Structured Materials Industries, Inc.
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Superconducting YBCO MOCVD Technology at SMI

Summary of superconducting YBCO thin film technology at Structured Materials Industries, Inc. (SMI)

January 2011

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Superconducting YBCO MOCVD Technology at SMI

Presentation Outline:

- Introduction to SMI
- Process Development for Undoped $YBa_2Cu_3O_x$ on $SrTiO_3$
- Process Development for Ho Doped $YBa_2Cu_3O_x$ on $SrTiO_3$
- Process Development for CeO_2 Buffer Layers for $YBa_2Cu_3O_x$
- Process Development for $YBa_2Cu_3O_x$ on Buffer Coated Metal Tape
- Hardware Development for Reel-to-Reel MOCVD of $YBa_2Cu_3O_x$ on Kilometer Scale Metal Tape
- Next Generation Hardware for MOCVD of YBCO Tapes

SMI CVD Technology

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SMI/GNM Founder

Dr. Gary S. Tompa: Materials Science Expert and Serial Entrepreneur

-President and CEO of SMI,

- **Former Head of Systems Research, Engineering and other positions at Emcore Corp. (TurboDisc group - Veeco subsequently purchased that group)**
- **Contracted by Applied EPI 2001 ($10M$ budget –build 4 MOCVD tools (Veeco bought them out)**
- **Co-Founder of multiple companies— exited three successfully, still participates in 3: CoB/co-founder of NEI Corporation (www. NEICorporation.com); Board member of UNTPL (joint venture of NEI and UNPL of India to manufacture battery electrode material, Board member American Nanomite)**
- **Managed >$40M in development contracts**
- **>$10M in commercial sales to Companies, Universities and Government Laboratories**
- **Came to SMI to develop/implement Si QNC light emitters – moved it to MOCVD niches and ultimately to "organically" grow with customers and spinouts.**
- **Understands what can be done, how to build a team and how to build a business**
- **>100 technical publications, ~>100 conference papers, several patents**
- **Member of advisory board to multiple universities**

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Structured Materials Industries Inc. (SMI)

Tibbets Award Winner

Core Business:

New Devices are Built in New Materials
New Materials Need (New) Production Tools

SMI's produces Metal Organic Chemical Vapor Deposition (MOCVD) tools that *Enable* Next Generation Devices

½ to 2 Million Dollar Tool Sales

Examples: **Wide Bandgap Materials**
Memory Materials, Graphene
Transparent Conductive Materials
Superconductors, Other Materials

Business Model:

- **Development Funded with SBIR's/Service Contracts**
- **Sell MOCVD Systems, Components, Services**
- **Grow Organically or With Scale-up Investment**
- **Spin-off Companies (4 to date)**
- **Strategically/Optionally Commercialize Resulting Devices**

SMI CVD Technology

SMI is a Sound Company

Incorporated:	**1992**
Privately held:	**1 principle with ~ 90% ownership**
Financial:	**Self-funded: no long-term debt, loans, warrants, liens, or other financial obligations**
	Defense Contract Auditing Agency
	- annual accounting audit passed every year
	Profitable operation since 1995
	Retained earnings are used for self-funded working capital
Legal:	**No known negative issues: No past, present or known / anticipated legal actions -- by us or against us**

SMI CVD Technology

SMI is Presently "Two Businesses"

1. **Government/Commercial contract R&D services –**
   research of processes, tools, materials, and devices

2. **Equipment developer / provider –**
   R&D scale by infrastructure and resources

   "Organic" growth with customers for production

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Selected Major Government Contracts @ SMI	
Si nanocrystals for light emission	Large area optical coatings
ZnO TCO	Re-Programmable FPGA
PZT CVD	Prompt Dose FPGA
PLT/PZT pyroelectric	Rad Hard COTs
Al2O3 H passivation	Graphene tools
CMO NDRO EEPROM	2DEG LaAlO ALD
Sb HBT	InGaN PV I
YBCO TAPE TOOL	Carbon Nitride
p-type ZNO	CF-CVC nanopowd
Radiation Sensor	TPV InGaSb
Phase Change memory material	LNBO waveguide
Pyrophoric Coatings	FBCVD particle coating
InGaN HOVPE	InGaN PV II
WPT	Si Photonic waveguide
Thermoelcctrics	2DEG films
BST variable dielectric	Si resonator LIDAR

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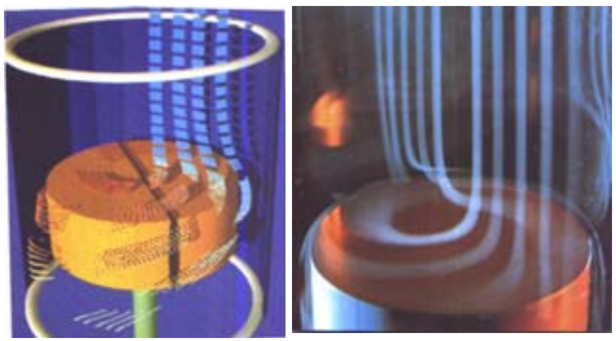
MOCVD tools that SMI has developed and implemented cover the range from R&D to Cluster Tool Production.

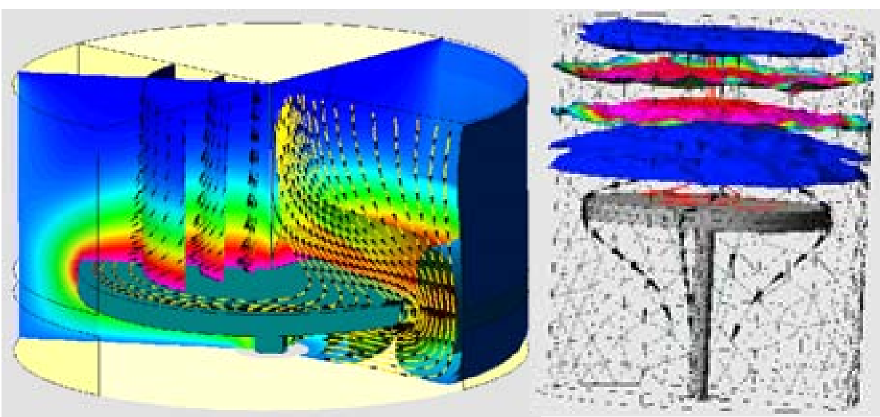
SMI CVD Technology

Tools Designed by Modeling

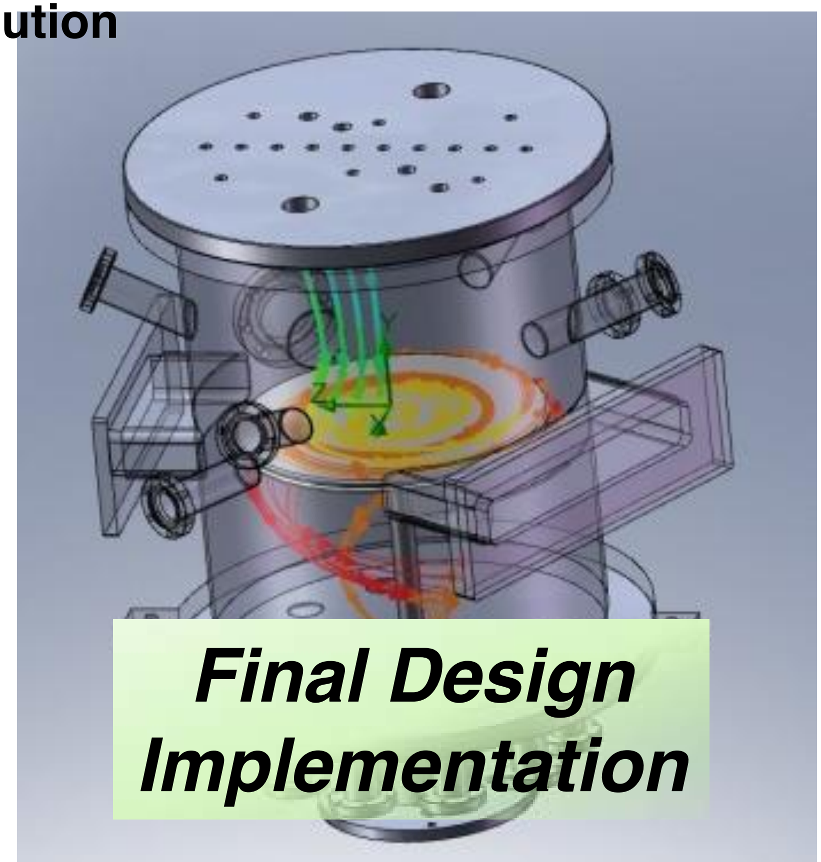


Courtesy of Sandia National Laboratories

Parallel modeling effort will help converge on optimal solution



Uniformity & Nanolayer (quantum well) Control



SMI Has aVery Broad Range of Materials Expertise

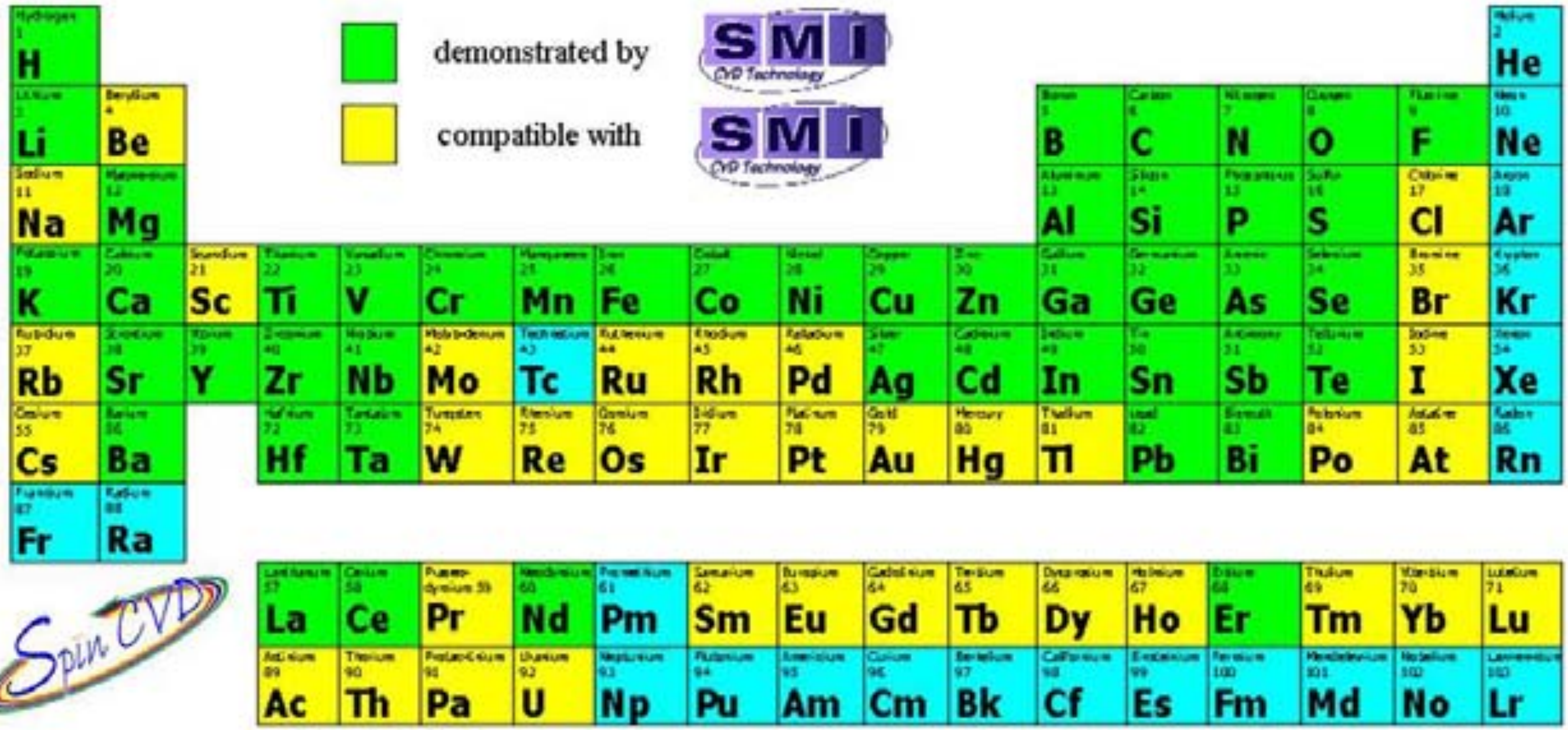


Table of elements showing the range of Elements that SMI's MOCVD technology has or can produce.

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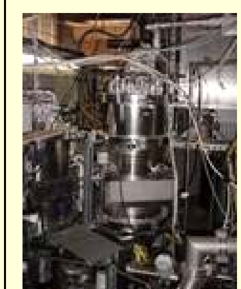
Facilities I (7,500 sq. ft.) – more on the way

Table F1: SMI In-House Applications Laboratory: MOCVD Tools from RESEARCH to PRODUCTION				
				
MOCVD: p-type ZnO	MOCVD: Static Optical	MOCVD: Electro-Optical	MOCVD: TCOs	MOCVD: NanoCVD
				
MOCVD: GaN	Production Cluster Tool: SiGe/GeSbTe	Production Cluster Tool: Ferroelectric	MOCVD: Stand-Alone Ferroelectric	Production Cluster Tool: Dielectrics

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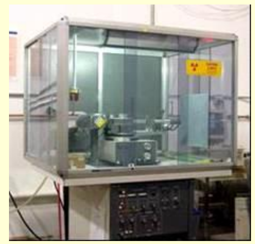
Facilities II

Table F2: SMI Analytic and Related Capabilities

MEI Wedge Bonder



Rigaku X-Ray Diffraction System

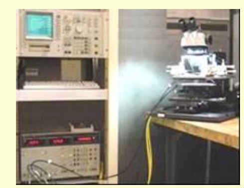
Hall Effect Measurement station

Inert atmosphere glove box (<1 ppm H_2O, O_2)

1500x Polylite Inspection Microscope

Filmetrics Thin Film Reflectance Spectrometer

JOBIN YVON Optical Spectrometer



HP Parametric and Impedance Analyzers, and Wafer Probe

8” wafer photoresist spinner

Dektak profilometer

Differential Scanning Calorimeter

Annealing Furnace

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Facilities III

SMI Manufacturing Infrastructure

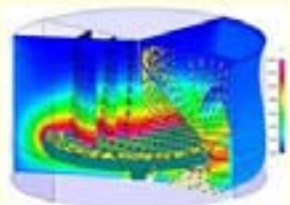
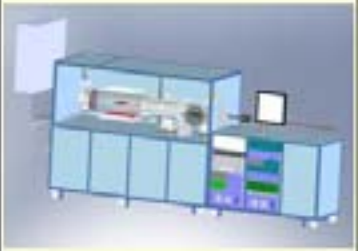
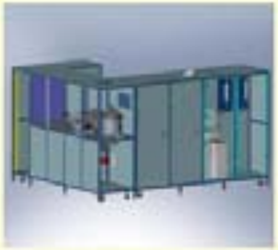
				
SolidWorks and AutoCad Design Station	CFD Process Modeling Station	Tube welding, 1/8" to 1"	Metal Milling	Welding Station

Table 8.4: SMI –From Design to Production

			
Nanowire Tool - Design	Nanowire Tool	GaN Tool - Design	GaN Tool- Under Construction

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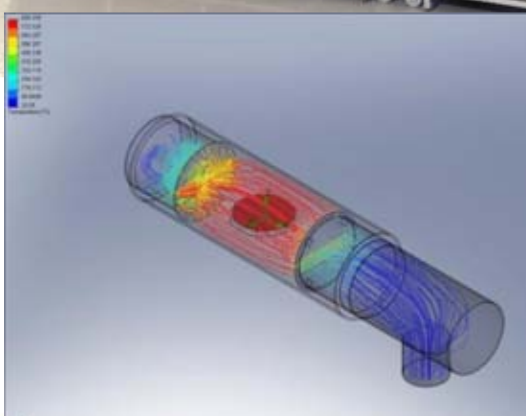
Horizontal SiGe Nanowire Tube MOCVD Deposition

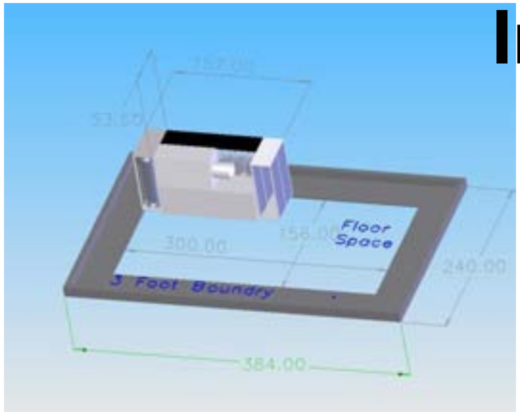
Design

Actual

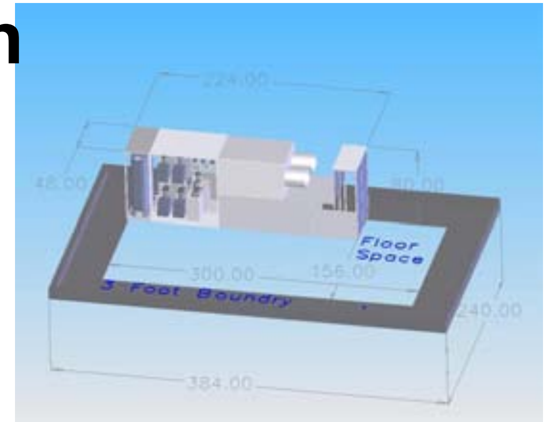


Process Model

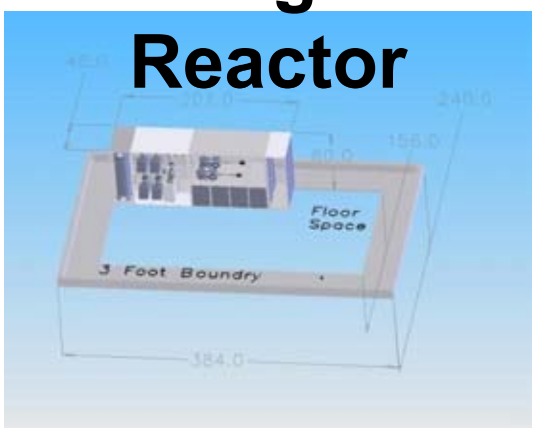
Facility Integration



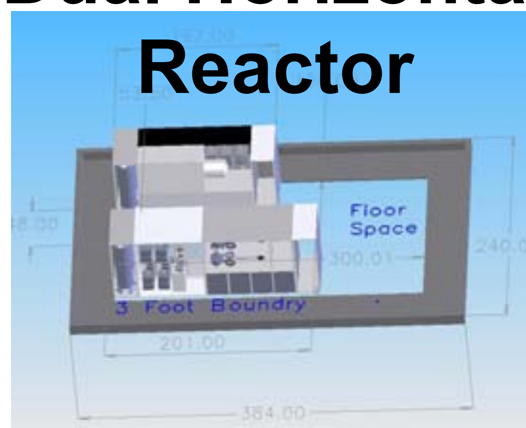
Single Reactor



Dual Horizontal Reactor



Dual Vertical Reactor



Two Systems

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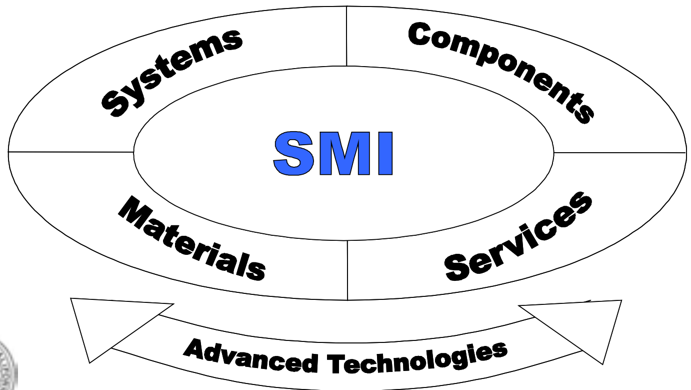
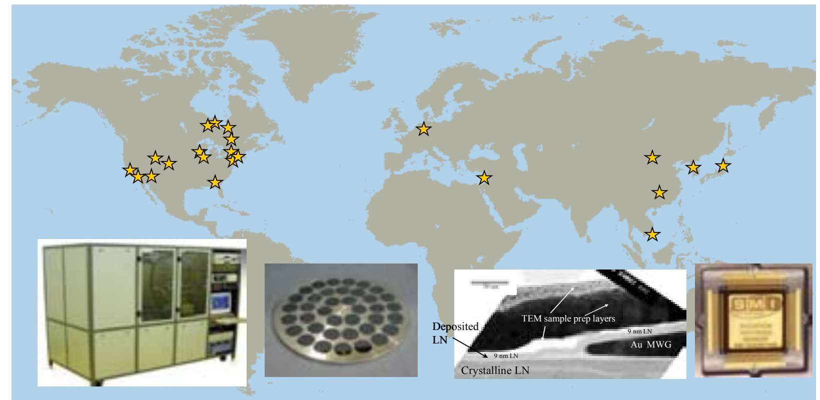
SMI International Commitment to Customer Excellence (selected logos)





IBM
SOLA
BAE SYSTEMS
DARPA
ARL
WRIGHT STATE UNIVERSITY
DARPA
ATMEL
NIST
NASA
ASU Arizona State University
GM
Raytheon
NIST
THE STATE UNIVERSITY OF NEW JERSEY RUTGERS
Cermet, Inc.
FUJITSU
BROWN
EPSON
MICREL Innovation Through Technology
spectalis
kulite
ENERGY
Drexel University
TriQuint SEMICONDUCTOR
CORNING
PENNSTATE
NJIT
U.S. AIR FORCE
IGC
Berkeley University of California
SARNOFF Corporation
OAK RIDGE
NSF
清華大學 Tsinghua University
sub|one Sub-One Technology
ARGONNE NATIONAL LABORATORY
National Chung Hsing University
LINCOLN LABORATORY Massachusetts Institute of Technology
NORTHWESTERN UNIVERSITY
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LOREX
SHARP

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Government Contracts: Closed, Active, Awarded:			>$30,000,000.00	
Government Contracts: Pending:				~>$3,500,000.00
Commercial contracts: Closed, Active, Awarded::			>$7,000,000.00	
Commercial contracts: Pending with >50% proibability:				>$4,000,000.00
SMI Spinouts - Raised & Sold			>$30,000,00 0.00	
	SMI Spin-Out Joint Venture in India		~$4,000,000 .00	
Summary of Major Sales/Services				
	TOOLS	**Does not include ~10 in-house tools**	Subsystems	
				Multiple showerheads, som
		GaN Reactor Assembly		Control systems multiple (A
		GaN system		
		GaN test system	Coatings	
		GaN heater assembly		Oxide coatings, LiNbO, PZT,
		Dielectric/Ferroelectric System		Transistor, chloride
		Dielectric oxide system		Oxide coatings luminescent
		GaN Tube tool (in process)		Calcoginides/CBRAM/PCRAM dep services
		PV HWCVD tool (2 on a cluster - in process)		ZnO tool use / services
		ZnO System		Special Nitride Foil Depositions
		ZnO system		InGaSb - - InGaAs - - ErSb
		SiC Bulk material growth		High temperature lamp coating
		Superconductor tape tool, Tape tool rebuild, Deposition services		PZT evaqluation
		Ferroelectric System		Several others
		SiGe Nanowire Tool		
		High Temperature Oxide MOCVD system	System Rebuilds Conversions	
		NanoH Si/SiO2		SiC, GaN System rebuilds, GaN Heater conversion
		DeskTop CVD™ oxides		Conversion GaAs to TCO (2), GaN to TCO, Plasma dep to PZT+C30
		Thin Flim Battery PECVD Tool		GaN Shaft heater conversion
		Graphene DeskTop CVD™		
		NanoV CNTs	Other Tools	
		Vacuum nanopowder system		GFHC
				DESIGN PV coater and PV Annealer
				Design Applied Epi MOCVD tools (sold out to Veeco)

New Orders: - 2010
ND – Graphene
NR – Graphene
UTo – Graphene
NRXX – 2 HWCVD
UFX – Nitride/oxide
UCX – III-V
CXX – TCO
AFXX – GaN

New Orders in Jan 2011
XXR – GaN

Major in-house tool addition starts:
Graphene (2)
Subl;imation tool (1)
ALD tool (2)
GaN HOVPE Tool (1)

CVD Technology

EMCORE DEPOSITION SYSTEMS DESIGNED
Principally by Dr. G. S. TOMPA

ORGANIZATION	SYSTEM TYPE
EASTMAN KODAK CORPORATION ROCHESTER, NY	ZnO/SiO2 OXIDE MOCVD
FLORIDA STATE UNIVERSITY TALLAHASSE, FL	HTC OXIDE MOCVD
MOTOROLA* AUSTIN, TX	OXIDE PEMOCVD GASPANEL
NASA, GODDARD** GREENBELT, MD	III-V/OXIDE MOCVD
NATIONAL INSTITUTE OF STANDARDS BOLDER, CO	III-V CBE
NAVAL RESEARCH LABORATORIES; WASHINGTON D.C.	HTC OXIDE MOCVD
NORTH AMERICAN PHILLIPS BRIARCLIFF, NY	II-VI MOCVD
STEVENS INSTITUTE OF TECHNOLOGY HOBOKEN, NJ	HTC OXIDE MOCVD
DUPONT DELAWARE	HTC OXIDE MOCVD
UNIVERSITY OF CONNECTICUT STORRS, CT	II-VI MOCVD
EMCORE SOMERSET, NJ	II-VI VTE(CBE) IV VTE(CBE) YBCO OXIDE-PROTOTYPE MOCVD II-VI MOCVD 3600 PROTOTYPE (E400 forerunner) ENTERPRISE SYSTEM (1st ONE)

*GAS PANEL TO MATE WITH PLASMA QUEST GROWTH REACTOR SYSTEM
** OXIDE PORTION OF DUAL SYSTEM

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Example Installed Customer Tools

Figure 3.4 Examples of Commercially installed SMI MOCVD reactor systems

				
YBCO Tape Tool	Ferroelectric	Nanowire 8" Wafer Tool	GaN Reactor	
				
Dielectric CVD Tool	ZnO CVD	Plasma Enhanced CVD Static Tool	Bulk SiC 2400° C Tool	Epic ++ Oxide Reactor

Examples of SMI's commercially installed MOCVD reactor products that span the range from research to production, in sizes ranging from small stand-alone units up to cluster tools for high-volume production; producing materials from oxides to GaN to SiC.

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SMI Projects on Superconducting $YBa_2Cu_3O_x$ MOCVD

- **"High Current Capacity $YBa_2Cu_3O_x$ Coated Conductors" – Sponsor DOE**
- **"Thick $YBa_2Cu_3O_x$ Films for Coated Conductors with Improved Critical Current" - Sponsor Air Force**
- **"Effective Flux Pinning In $YBa_2Cu_3O_x$ Coated Conductors by Continuous MOCVD" – Sponsor Air Force**
- **Delivery and Implementation of Reel-to-Reel MOCVD Tool for $YBa_2Cu_3O_x$ Superconducting Tape Production to Air Force Research Laboratory at WPAFB**
- **"Multi-Kilometer Superconducting Tape Production Tool" – Sponsor MDA/Air Force**

SMI CVD Technology

SMI Core Superconducting Team:

Dr. Gary S. Tompa, Corporate and Technical Leadership
Dr. Nick Sbrockey, PI on Several Government Programs, YBCO process and characterization leader
Mr. Tom Salagaj, Sr. Process & Tooling Development Engineer
Mr. L. Gary Provost, Sr. Design and Manufacturing Engineer

Several outside consultants and manufacturing service providers as needed.

Dr. Nick Sbrockey:

Structured Materials Industries, Piscataway, NJ (2002 - Present): Principal Scientist
Develop new process and hardware technologies for SMI's line of thin film deposition equipment. Initiate, manage and conduct R&D programs, including development of strategic partnerships with companies, universities, government laboratories and funding agencies. Dr. Sbrockey has managed R&D programs at SMI on graphene and diamond based devices, tunable RF devices based on ferroelectric and multiferroic materials, high-k dielectrics, optical coatings, laser damage resistant optical coatings, photovoltaics, thermophotovoltaics, electro-optic and photonic crystal devices, laser wireless power transfer and superconducting $YBa_2Cu_3O_x$ coated conductors.

Axcelis Technologies/Eaton Corporation, (1986 - 2001): Various Positions
Develop new technologies and new products for Axcelis/Eaton, including ion implantation, thermal processing, photoresist processing and cluster tool equipment. Dr. Sbrockey managed R&D programs for Axcelis/Eaton on plasma immersion ion implantation, flat panel display processing tools, broad beam ion source development, microwave plasma processing, diamond CVD, CVD of tungsten and tungsten silicide and unbalanced magnetron sputtering of hard coatings. Dr. Sbrockey's responsibilities also included Thin Films Research Group Manager (1986 - 1991) and Technical Liaison between Eaton's R&D Center and Semiconductor Equipment Divisions (1994 - 1997).

Balzers High Vacuum Systems and Components, Hudson, NH (1984 - 1986): Process Scientist
Develop new process and hardware technology to support Balzers line of plasma etching and thin film deposition equipment products.

Synergistic Activities:
Member - Board of Directors for Electro-Optic Alliance at Penn State University: 2005 - 2006.
Member - Organizing committee for AVS Spring Meeting: 1998 - 1999.
Session Chairman at AVS Int. Conf. on Microelectronics and Interfaces: 1996 - 1999.
Session Chairman at Int. Materials Research Congress: 2010.
Member - Materials Research Society and American Vacuum Society: since 2000

Mr. Tom Salagaj:

Structured Materials Industries, Piscataway, NJ (2010-Present): Project Manager

Coordinate the design and process development for custom designed MOCVD/CVD deposition systems used in the Nano, Solar, and Semiconductor markets. Provide technical support to customers and to the "In-House" research team in the SMI applications lab.

First Nano/CVD Equipment, Ronkonkoma, NY (2006- 2010): Applications Laboratory Manager

Manage the daily operations of the 15,000sqft laboratory facility. Oversee a team of scientists and engineers for the development of Carbon Nanotubes, ZnO & GaN nanowires, and Si and ZnO epitaxial layers. Coordinate the schedules and provide technical support to the customers.

IGC-SuperPower, Schenectady, NY (2003-2006)_Senior Process Specialist

Transition the Metal Organic Chemical Vapor Deposition (MOCVD) process for the deposition of YBaCuO superconducting materials from development into full scale production. Responsible for the "Scale-Up" of the MOCVD reactor from a research test stand to a kilometer length production scale system. Awarded a patent for the reactor and tape handling system design for the "Method of making a superconducting conductor"

Uniroyal Optoelectronics, Tampa Fl (2001-2003) Senior Epi Manufacturing Engineer

Oversee daily operation and maintenance of Metal Organic Chemical Vapor Deposition (MOCVD) reactors, for the growth of Gallium Nitride UV (400nm), Blue (470nm), and Green (505nm) Light Emitting Diodes (LEDs).

Emcore Corporation Somerset, NJ (1986-2001) Senior Manufacturing Engineer (1996-2001)

Assist in the transition of processes from R&D into production for the Electronic Materials Division. Create related documentation (i.e. work instructions, test plans, delivery schedules, etc.) to maintain compliance to ISO 9000 guidelines. Sustain the manufacturing of a product through a high volume production line. Managing and maintaining yields, resources, and deliverables for a 24 hour 7day a week operation. Increase overall throughput of product by utilizing Cycle Time Reduction and Failure Mode Effects Analysis (FMEA) techniques.

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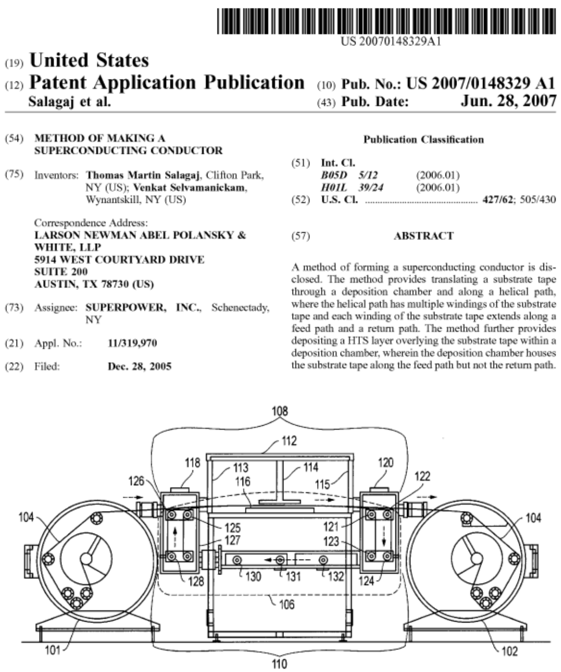
Tom Salagaj: Key Technology Patents and Publication



US 20070148329A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2007/0148329 A1
Salagaj et al. (43) Pub. Date: Jun. 28, 2007

(54) METHOD OF MAKING A SUPERCONDUCTING CONDUCTOR

(75) Inventors: **Thomas Martin Salagaj**, Clifton Park, NY (US); **Venkat Selvamanickam**, Wynantskill, NY (US)

Correspondence Address:
LARSON NEWMAN ABEL POLANSKY & WHITE, LLP
5914 WEST COURTYARD DRIVE
SUITE 200
AUSTIN, TX 78730 (US)

(73) Assignee: SUPERPOWER, INC., Schenectady, NY

(21) Appl. No.: 11/319,970

(22) Filed: Dec. 28, 2005

Publication Classification

(51) Int. Cl.
B05D 5/12 (2006.01)
H01L 39/24 (2006.01)
(52) U.S. Cl. 427/62; 505/430

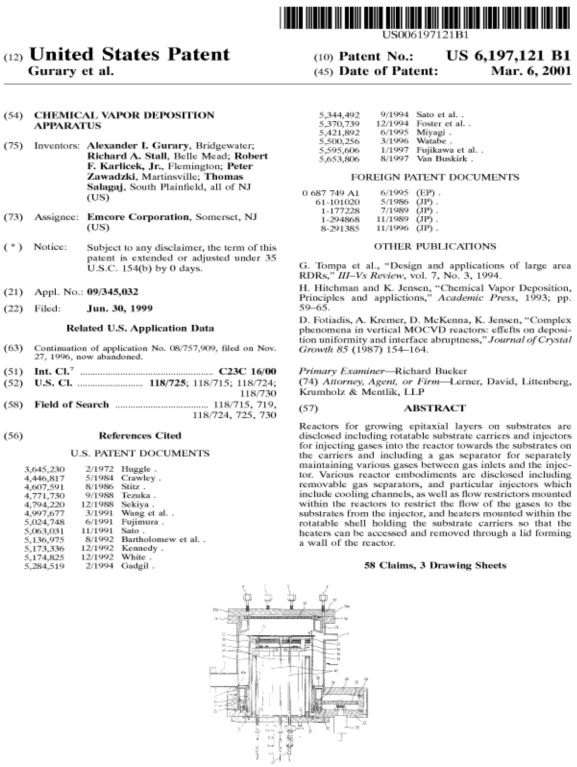
(57) ABSTRACT

A method of forming a superconducting conductor is disclosed. The method provides translating a substrate tape through a deposition chamber and along a helical path, where the helical path has multiple windings of the substrate tape and each winding of the substrate tape extends along a feed path and a return path. The method further provides depositing a HTS layer overlying the substrate tape within a deposition chamber, wherein the deposition chamber houses the substrate tape along the feed path but not the return path.

Co-Author of over 30 technical publications and presentations.

Selected Publications relevant to the project:

1. "Scale-up of Applications-ready Practical Y-Ba-Cu-O Coated Conductors," *IEEE Trans. Appl.Supercond.* 15, pp. 2596- 2499 (2005), V. Selvamanickam, A. Knoll, Y. Xie, Y. Li, Y. Chen, J. Reeves, X. Xiong, Y. Qiac T. Salagaj, K. Lenseth, D. Hazelton, C. Reis, H. Yumura, and C. Weber,
2. "Progress in Scale-Up of Second-Generation High-Temperature Superconductors at Superpower" *Physica C.* 426-431, pp. 849-857 (2005), Y.-Y. Xie, A. Knoll, Y. Chen, Y. Li, X. Xiong, Y. Qiao, P. Hou, J. Reeves, T. Salagaj, K.Lenseth, L Civale, B. Maiorov, Y. Iwasa, V. Solovyov, M. Suenaga, N. Cheggour, C. Clickner, J.W Ekin, C. Weber, and V. Selvamanickam
3. "Progress towards Application Readiness of Coated Conductors at SuperPower" *Proc. Intl. Workshop on*
4. *Coated Conductors for Applications,* Oct. 3' – Nov. 2, Kanagawa, Japan (2004), Y.-Y. Xie, A. Knoll, Y. Li, X. Xiong, Y. Qiao, Y. Chen, P. Hou, J. Reeves, T. Salagaj, K. Lenseth, C. Weber, and V. Selvamanickam



US006197121B1

(12) United States Patent (10) Patent No.: US 6,197,121 B1
Gurary et al. (45) Date of Patent: Mar. 6, 2001

(54) CHEMICAL VAPOR DEPOSITION APPARATUS

(75) Inventors: **Alexander I. Gurary**, Bridgewater; **Richard A. Stall**, Belle Mead; **Robert F. Karlicek, Jr.**, Flemington; **Peter Zawadzki**, Martinsville; **Thomas Salagaj**, South Plainfield, all of NJ (US)

(73) Assignee: **Emcore Corporation**, Somerset, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: 09/345,032

(22) Filed: Jun. 30, 1999

Related U.S. Application Data

(63) Continuation of application No. 08/757,909, filed on Nov. 27, 1996, now abandoned.

(51) Int. Cl.[7] C23C 16/00
(52) U.S. Cl. 118/725; 118/715; 118/724; 118/730
(58) Field of Search 118/715, 719, 118/724, 725, 730

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Primary Examiner—Richard Bueker
(74) *Attorney, Agent, or Firm*—Lerner, David, Littenberg, Krumholz & Mentlik, LLP

(57) ABSTRACT

Reactors for growing epitaxial layers on substrates are disclosed including rotatable substrate carriers and injectors for injecting gases into the reactor towards the substrates on the carriers and including a gas separator for separately maintaining various gases between gas inlets and the injector. Various reactor embodiments are disclosed including removable gas separators, and particular injectors which include cooling channels, as well as flow restrictors mounted within the reactors to restrict the flow of the gases to the substrates from the injector, and heaters mounted within the rotatable shell holding the substrate carriers so that the heaters can be accessed and removed through a lid forming a wall of the reactor.

58 Claims, 3 Drawing Sheets

SMI CVD Technology

L. Gary Provost

Under Development

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Process Parameters for $YBa_2Cu_3O_x$ MOCVD

MOCVD Process Parameters	
Metal Organic Precursors	$Y(thd)_3$ / $Ba(thd)_2$ / $Cu(thd)_2$
Precursor Ratio	10% / 53% / 37%
Solvent	Tetrahydrofuran
Molar Ratio Precursor / Solvent	0.06 moles/liter
Feed Rate	0.25 ml/minute
Flash Evaporator Temperature	260 C
Gas Line Temperatures	280 C
Shower Head Temperature	280 C
Susceptor Temperature	750-850C (775C typical)

SMI CVD Technology

Process Parameters for $YBa_2Cu_3O_x$ MOCVD

MOCVD Process Parameters	
Uniform O_2 Flow	300 sccm
Uniform Ar Flow	300 sccm
Flash Evaporator Push (Ar)	500 sccm
Chamber Push (Ar)	500 sccm
Chamber Pressure	2.50 Torr
Flash Evaporator Pressure	~ 40 Torr
Deposition Rate	0.30 µm/hr

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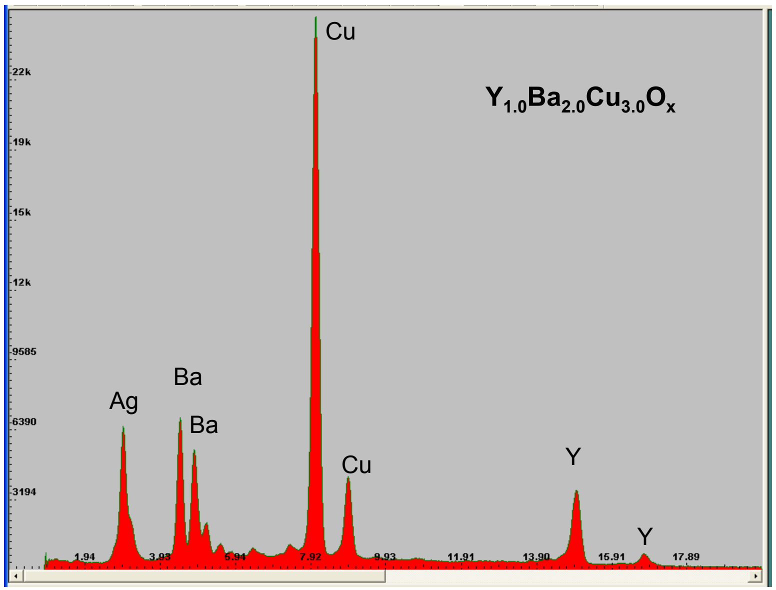
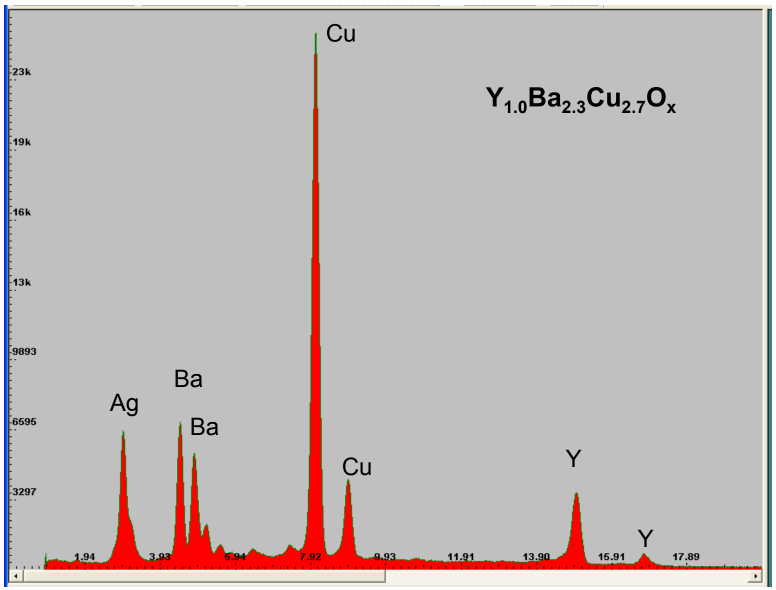
X-Ray florescence (XRF) provides for easy *qualitative* analysis of YBCO films on silicon witness substrates.

Most of the common substrates for YBCO (i.e. $SrTiO_3$, $LaAlO_3$, YSZ) have overlapping peaks with YBCO, which interfere with *quantitative* XRF analysis.



Bulk $YBa_2Cu_3O_x$ Standard



MOCVD YBCO Film on Silicon

X-ray Florescence using Silver ($Ag_{K\alpha}$) primary beam.

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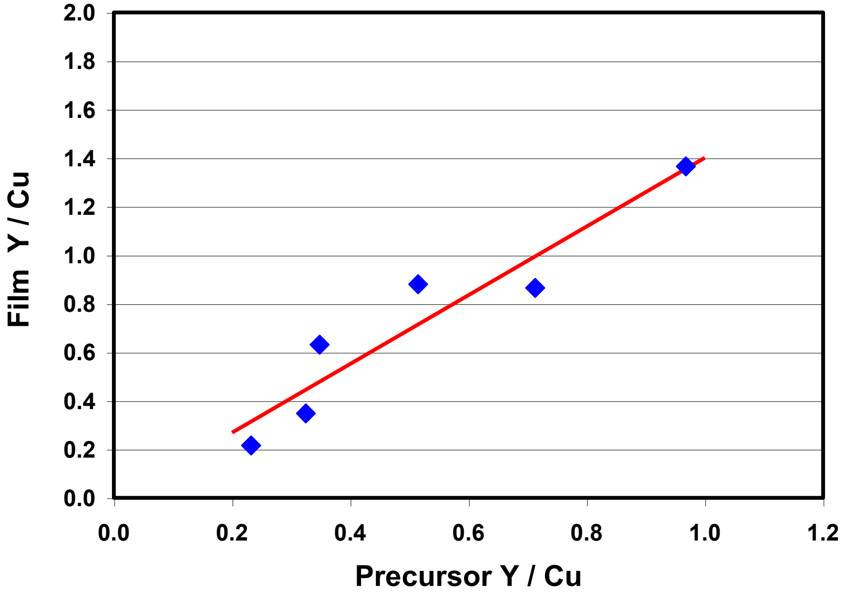
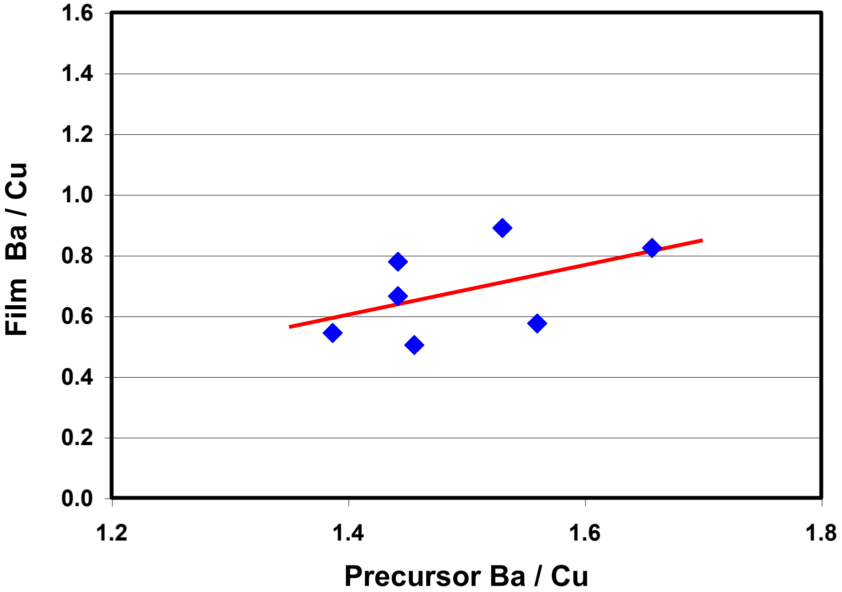
Quantitative analysis of YBCO films is done by Rutherford Backscattering Spectroscopy (RBS).

RBS is used for calibration of the YBCO Composition relative to Precursor Concentrations.





YBCO film composition determined by RBS.

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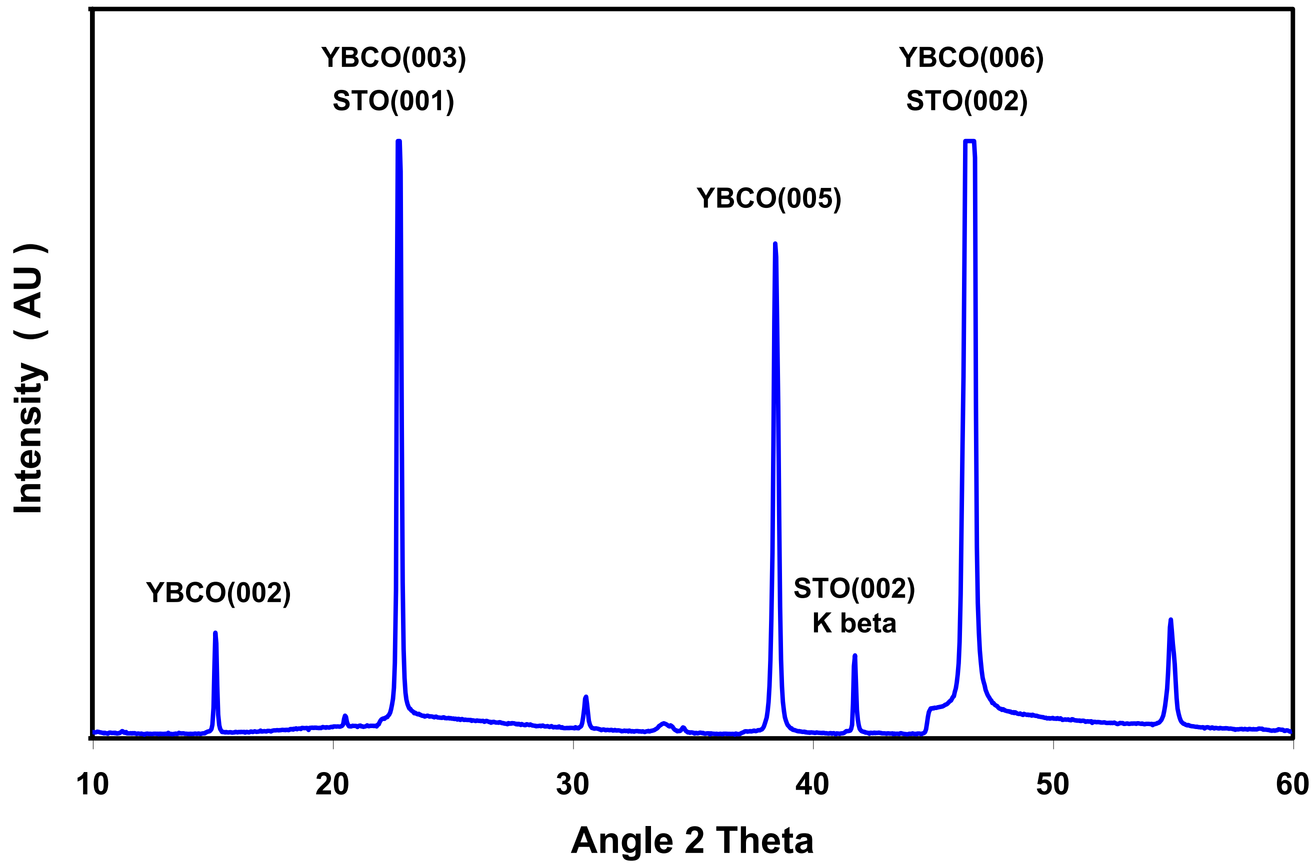
Epitaxial $YBa_2Cu_3O_x$ Films on $SrTiO_3$



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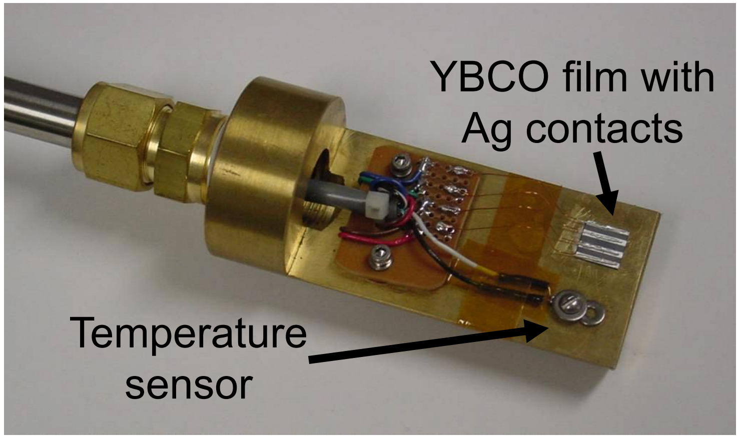
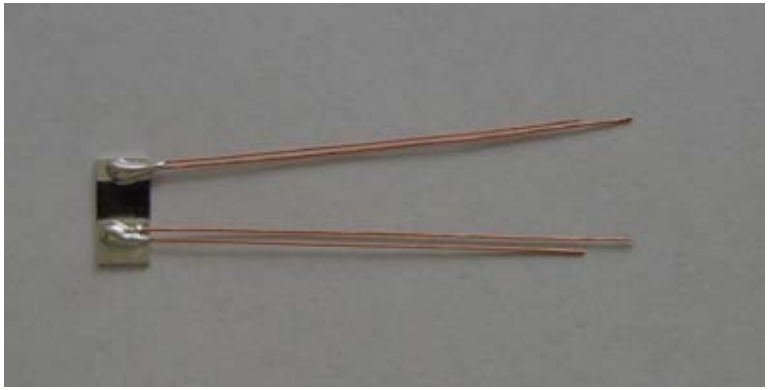
SMI developed in-house capabilities for T_c and J_c characterization of superconducting $YBa_2Cu_3O_x$ films.



Unpatterned YBCO film

Mounted for 4-point probe measurement of T_c



YBCO film with laser patterned microbridge

For 2-point probe measurement of J_c at 77 K

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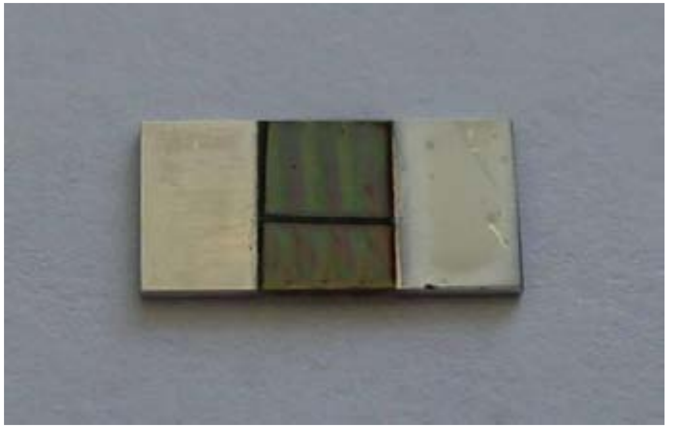
J_c Characterization of Superconducting $YBa_2Cu_3O_x$ Films at SMI



YBCO films on 4 mm x 10 mm $SrTiO_3$ Crystal by MOCVD. Thickness ~ 0.5 µm.

Silver contacts applied by sputtering through a shadow mask.

YBCO Patterned to ~ 250 µm wide micro-bridge by laser ablation for Jc measurements.

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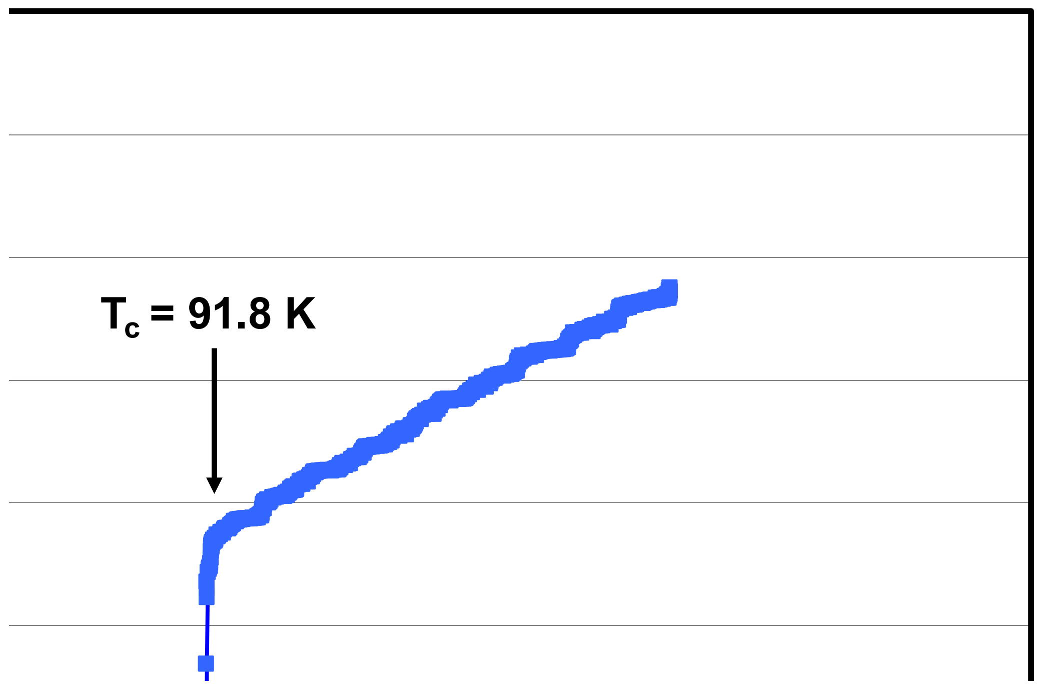
Epitaxial $YBa_2Cu_3O_x$ Films on $SrTiO_3$



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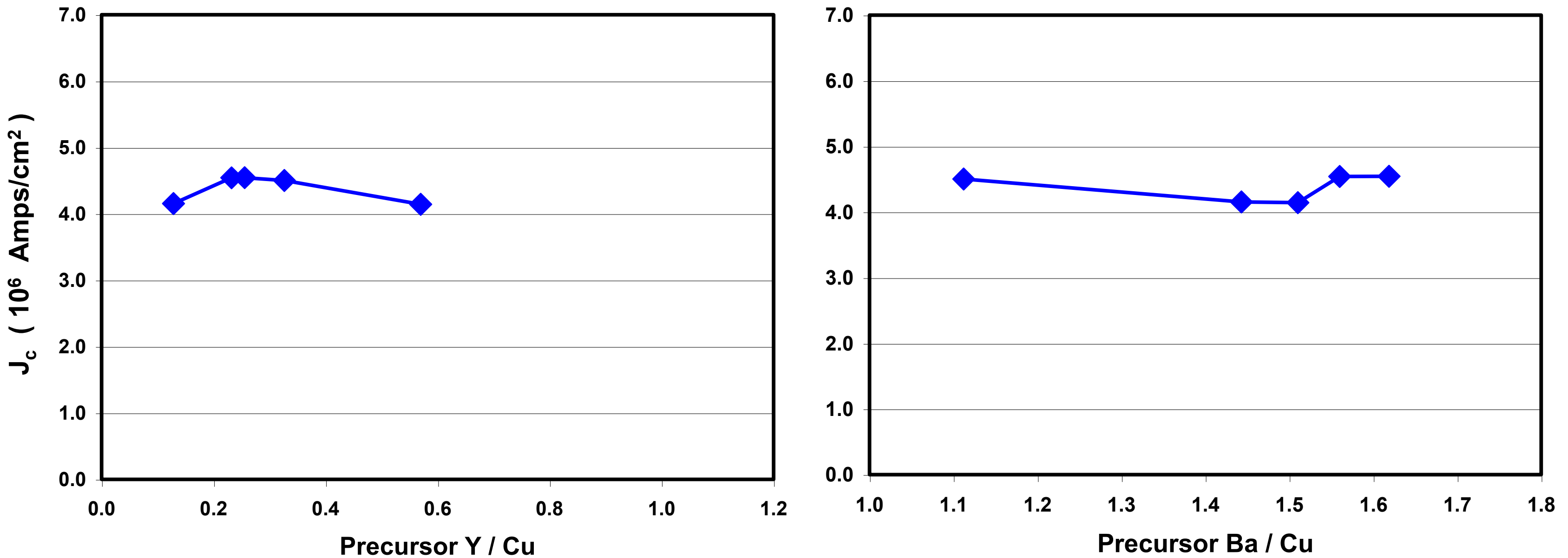
Critical current density (J_c) is relatively insensitive to composition, for films near the $Y_1B_2C_3O_x$ stoichiometry.



YBCO films on $SrTiO_3$ single crystals

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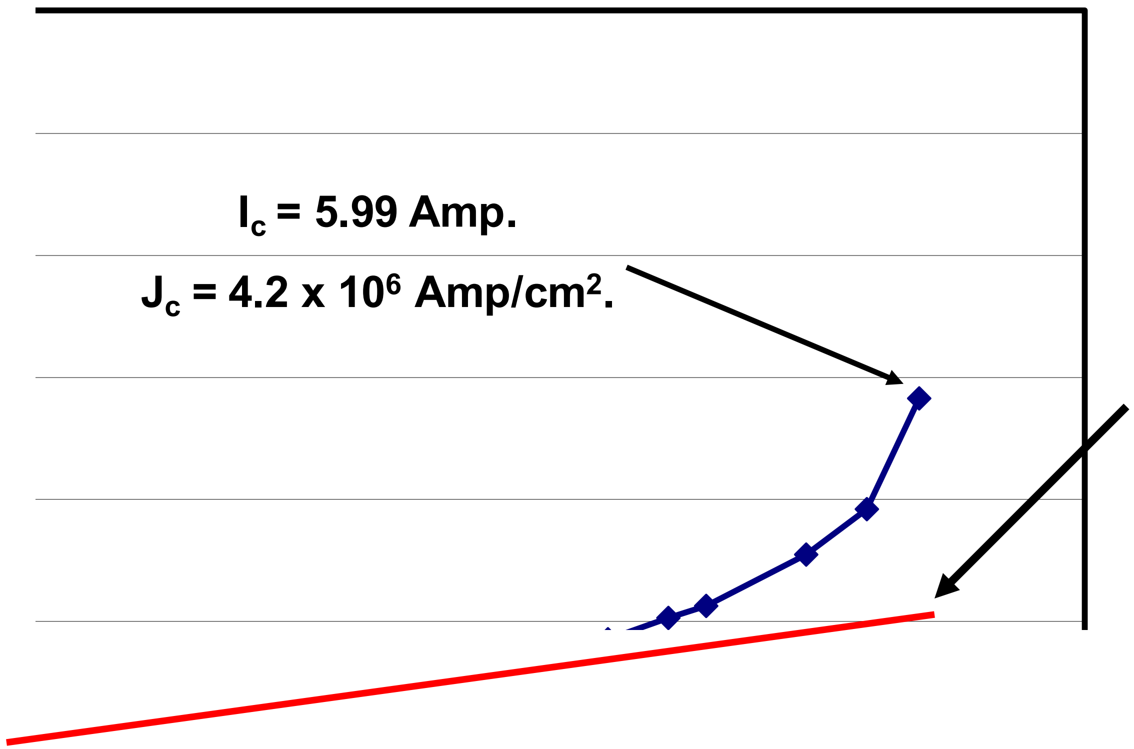
Epitaxial $YBa_2Cu_3O_x$ Films on $SrTiO_3$



The resistance versus current data contains a contribution from the contact resistance, since we use a 2-point measurement.

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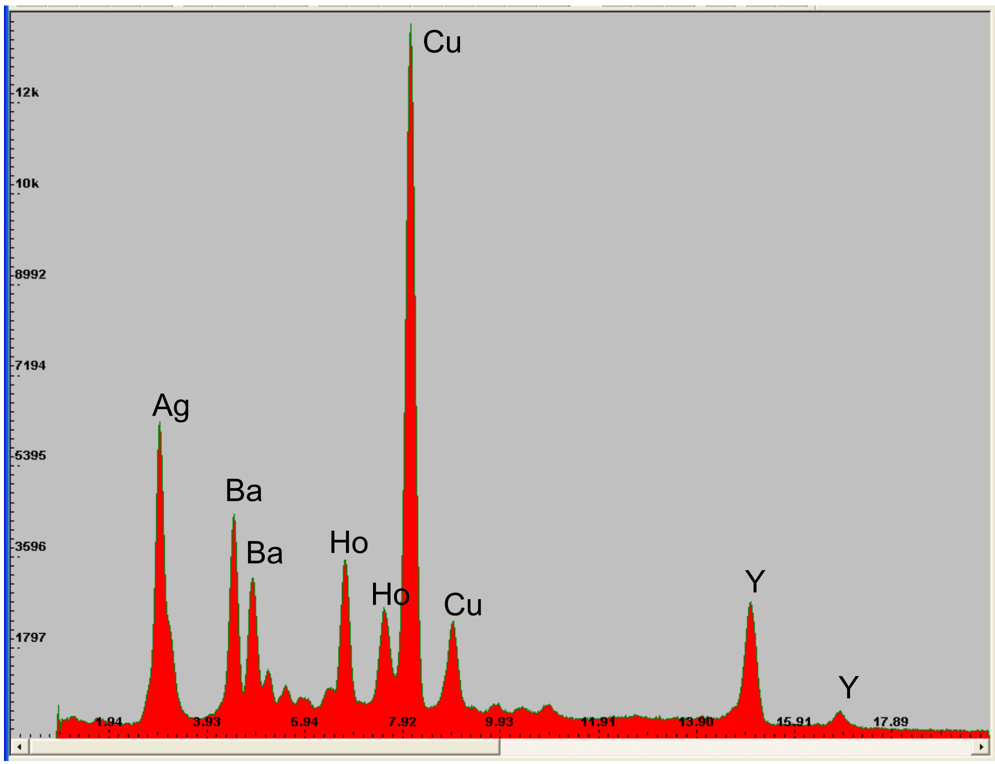
Rare Earth (Ho) doped $YBa_2Cu_3O_x$ Films by MOCVD



X-ray Florescence using Silver ($Ag_{K\alpha}$) primary beam.
XRF qualifies films; RBS quantifies composition.

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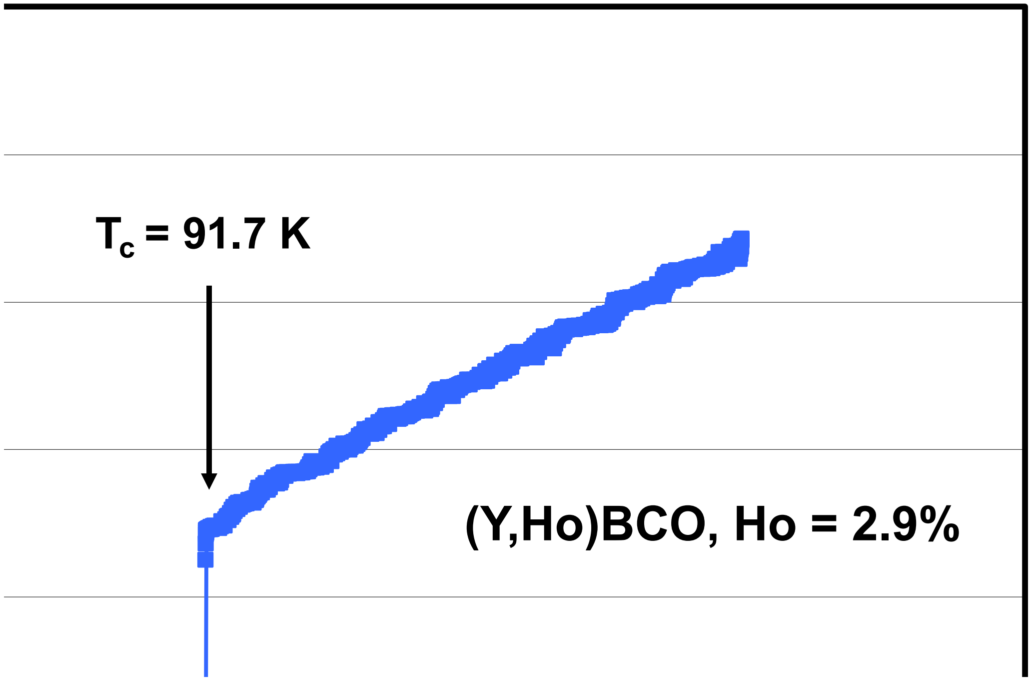
Rare Earth (Ho) doped $YBa_2Cu_3O_x$ Films by MOCVD



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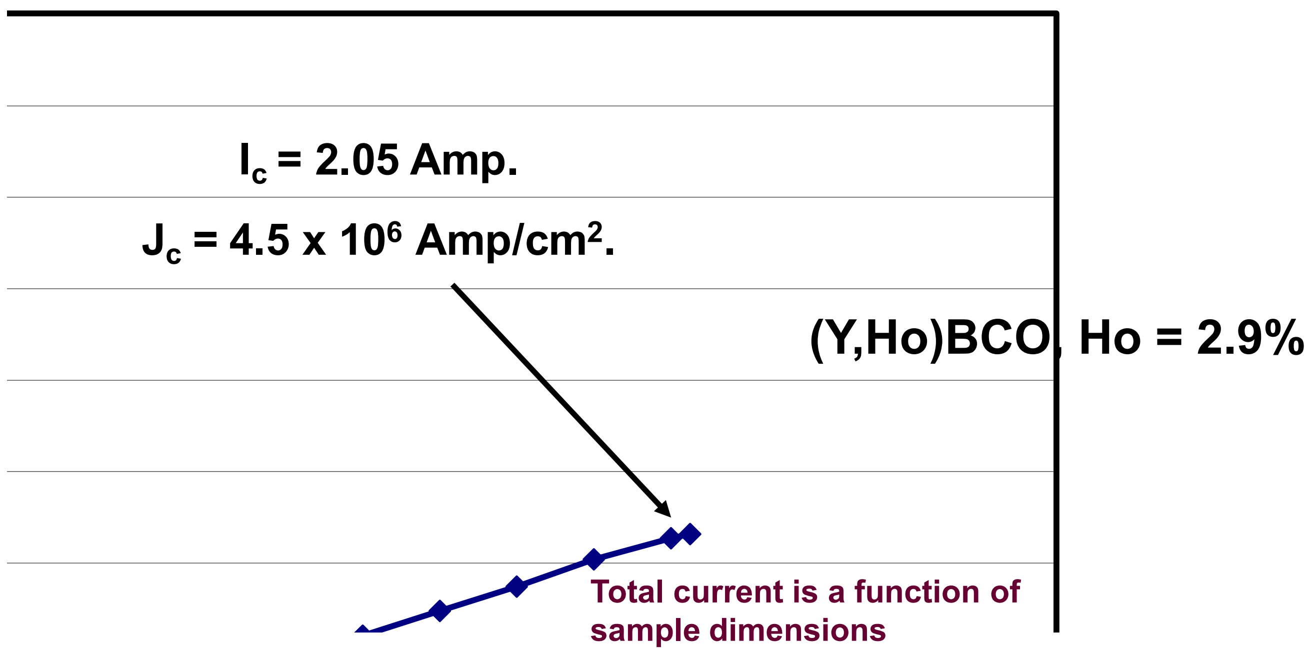
Rare Earth doped $YBa_2Cu_3O_x$ Films by MOCVD



Rare Earth doping improves current capability in high magnetic field

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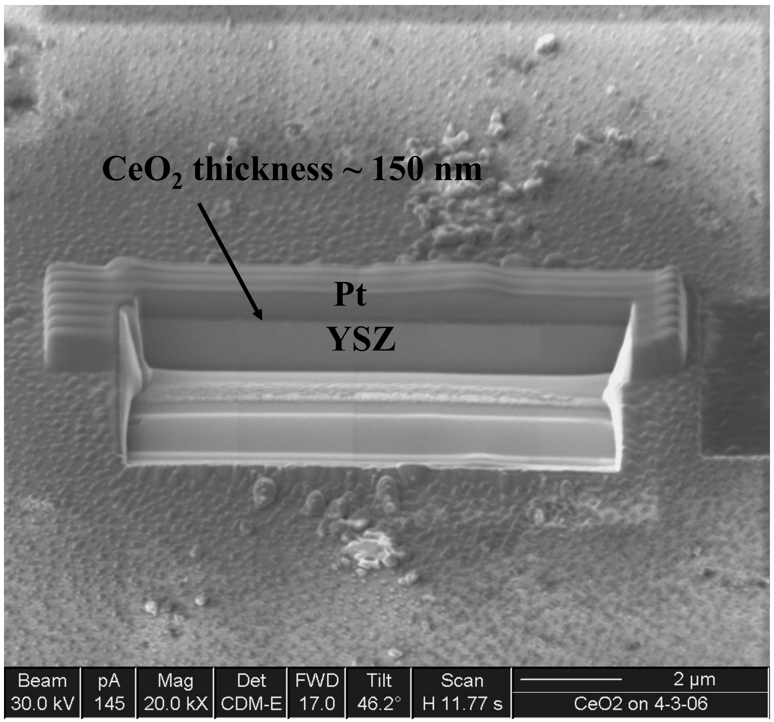
CeO_2 MOCVD on Single Crystal Substrates



Focused Ion Beam Microscopy Image

Typical results for CeO_2 films deposited at 725 C to 800 C	
Deposition Rate	2.7 nm/minute
Deposition Efficiency [per mole of $Ce(thd)_4$]	840 to 930 microns/mole
Measure Index of Refraction (*n*)	2.20 to 2.39

Future potential for multiple layer YBCO films – Ie YBCO/CeO/YBCO/CeO/YBCO/standard tapes

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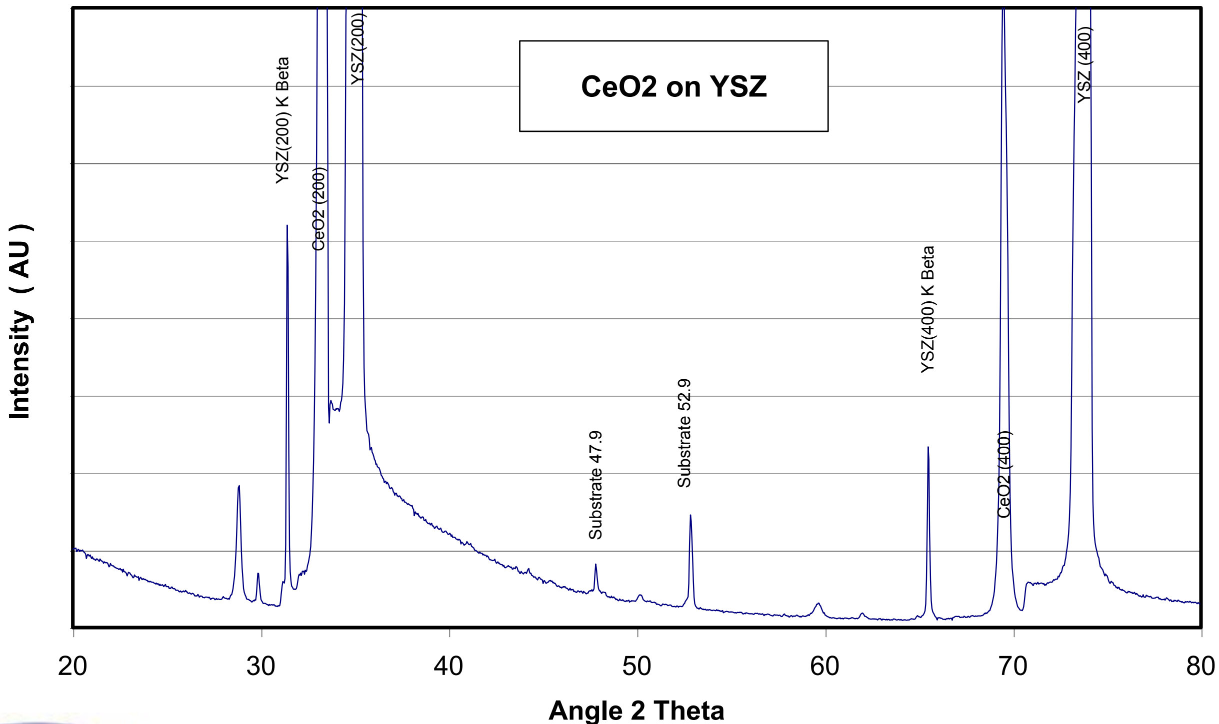
CeO_2 MOCVD on Single Crystal Substrates

Epitaxial CeO_2 films were deposited by MOCVD on (100) single crystal YSZ substrates at all temperatures in the range 725 C to 850 C.



X-ray diffraction results for a CeO_2 film deposited on (100) YSZ by MOCVD at 725 C.

Ni filtered Cu K_α radiation.

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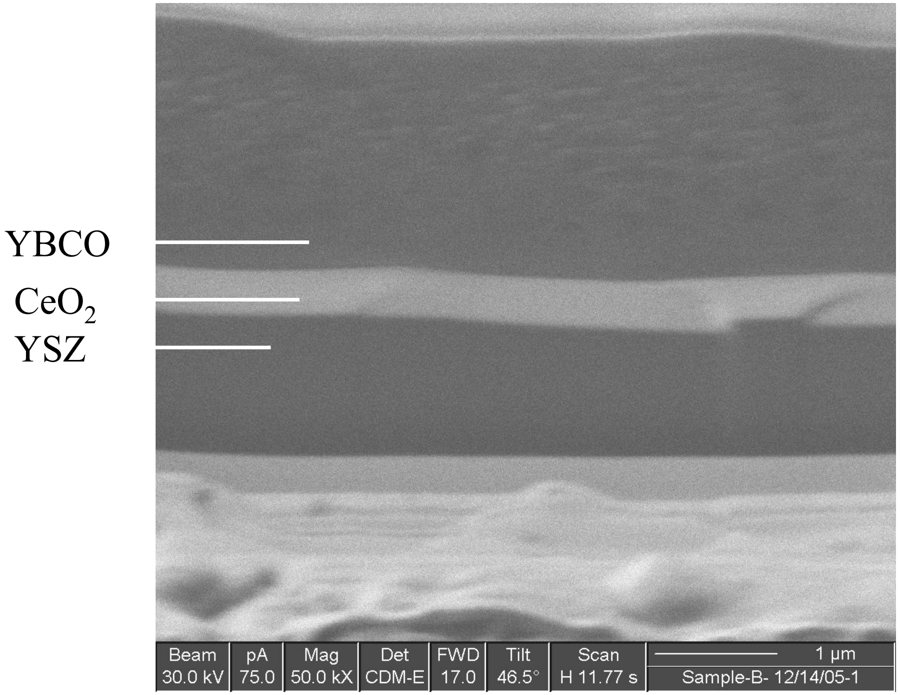
$YBa_2Cu_3O_x$ MOCVD on CeO_2 Coated YSZ Substrates



FIB Microscopy Image

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$YBa_2Cu_3O_x$ MOCVD on Buffer Coated Metal Tape

IBAD coated flexible metal tape obtained from Los Alamos National Laboratory

Initial, limited trial depositions

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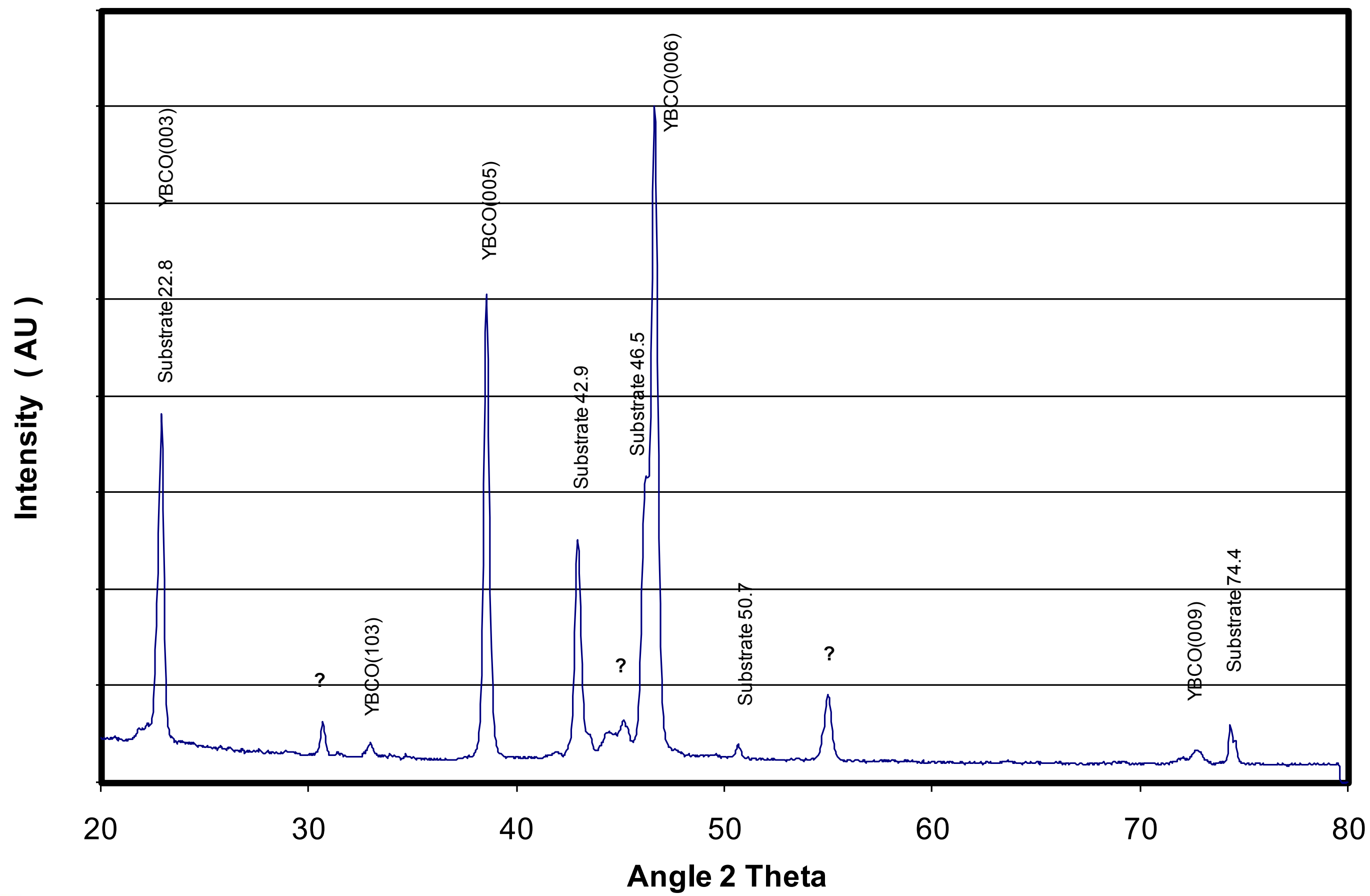
$YBa_2Cu_3O_x$ MOCVD on Buffer Coated Metal Tape



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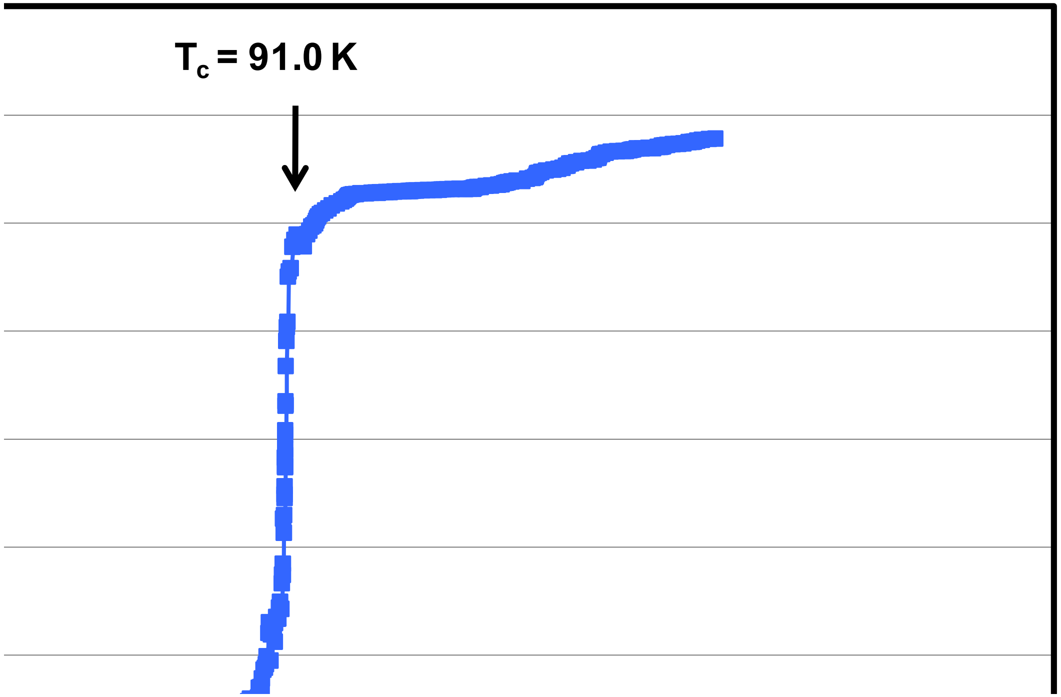
$YBa_2Cu_3O_x$ MOCVD on Buffer Coated Metal Tape



SMI CVD Technology

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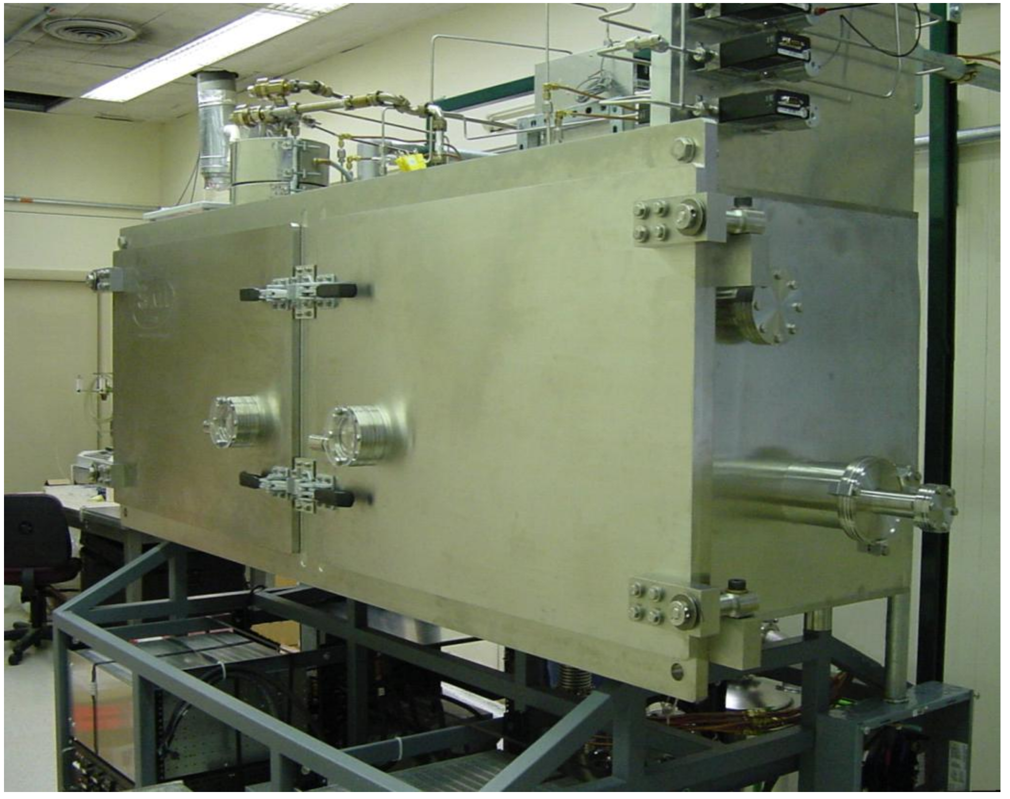
Intermediate Development of Reel-to-Reel MOCVD System for Kilometer Scale Coated Conductors

- **Large chamber accommodates internal or external tape drive system.**
- **Expandable to multiple chambers.**
- **Multiple ports for additional process enhancements or process monitors.**



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MOCVD System Internals: Substrate Heater and Gas Showerhead

Substrate hot zone = 36” x 6”.

Showerhead deposition area = 22” x 5”.

The large area deposition zone provides for high tape throughput and for simultaneous deposition on multiple tapes.

Multiple showerheads can be installed for multi-layer films.

Internal tape drive not shown.

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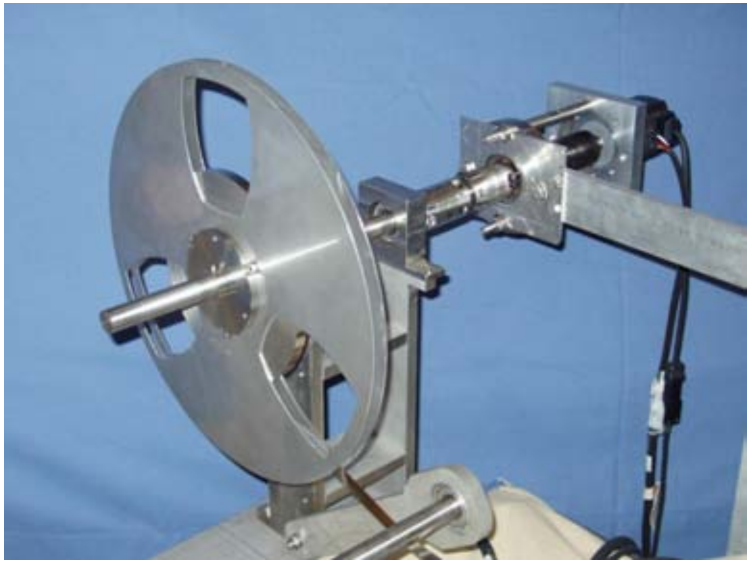
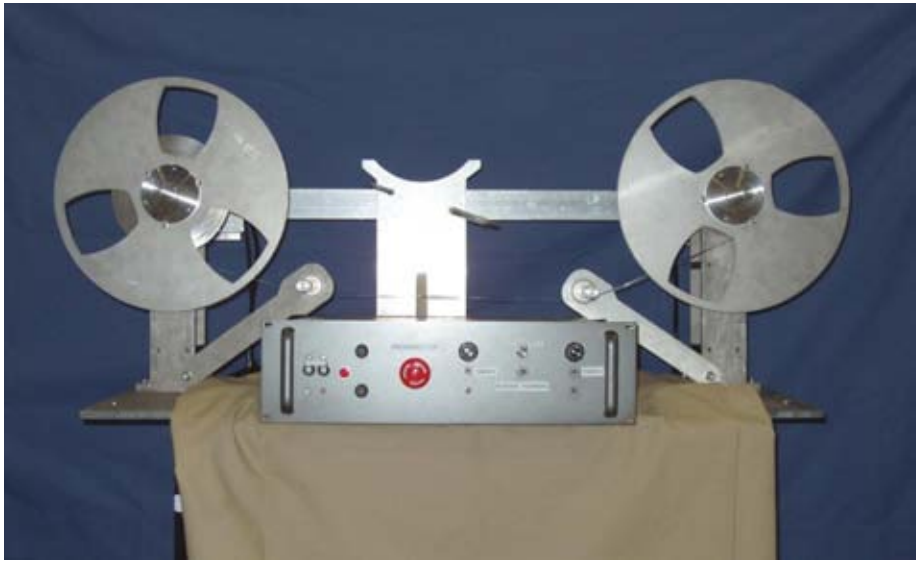
Kilometer Scale Tape Drive System

The tape drive system is shown mounted on a test stand. The tape drive can accommodate a single tape or multiple tapes running in parallel. A proprietary tension control system enables balanced forward or reverse tape motion.





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Reel-to-Reel MOCVD System Delivered and Installed at AFRL

System developed by SMI and presently installed at the Air Force Research Laboratory at WPAFB.

SMI CVD Technology

MOCVD Reel-to-Reel (R2R) System for Kilometer Scale YBCO (rare earth doped) Tapes

Major Features:

- MOCVD Reactor and optional stations (Anneal, Alt. Layer, Etc.)
- >100 meter tape reel-to-reel chambers (2) with Tensioners & Aligners (With loaders)
- Optional In-situ Monitors: XRD, XRF, RGA, others possible
- Chemical Delivery System(s); liquid flow controllers (or pumps)
- Control System & Electronics
- Exhaust System
- Framing and utilities

MOCVD Reel-to-Reel (R2R) System for Kilometer Scale YBCO Tapes

- YBCO Deposition Station
  - Pre-heat, Post anneal and/or cool
  - 1 or More Process Zones
    - Primary – YBCO 0.5m
    - Optional– Clean, CeO, Anneal, Passivation, or additional YBCO stations

MOCVD Reel-to-Reel (R2R) System for Kilometer Scale YBCO Tapes

Control System

- Computer to PLC Control System
- Real Time Graphical User Interface
- Automatic Control, manual override
- All Analog and Digital Inputs and Outputs Controlled
- Safety Features Interlocked
- Program/Data Logging

Proposed Reel-to-Reel MOCVD System for Scale 100 Meter Coated Conductors

- Basic Pricing
  - Complete System $$TBD$$
  - RGA option
  - In-Situ XRD or XRF options
  - Spare Parts Kit
  - Service Agreement

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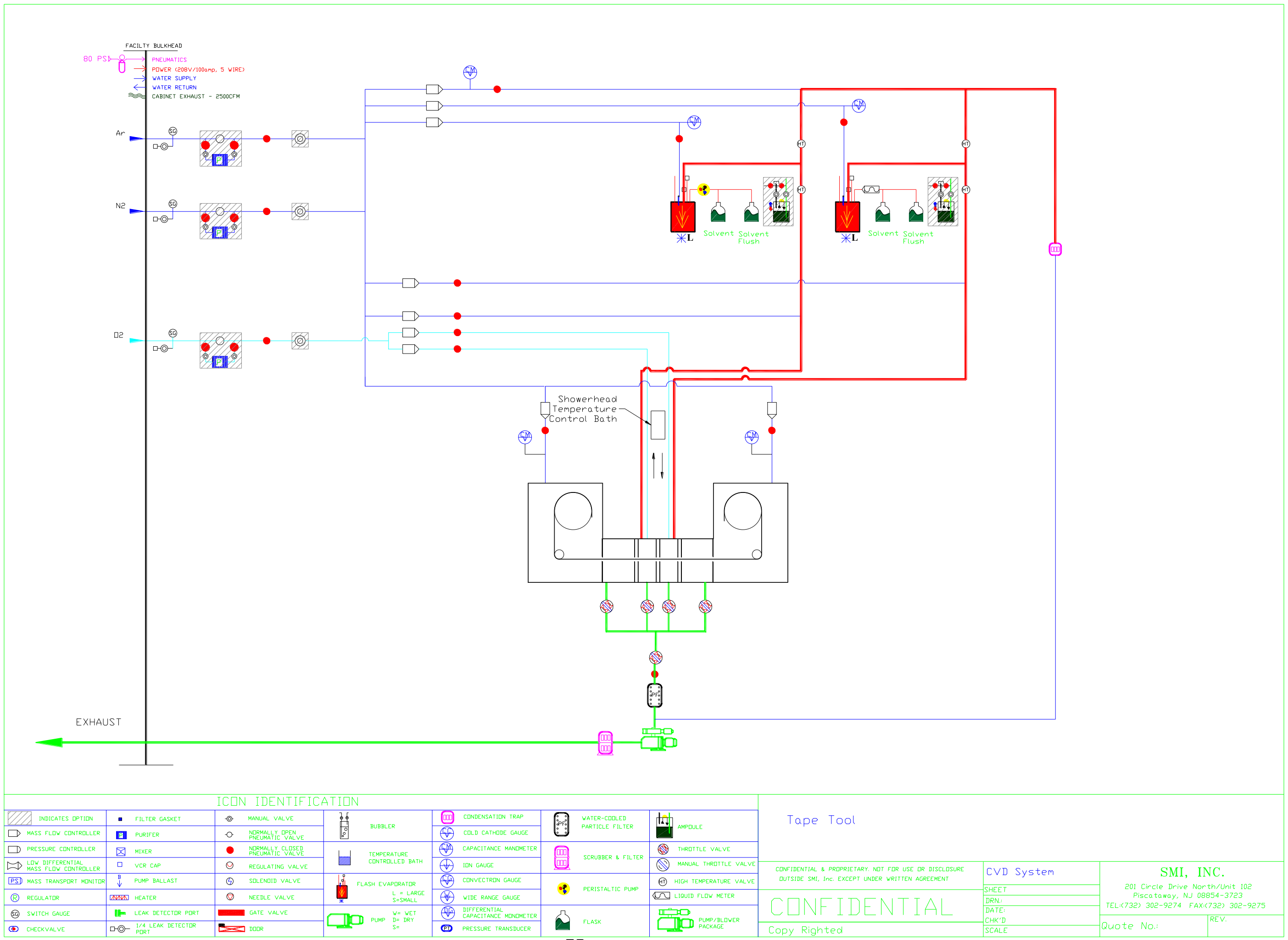
MOCVD Gas Panel Reel-to-Reel (R2R) System for Kilometer Scale YBCO Tapes



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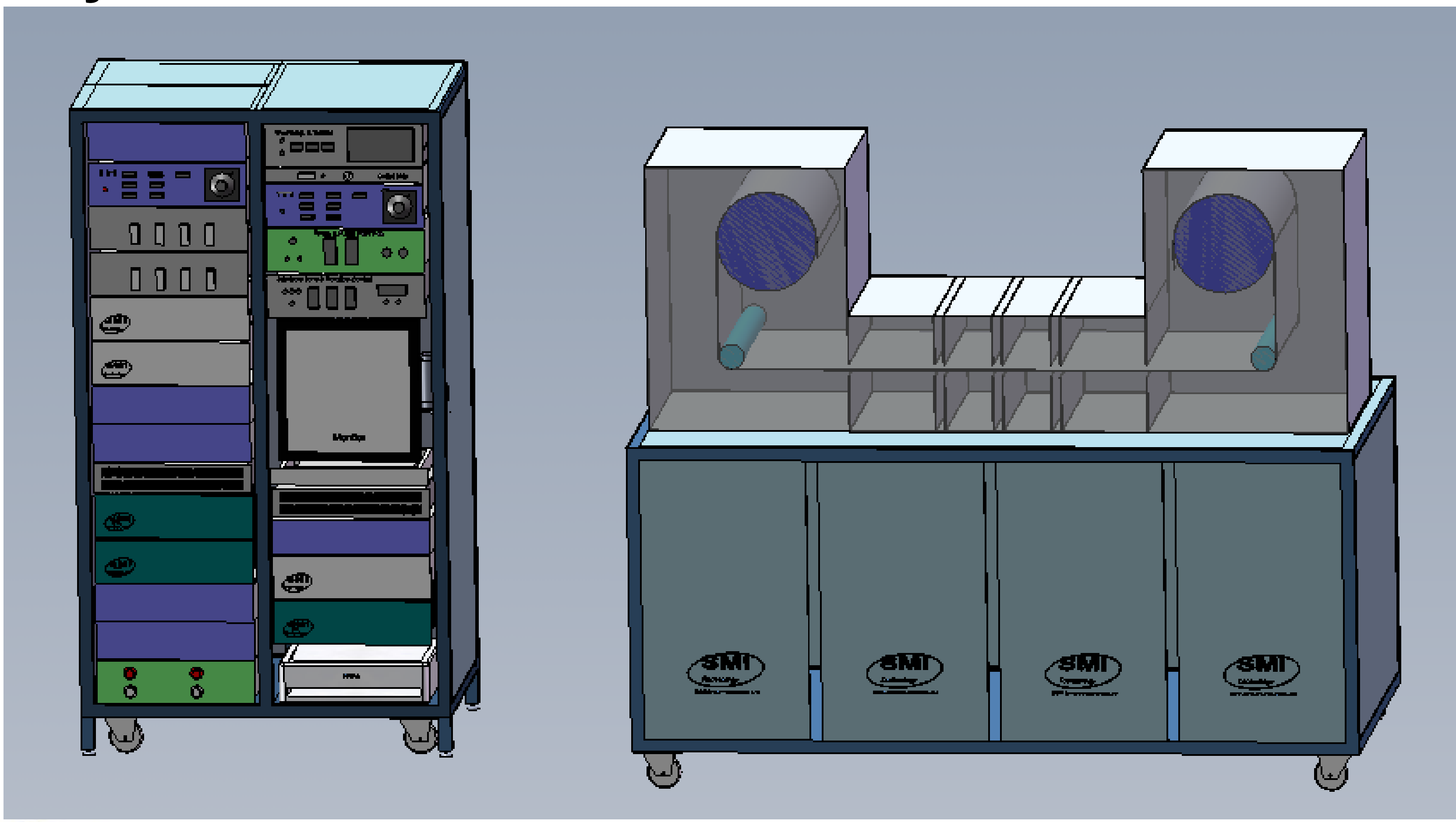
Next Generation Reel-to-Reel (R2R) Production MOCVD System for Kilometer Scale Coated Conductors



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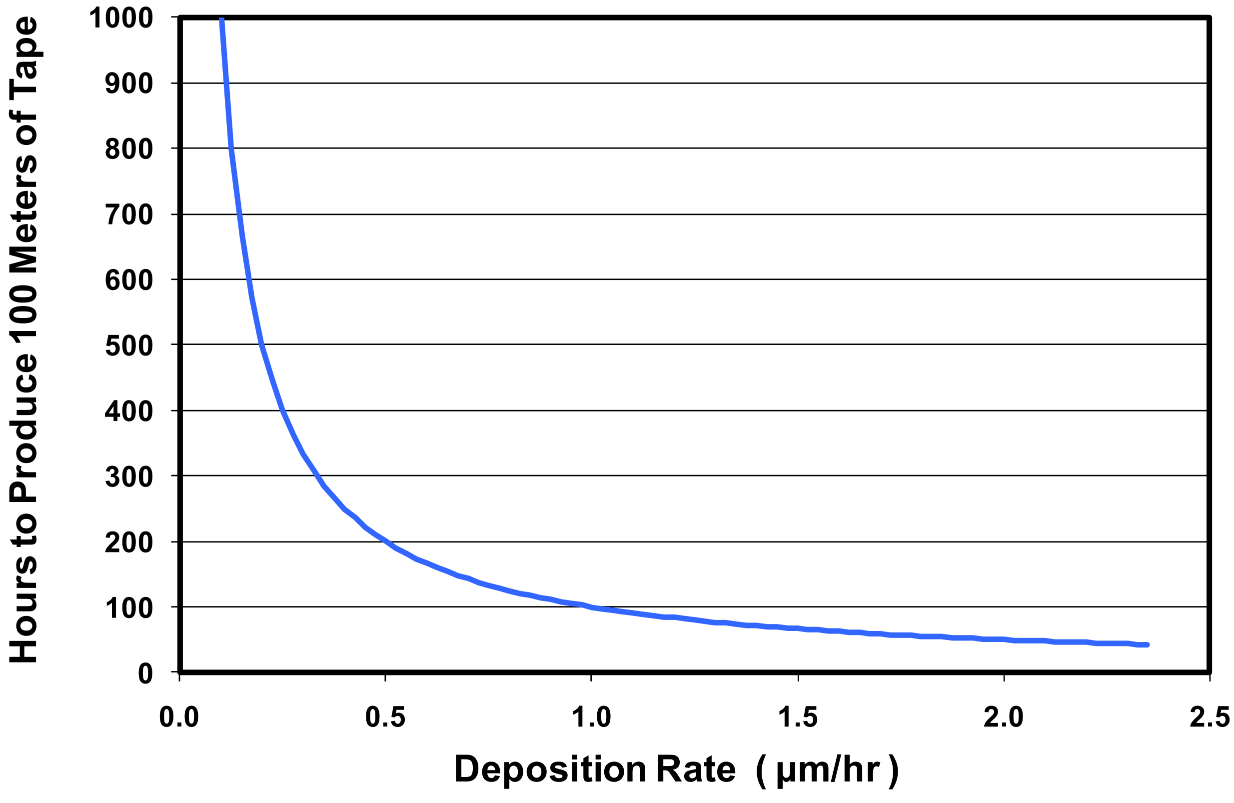
Tape Production Yield Estimates



Deposition Area = 50 cm in Length.

YBCO Thickness = 0.50 µm.

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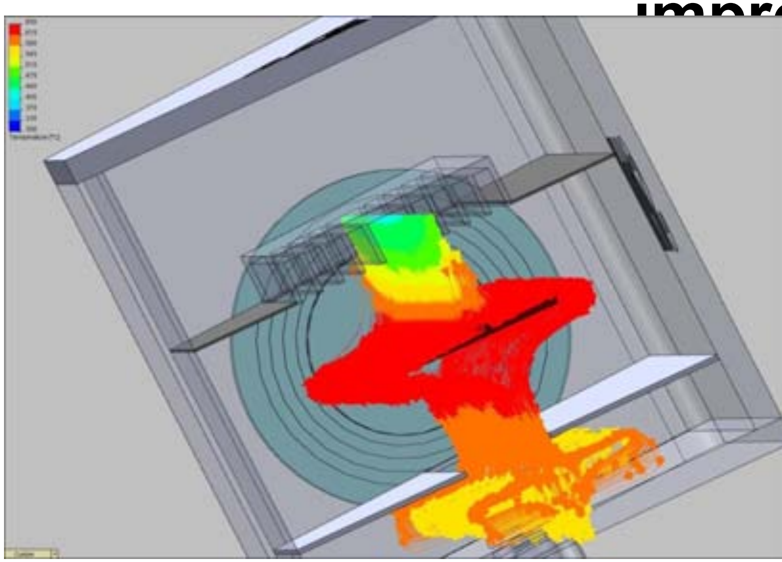
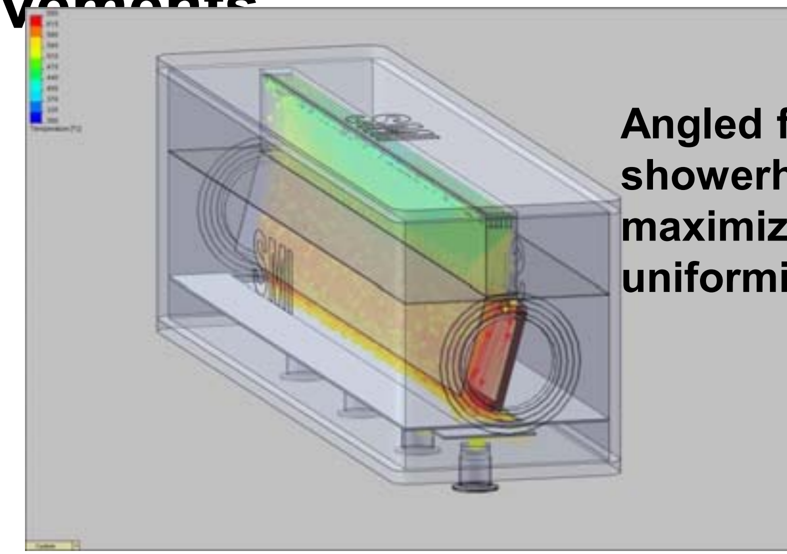
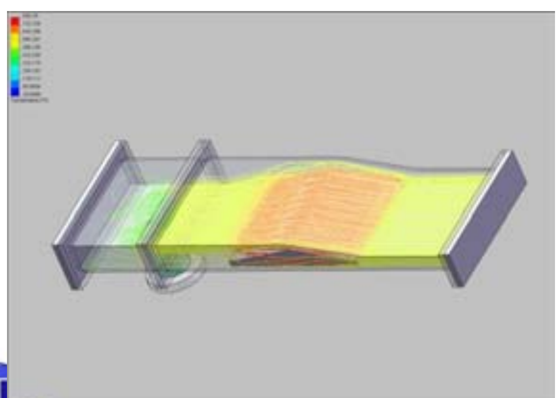
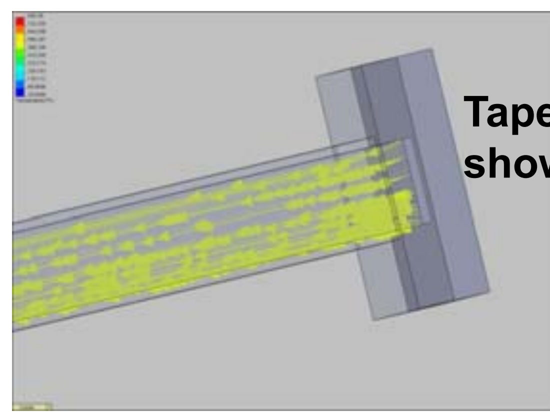
Flow/Thermal and Chemical modeling support design improvements





Angled flow showerhead maximizes uniformity





Tapered flow showerhead

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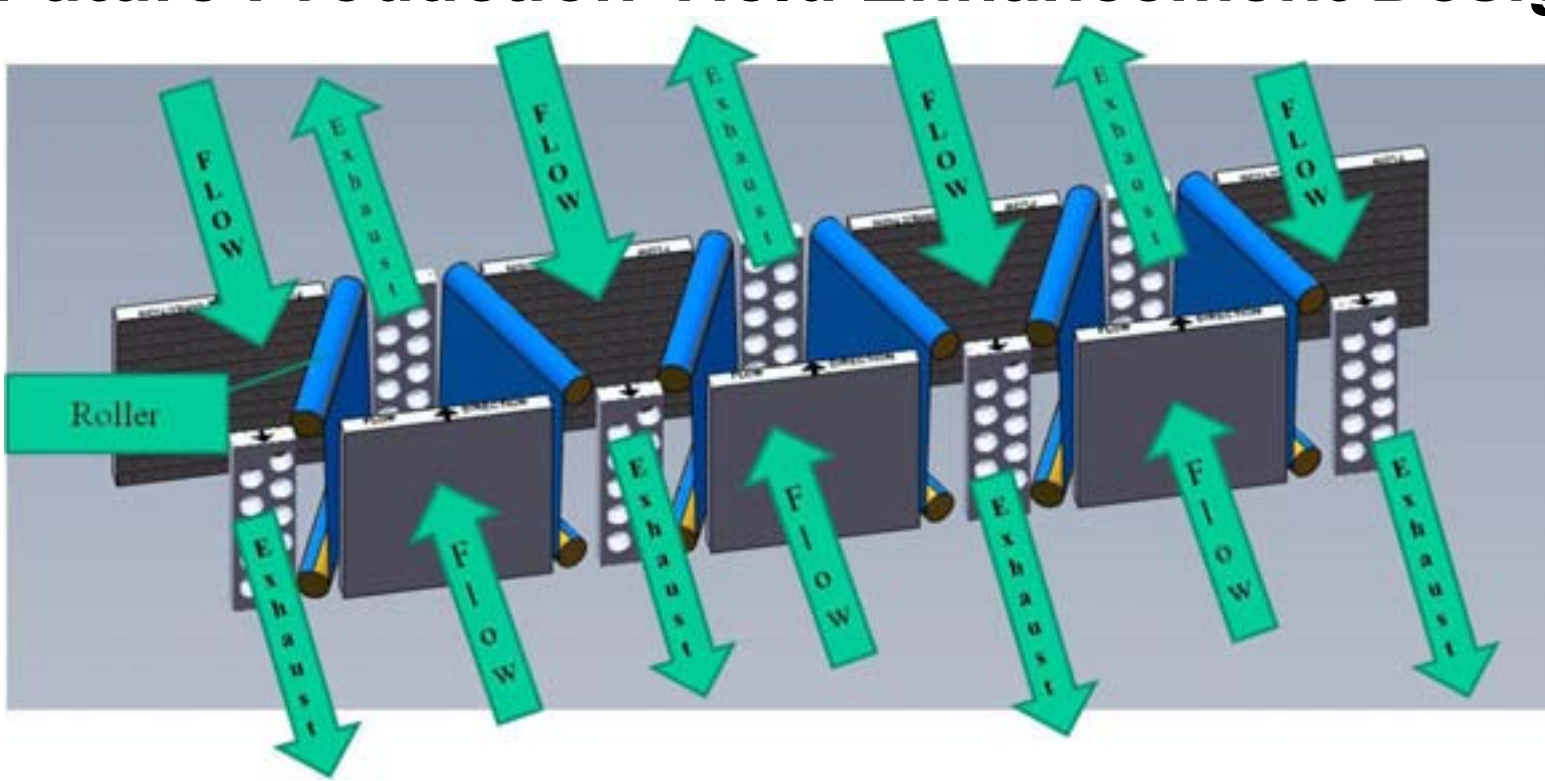
Patent Pending
Future Production Yield Enhancement Design



Simple Patent Pending innovation can essentially halve production costs

Some of SMI's External Design and Manufacturing Support

P Subcontracted Capabilities

Quality You Can Count On:
Operating in modern facilities covering more than100,000 square feet with state-of-the-art equipment, clean room facilities and assembly services – P utilizes all of its resources to provide OEM build to order manufacturing services for fixed and tape drive systems.

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IL Subcontractor Capabilities

- **Engineering**
  - SolidWorks software with structural finite element analysis add-ons
  - Robust CAD stations
  - Significant standard part CAD model database assists in efficient and accurate design
  - Document and version controls
  - ERP/MRP system
- **Manufacturing**
  - Conventional machine shop tools and staff machinists
  - Assembly tables, hand tools, precision measurement tools
  - Additional equipment:
    - TIG welder, 9000lb forklift and rigging equipment, 16' tandem axle trailer
  - Relationships with many US vendors for manufacture of:
    - Vacuum chambers
    - Fabricated parts
      - CNC mills and lathes with very large capacity available
    - Specialty brazed, welded, or heat treated parts
    - Ceramics

SMI CVD Technology

Structured Materials Industries, Inc.
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AV Subcontractor Capabilities

THIN FILM SOLAR (CIGS)

Sputter-based layers

- Back Electrode
- CuInGa absorber layer with proprietary co-selenization
- CdS integrated into the absorber layer system
- Window Layer

•WEB CIGS co-sputtering technology offers the following advantages vs co-evaporation process:

- Higher web speed
- Easier process control
- Less power consumption
- Easier maintenance
- Lower operating cost

•WEB's three-tool set has matched outputs

•Custom web widths and number of magnetrons

- 5 to over 30 magnetrons per system

•Common payout & take up system

•SUPER CONDUCTOR MATERIAL

•Broad Process Expertise

- Sputtering/Reactive (Proprietary Technologies for Fast Line Speeds)
- CVD (Proprietary Injection Design)

•Continuous Flow Processing

- Roll to Roll (Flexible Substrates)
- 5 cm to >100 cm web
- Extensive Range of Web Materials: Metals (Al, Ti, SS, Cu, etc.)
- Load locked Architecture
- Independent Process Zones
- High Throughput
- Pre-cleaning/conditioning

Many Engineering services may be hired for temporary development efforts

Contract Engineering Services

Engineered Support - for Innovators

All Services ▾

Overview

Contract Engineering Services

Contract Engineering Services is a unique resource. We "speak the language" of manufacturers, inventors, researchers and product developers who need electromechanical engineering support. For over 15 years, we have provided engineered solutions to a diverse clientele of businesses, inventors, and professionals working in medicine, energy, optics, advanced materials, and consumer products.

We work closely with our clients, to truly understand and clarify their problems and objectives. Then we apply our SolidWorks CAD, FEA, Rapid...

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Engineered Packaging Example

Illustrated is a lightweight, ruggedized, Fuel Cell Power Supply designed for a Military Client. The entire case was composed of plastic components fabricated by a Rapid Prototyping process called Selective Laser Sintering (SLS). Strong, functional components can now be obtained by SLS directly from CAD files and with no tooling or molds required. Additionally, SLS can produce parts with internal cavities and other features unproducible by other methods.

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In addition to in-house Multiple MOCVD Modeling Services Available

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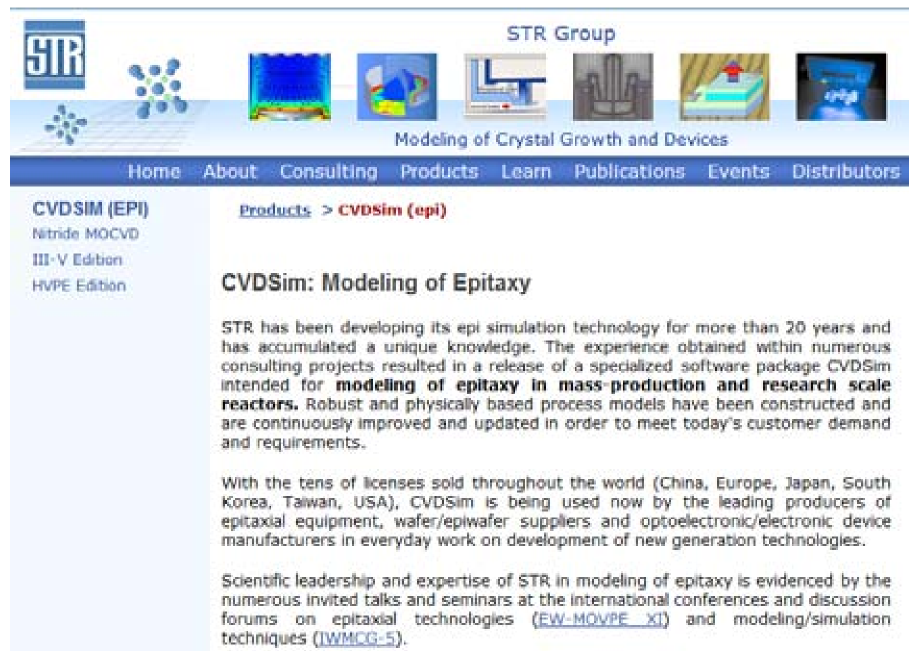
Epitaxy/MOCVD

Organo metallic vapor phase epitaxy, also known as MOCVD, is a primary technique to grow thin film III-V compound semiconductors such as gallium nitride (GaN), gallium arsenide (GaAs), and indium phosphide (InP) based materials. These materials are used in devices such as light-emitting diodes, solid-state lasers, photovoltaics, IR detectors, and heterojunction bipolar transitors. MOCVD is the critical enabling technology with several advantages including highly uniform thickness, excellent repeatability, low maintenance, high throughput and low cost of ownership. Fluent's CFD software combines physically accurate transport models with proposed gas-phase and surface chemistry mechanisms, and predicts uniformity of film thickness and composition variation during selective growth.

Flow path lines, concentrations of AsH3, GaAs deposition on a substrate in a MOCVD system.
Courtesy of Emcore Corporation

fluent



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Modeling of Crystal Growth and Devices
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CVDSIM (EPI)
Nitride MOCVD
III-V Edition
HVPE Edition

Products > CVDSim (epi)

CVDSim: Modeling of Epitaxy

STR has been developing its epi simulation technology for more than 20 years and has accumulated a unique knowledge. The experience obtained within numerous consulting projects resulted in a release of a specialized software package CVDSim intended for **modeling of epitaxy in mass-production and research scale reactors.** Robust and physically based process models have been constructed and are continuously improved and updated in order to meet today's customer demand and requirements.

With the tens of licenses sold throughout the world (China, Europe, Japan, South Korea, Taiwan, USA), CVDSim is being used now by the leading producers of epitaxial equipment, wafer/epiwafer suppliers and optoelectronic/electronic device manufacturers in everyday work on development of new generation technologies.

Scientific leadership and expertise of STR in modeling of epitaxy is evidenced by the numerous invited talks and seminars at the international conferences and discussion forums on epitaxial technologies (EW-MOVPE XI) and modeling/simulation techniques (IWMCG-5).

SMI CVD Technology