ* capability**
- **Forms epitaxial and preferred growth films**
- **Avoids use of high vapor pressure precursors**
- **Enables up to 1 µm/minute dense oxide coatings**
- **Facilitates quick development cycles**

Dense and Oriented Coatings Grown via CCVD

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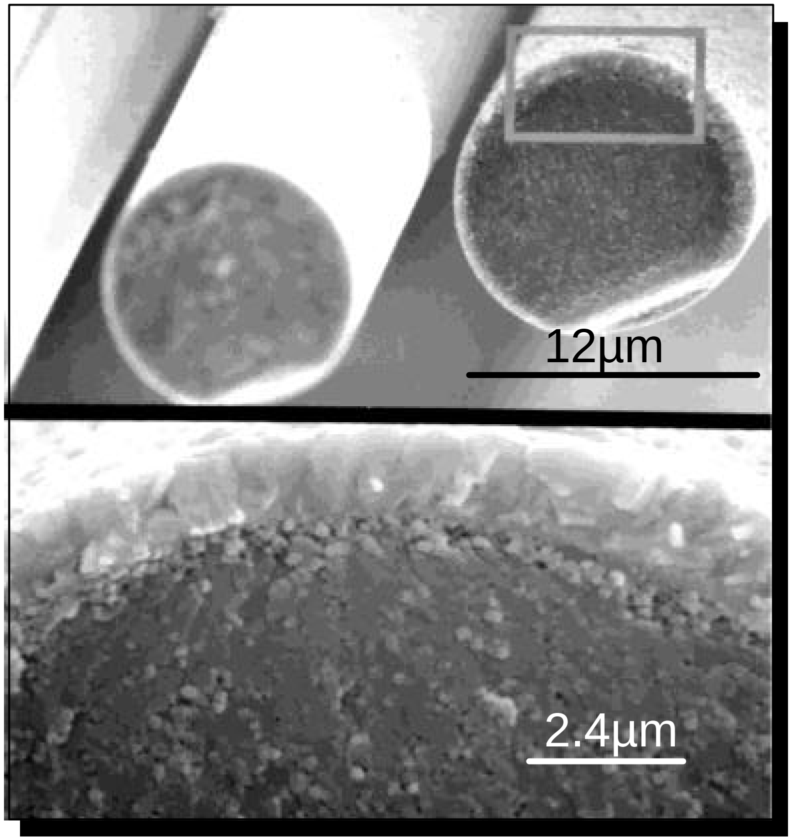
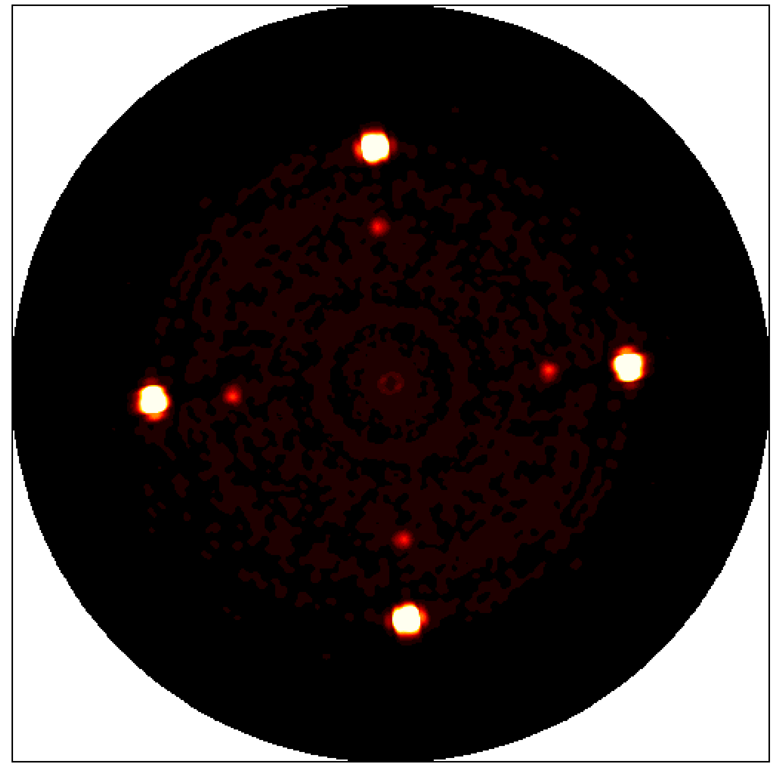


$LaPO_4$ Coatings on a Nextel Fiber Tow

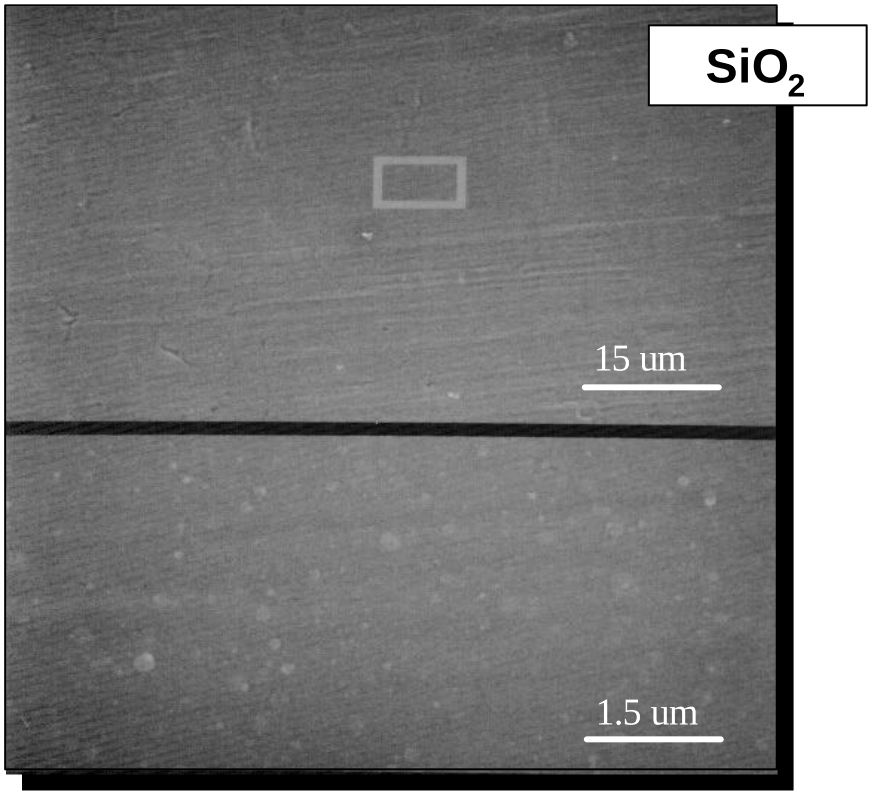


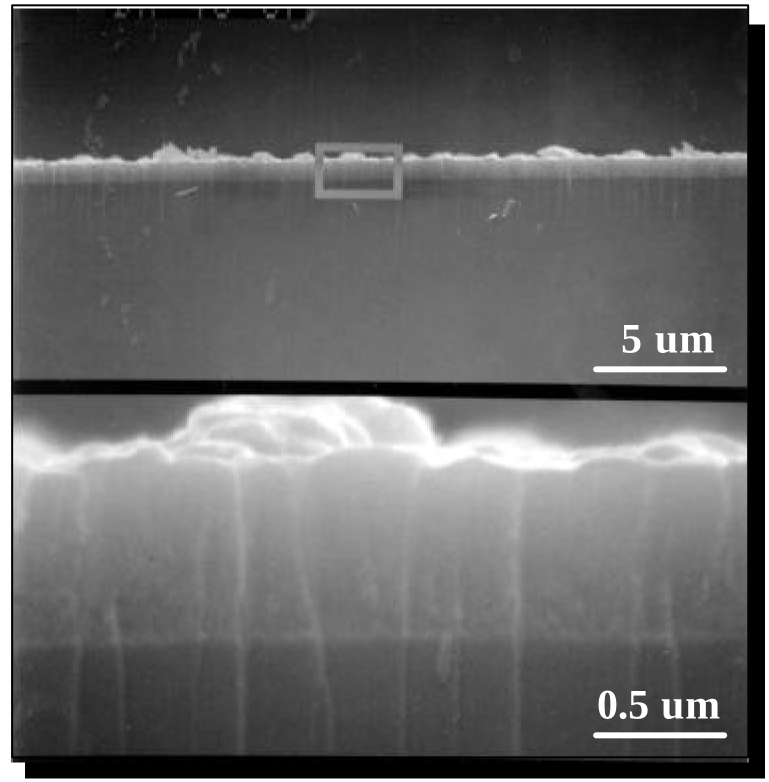
CCVD Yb_2O_3 on CCVD Y_2O_3 on (100) $LaAlO_3$ (222)

Oxide Coatings Development

- Carbon steel
  - Silica, alumina, chromia and multilayers (< 0.7 microns)
  - Static oxidation at 500º C
- Titanium alloy (6Al-4V-Ti)
  - Silica, chromia and multilayers (< 0.7 microns)
  - Static oxidation at 540º C

Dense Silica and Chromia Coatings were Grown





Cross-section of CCVD Cr_2O_3
on fused silica

CCVD Oxides Reduce Oxidation Rate of Carbon Steel

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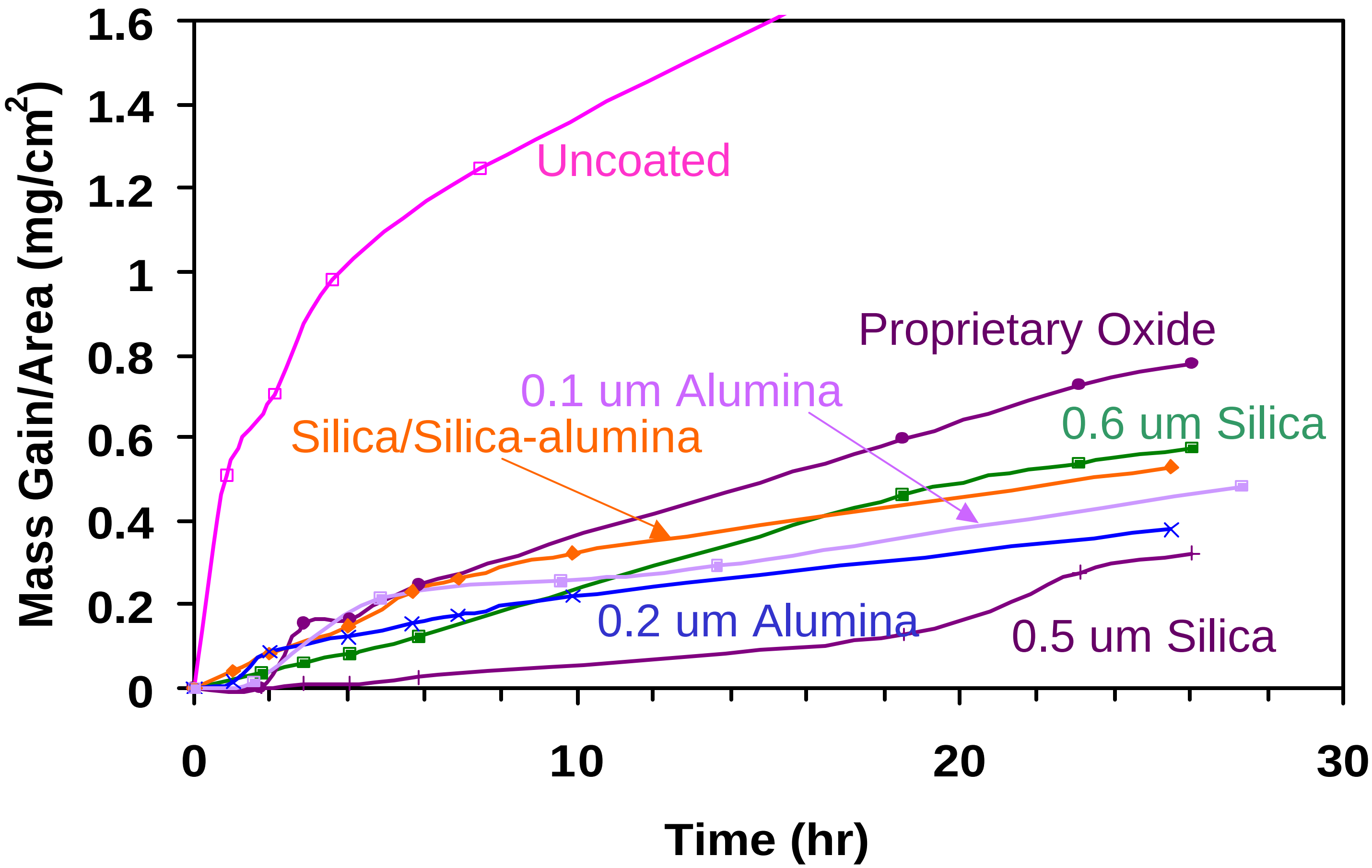
T = 500 °C Substrate = AISI 1010 Steel



CCVD Oxides Perform Well in Testing

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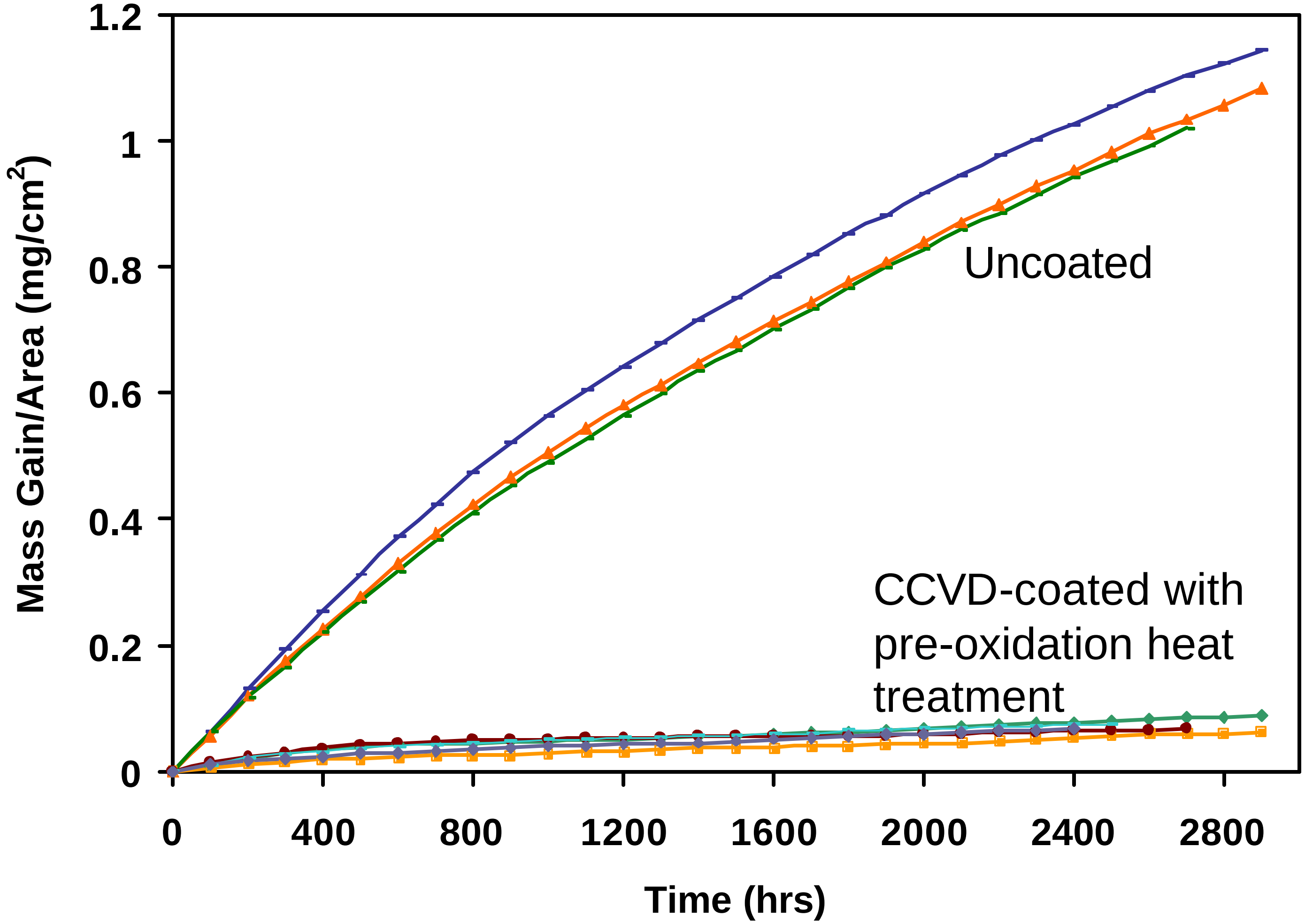
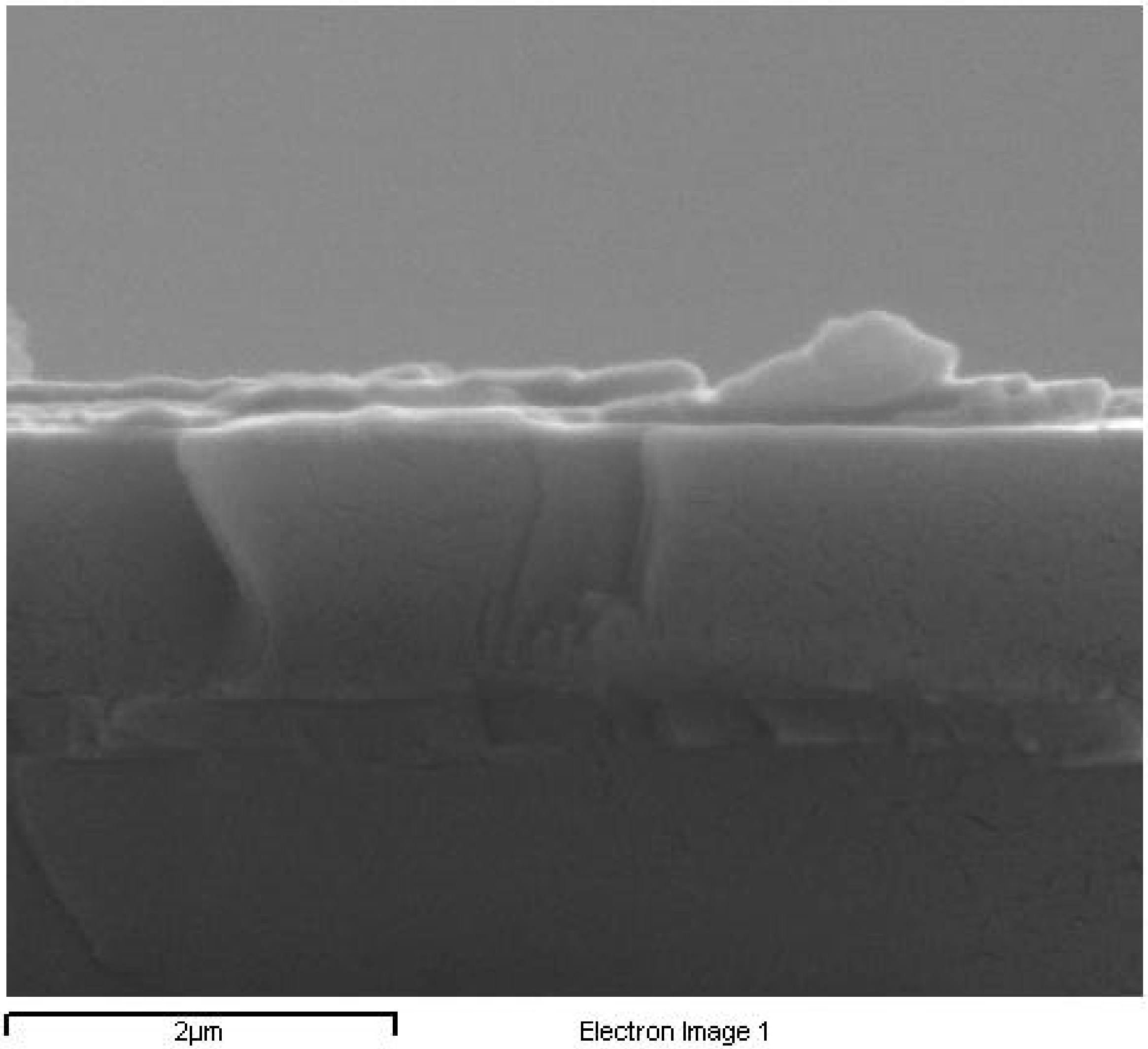
T = 540 °C Substrate = Ti-6Al-4V Coating = Proprietary



Coatings for Superalloys and TBCs

- Alumina, yttria and proprietary multilayer coatings
- Coatings grown on sapphire and YSZ substrates
  - Oxidation at 1100º C up to 300 h to evaluate stability
- Coatings subsequently deposited on TBCs and currently undergoing testing

Amorphous Alumina Coatings were Grown



Alumina

Sapphire

Dense Alumina on a Superalloy Substrate

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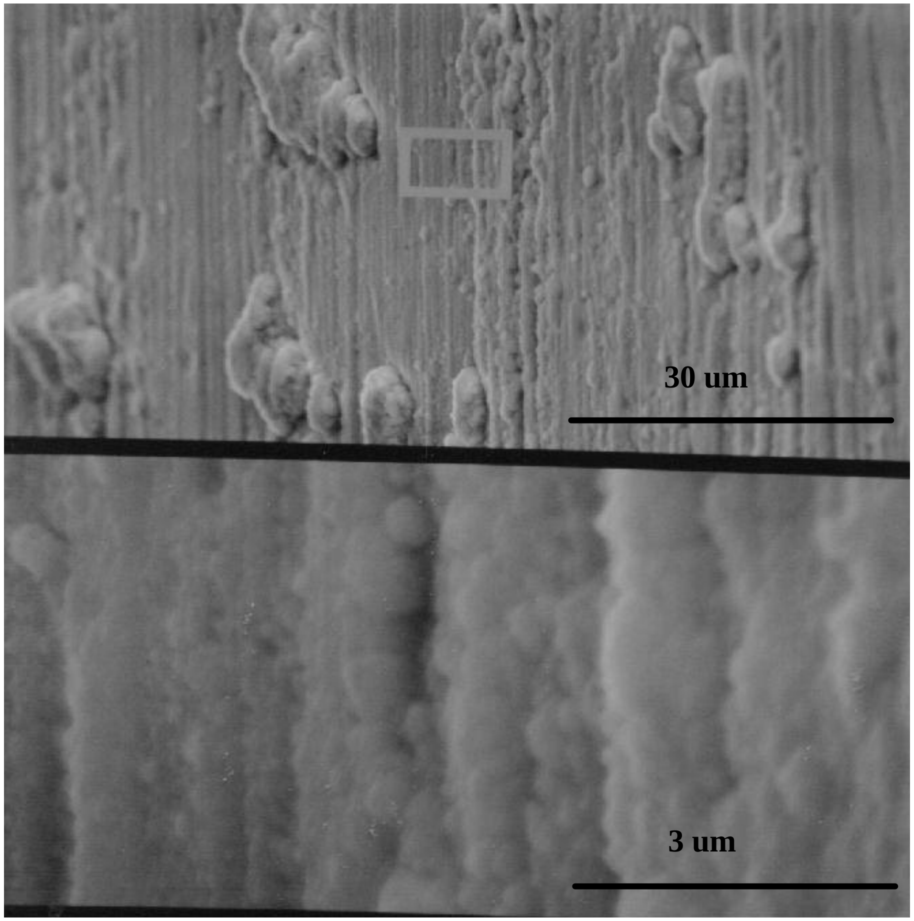

Dense Yttria Coatings were Deposited

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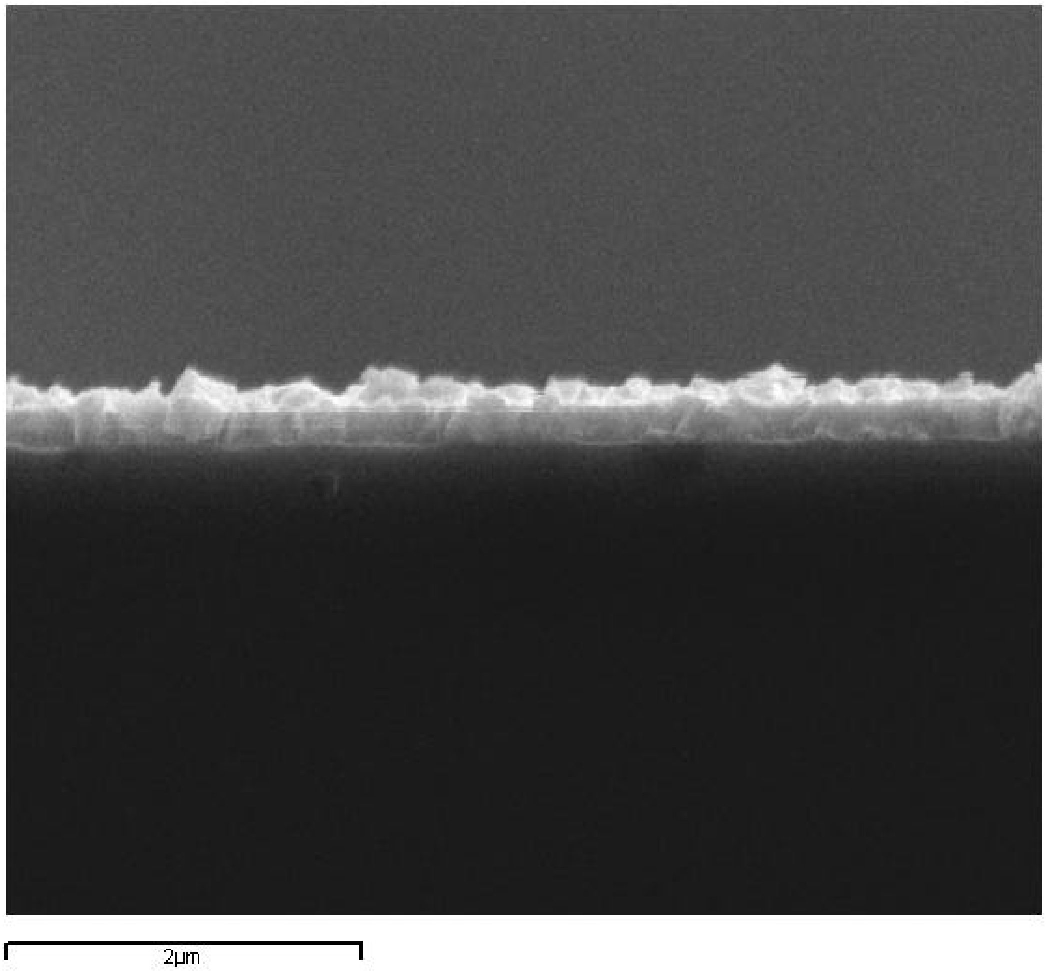
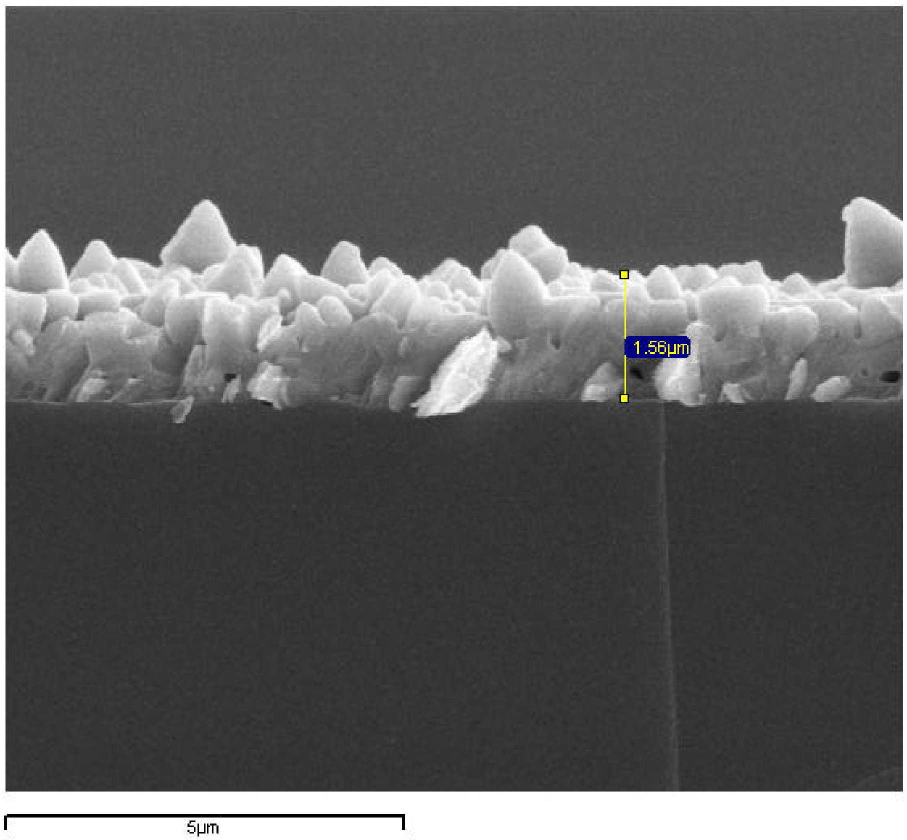
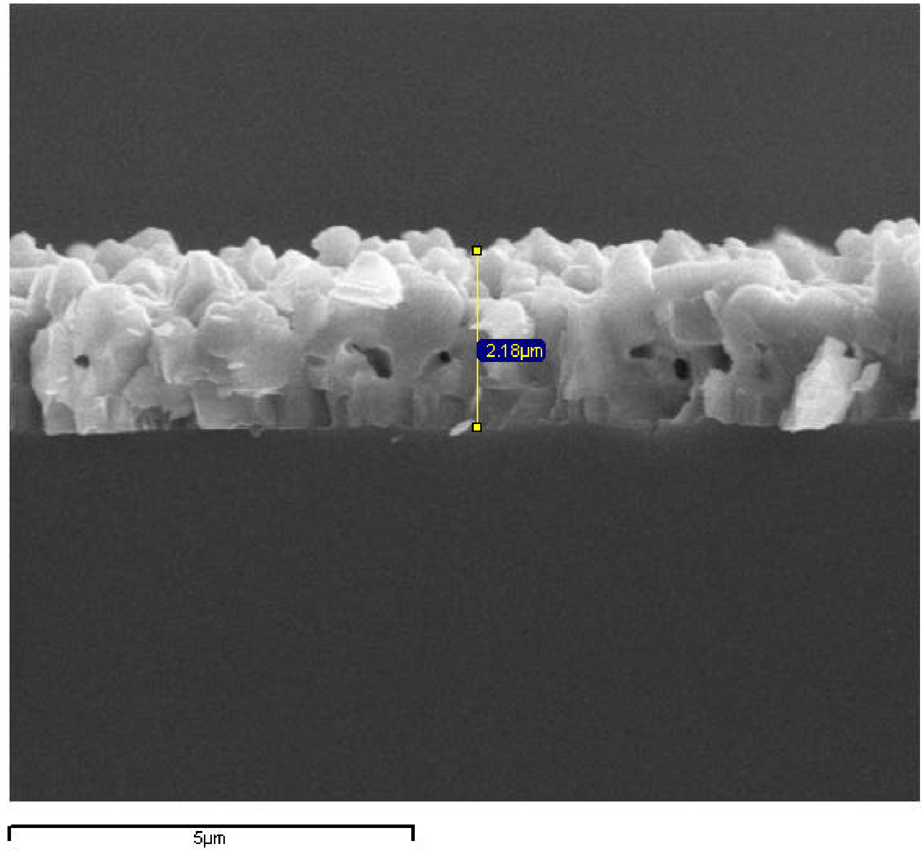


Dense Multilayer Coatings were Grown and Tested



After 100 h at 1100º C



After 300 h at 1100º C

Summary

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- CCVD process is well suited for producing oxides, noble metals and composites
- Silica, chromia, alumina, yttria and multilayer coatings were successfully grown via CCVD
- CCVD oxide coatings decrease oxidation rate of carbon steel and titanium alloy by 50 to 90 %
- CCVD oxide coatings are currently being tested for their effectiveness on TBCs

Acknowledgments

- DOE SBIR funding
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- Help of other team members
  - Neville Richards
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  - Melanie Gast

Benefits of CCVD

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Environmentally Friendly

- Non-Toxic Precursors
- Simple Organic Solvents
- Benign By-products (typically H_2O and CO_2)

Production Flexibility

- Rapid Changeovers
- Short R&D Cycle

Low-cost

- Capital Costs
- Precursor Costs