Pulsed Laser Deposition

¾ Unsurpassed experience in the development of PLD equipment and processes for research and production applications.

¾ Pioneer PLD systems are the world’s most widely used commercially available PLD system for R&D applications.

¾ Complete turnkey PLD laboratories or basic systems are available.

Pulsed Laser Deposition

A versatile method for the deposition of thin films and synthesis of nanostructures and nanoparticles.

PLD is the smart approach to complex materials deposition.

Pulsed laser deposition (PLD) is a versatile thin film deposition technique. A pulsed laser rapidly evaporates a target material forming a thin film that retains target composition. The uniqueness of PLD is that the energy source (pulsed laser) is outside the deposition chamber. This facilitates a large dynamic range of operating pressures (10^{-10} Torr to 100 torr) during material synthesis. By controlling the deposition pressure and temperature, a variety of nanostructures and nanoparticles can be synthesized with unique funcionalities. In addition, PLD is a ‘digital’ technique and provides process control (Å/pulse) at the nano scale.

Neocera Pioneer PLD systems – proven design based on unsurpassed experience

Neocera’s extensive research using PLD established certain critical parameters to maximize thin film quality, especially for the deposition of complex oxide thin films. These considerations have been incorporated into the Pioneer system design.

Many complex oxide thin films benefit from cooling down in a relatively high pressure (>100 Torr) of oxygen. All Pioneer system are designed to operate in the full pressure range from their rated base pressure to atmospheric pressure. This is also beneficial for nanoparticle generation.

Pioneer PLD systems use a laser beam angle of incidence of 45º, preserving optimum uniformity of laser fluence on the target without resorting to complex and costly optical elements. Shallow angles of incidence can cause the laser spot to elongate on the target, resulting in loss of fluence uniformity.

To eliminate the use of costly oxygen-compatible vacuum pump fluids, and eliminate the concern of oil backstreaming affecting film quality, oil-free pumping stacks are standard on all Pioneer systems.

Our research has revealed that target-to-substrate distance is a critical parameter for optimum thin film quality. Pioneer systems offer variable target-to-substrate distances to provide maximum control of deposition conditions.

PLD is cost effective: one laser can serve many vacuum systems

Neocera’s Pioneer-120 *PLD System (with recommended laser)*

Control Window of Neocera’s Pioneer-180 *PLD System*

Pioneer PLD systems

Neocera has applied over 15 years of PLD experience in the creation of the Pioneer systems. With four available models, a system can be configured to meet the user's specifications and budget.

.	Pioneer 240	Pioneer 180	Pioneer 120	Pioneer 80
Maximum wafer diameter	4”	2”	1”	.5”
Maximum targets on carrousel	six 1” or three 2”	six 1” or three 2”	six 1” or three 2”	four 1”
Base pressure (Torr)	$<10^{-8}$	$<10^{-6}$	$<10^{-6}$	$<10^{-6}$
Chamber diameter	24”	18”	12”	8”
Substrate heater	4” rotating	3” rotating	2” flat plate	1” flat plate
Maximum temperature at substrate	850ºC	850ºC	950ºC	950ºC
Turbo-pump speed (liters/sec)	800	260	260	70
Computer control	Included	Included	Included	Included
Substrate Rotation	Included	Included	-	-
Substrate Load-lock	Included	Optional	Optional	-
Scanning-Laser-Beam Delivery	Included	Optional	-	-
Target load-lock	Included	-	-	-
Ion-Beam-Assisted Deposition	Optional	Optional[1]	Optional	-
Continuous Composition Spread	Optional	Optional	-	-
High-Pressure RHEED	Optional	-	-	-
520 liter/sec Pumping Package	n/a	Optional	-	-

All systems also available as **Complete PLD Laboratory**, including 248 nm excimer laser, gas cabinet for laser gases, laser and optics tables, and optics package.

Warranty: one year, parts and labor

[1] Requires 520 liter/second pumping package

Specifications subject to change without notice.

Ion beam assisted deposition

Ion beam assisted deposition has emerged as an important technique for the deposition of biaxially textured thin films on randomly oriented or amorphous substrates.

High performance IBAD systems

Ion beam assisted deposition has emerged as an important technique for the deposition of biaxially textured thin films on randomly oriented or amorphous substrates. Neocera has developed ion assisted PLD systems that combine IBAD capability with PLD's advantages in deposition of complex materials.

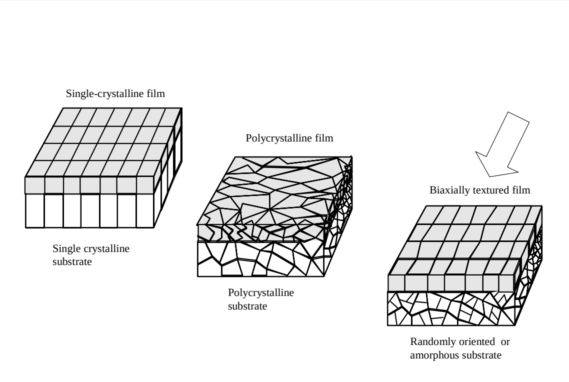
Backed by unmatched technical expertise

Neocera's ion assisted PLD systems are backed by significant application experience. System development combines Neocera's engineering and process experience to ensure maximum usability and process performance.

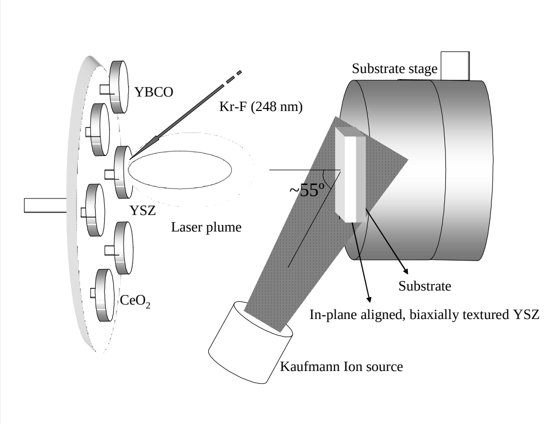
Using ion assisted PLD, Neocera developed biaxially textured $YBa_2Cu_3O_7$ (YBCO) films on flexible polycrystalline-yttria-stabilized zirconia (YSZ) substrates with the following materials properties:

- in-plane x-ray Φ-scan full width at half maximum of ~7°
- transition temperatures (T_c) in the range of 88–89 K with transition widths (ΔT_c) of ~0.5 K
- critical current densities (J_c) in the range 1.5– 2 x 10^6 A/cm2 at 77 K, zero field
- Magnetic penetration depth (λ) of 284 nm at 77 K;
- Surface resistance (R_s) of 700 μΩ at 77 K, 10 GHz.

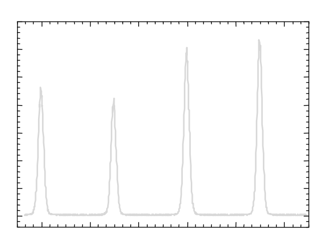
A reprint of the technical paper describing this work in greater detail is available upon request.



Deposition of biaxially textured films on randomly oriented substrates



Schematic of ion-assisted PLD



Phi-scan data of biaxially textured YBCO films on flexible, polycrystalline YSZ substrates (Applied Physics Letters, Vol. 78, No 13, 26 Mar 2001)

Ion beam assisted PLD system with load lock substrate transfer

Continuous Composition Spread

A novel continuous composition-spread (CCS) approach for combinatorial materials synthesis, based on pulsed laser deposition

Economical combinatorial synthesis

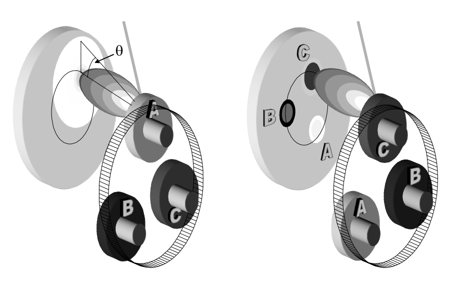
Combinatorial synthesis is one of the most exciting recent developments in materials science. The ability to produce many different material compositions in a single deposition run greatly accelerates the time to arrive at optimum composition having the desired material properties. However, the high cost of existing combinatorial synthesis systems is not practical for most research budgets.

Backed by Neocera's PLD experience

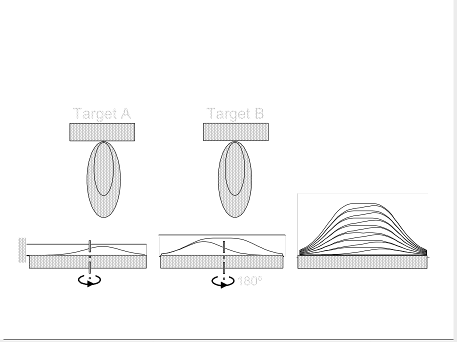
Neocera has applied our vast experience in PLD and the development of reliable, economical equipment to create the Neocera PLD-CCS (Pulsed Laser Deposition – Continuous Composition Spread) system. PLD-CCS benefits from the proven ease of multilayer deposition and the intrinsic forward-directed nature of the PLD process to vary the composition of a binary, pseudobinary, or ternary system over the substrate.

Combinatorial synthesis under normal deposition conditions.

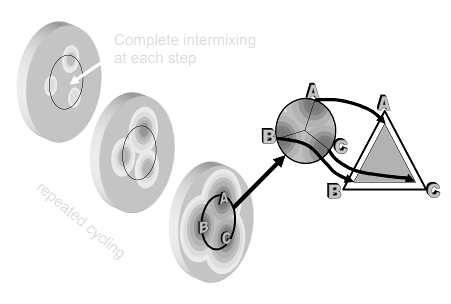
PLD-CCS varies the material in an analog scheme, rather than in discrete elements, thus eliminating the need for masks. This allows for a very rapid successive deposition of each constituent at a rate of much less than a monolayer per cycle, resulting in an approach that is fundamentally equivalent to a co-deposition method. The fact that this method does not depend on a post-deposition anneal to promote interdiffusion or crystallization makes it applicable to studies where growth temperature is a critical parameter, or to situations where high-temperature anneals are incompatible with either the deposited material or the substrate.



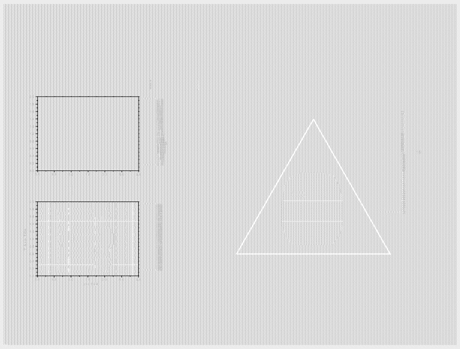
Deposition scheme for CCS



Alloy formation by Rapid Sequential Deposition



Deposition of Ternary Phase Diagram



(In-Sn-Zn) oxide phase diagram

CCS Routine editor screen

Laser MBE

Ideal for nanoscale thin films, the combination of PLD and in-situ high pressure RHEED provides precise control of film growth at the monolayer level.

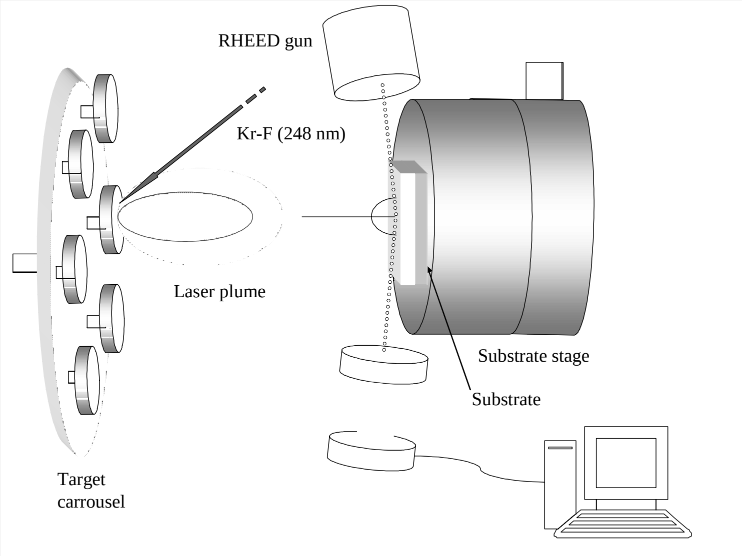
Use of Laser MBE is ideal for nanotechnology research.

Laser MBE is a commonly applied term to define PLD in ultra high vacuum combined with Reflection High-Energy Electron Diffraction (RHEED) for in-situ process monitoring. This offers the user MBE-like monolayer level control of thin film growth. As more PLD research becomes driven by nanotechnology, Laser MBE becomes more beneficial to the user.

Proper design is essential for successful use of RHEED with PLD.

RHEED is conventionally used in a high vacuum (<10^{-6} torr environment. However, because of the relatively high pressures used for PLD in certain special cases, differential pumping is necessary to maintain the operating pressure of the RHEED gun and still enable the PLD process to occur at up to 500 mTorr. Also, it is essential to design the complete system to prevent any magnetic fields from effecting the electron beam.

Neocera’s proven Laser MBE system design provides the user with the monolayer control desired at pressures up to 500 mTorr.



Schematic of Laser MBE system

Complete Laser MBE lab with laser and optics

Laser MBE deposition system

RHEED pattern on Laser MBE computer

Custom PLD Systems

Neocera's applies a unique combination of process knowledge and engineering capability to develop custom systems for specific requirements.

PLD continues to grow into new research and production applications

As pulsed laser deposition continues to evolve, innovative users continue to pursue new applications for this exciting technique. Some examples over the past few years include the simultaneous deposition of multiple substrates, deposition on non-planar surfaces, and ion-assisted deposition of large area thin films.

Neocera continues to develop systems to meet unique customer requirements.

While the Pioneer series of standardized PLD systems will meet a majority of PLD requirements, Neocera also applies our considerable engineering and process capability to the development of custom systems to meet unique customer requirements. Whether the process dictates unique deposition geometries, high levels of automation, or incorporation of additional deposition or characterization techniques, Neocera custom systems always meet or exceed customer expectations.

System for deposition on 7.5" diameter non-planar surface

System for simultaneous deposition of multiple substrates

User interface for fully automated load lock transfer of targets and substrates

Ion assisted PLD system with fully automated load lock transfer of targets and 4" diameter substrates

About Neocera

Our Thin-Film mission is to become researchers' and manufacturers' first choice for complex thin-film deposition equipment and thin-film foundry services.

World class products backed by unsurpassed technical expertise

Founded in 1989 as a commercial vehicle for conveying technological expertise in ceramic thin film materials, Neocera continues to develop PLD equipment and processes that result in products of high value to the customer. Neocera remains active in materials research, leading the application of PLD into new material systems, and participating directly in the transition from PLD processes from the research laboratory to the industrial marketplace.

Neocera PLD customers benefit not only from state-of-the art equipment, but also unsurpassed technical expertise in the deposition of quality thin films. Whether the requirement is for the application of a standard Neocera system or the development of a custom solution, Neocera's experienced researchers are involved in the development process every step of the way, ensuring that the systems and processes developed will meet your requirements.

Neocera brings together considerable experience in the design of vacuum systems, electronics and software to deliver systems that meet stringent requirements of reliability, usability, and performance.

Dr. T. "Venky" Venkatesan, Neocera's founder and Chief Technical Officer

Neocera's headquarters in Beltsville, Maryland

Epitaxial Metal-Oxide Heterostructures/Devices developed at Neocera

Metal-Oxide	Applications Area	Growth Substrate	Growth Scheme
HTS Oxides		$Y_3Fe_5O_{12}$ (YIG)	$YBCO/BaZrO_3/SrZrO_3/YIG$
Ferroelectric Oxides		$LaAlO_3$	$Sr_xBa_{1-x}TiO_3/LaAlO_3$
CMR Oxides		Si, $LaAlO_3$	$La_{66}Ca_{33}MnO_3/CeO_2/YSZ/Si$
High-k Oxides		GaAs	$(Ba,Pb)Nd_2Ti_5O_{12}/GaAs$
Oxides on Silicon		Si	$Pt/LSCO/PNZT/LSCO/Pt/Ti/SiO_2/Si$
Nonlinear Oxides		MgO, GaAs	$K(TaNb)O_3/SrTiO_3/MgO/GaAs$
HTS Oxides		$LaAlO_3$	$YBCO/LaAlO_3$
HTS Oxides		$LaAlO_3$, R-Al_2O_3	$YBCO/CeO_2/R\text{-}Al_2O_3$
HTS Oxides		MgF_2	$YBCO/SrTiO_3/MgO/MgF_2$
HTS Oxides		$Y_3Fe_5O_{12}$ (YIG)	$YBCO/BaZrO_3/SrZrO_3/YIG$
HTS Oxides		$BaSrTiO_3/LaAlO_3$	$YBCO/ BaSrTiO_3/LaAlO_3$
HTS Oxides		MgF_2	$YBCO/SrTiO_3/MgO/MgF_2$
HTS Oxides		$SrTiO_3$ bi-crystals	$YBCO/SrTiO_3$
HTS Oxides		Si	$YBCO/CeO_2/YSZ/Si$
HTS Oxides		$LaAlO_3$	$YBCO/Sr_2Ta\text{-}AlO_6/LaAlO_3$
HTS Oxides		Silicon-on-Sapphire	$YBCO/CeO_2/SOS$
HTS Oxides		Thin Sapphire (5µm)	$YBCO/CeO_2/R\text{-}Al_2O_3$

Some relevant Neocera patents

1. U.S. Patent No. 5,420,102, "Superconducting Films on Alkaline Earth Fluoride Substrate with Multiple Buffer Layers," K. S. Harshavardhan, T. Venkatesan (May 30, 1995).
2. U.S. Patent No. 5,458,686, "Pulsed Laser Passive Filter Deposition System," Albert Pique, T. Venkatesan, S. Green (October 17, 1995).
3. U.S. Patent No. 5,472,510, "Superconducting Films on Alkaline Earth Fluoride Substrates with Multiple Buffer Layers," K. S. Harshavardham, T. Venkatesan, S. Green (December 5, 1995).
4. U.S. Patent No. 5,635,453, "Superconducting Thin Film System Using a Garnet Substrate," A. Pique, K. S. Harshavardhan, T. Venkatesan (June 3, 1997).
5. U.S. Patent No. 5,654,975, "Scanning Laser Beam Delivery Systems," S. Green, T. Venkatesan, K. Patel (August 5, 1997).
6. U.S. Patent No. 5,993,544, "Non-Linear Optical Thin Film Layer System", Lee A. Knauss, Kolagani S. Harshavardhan (November 30, 1999).
7. U.S. Patent No. 6,074,990, "Superconducting Garnet Thin Film System," A. Pique, K. S. Harshavardhan, T. Venkatesan (June 13, 2000).
8. U.S. Patent No. 6,090,207, "Translational Target Assembly for Thin Film Deposition System," L. A. Knauss, S. M. Green (July 18, 2000).
9. U.S. Patent No. 6,491,759, "Combinatorial Synthesis System", Hans M. Christen, Sherwood D. Silliman (December 10, 2002).
10. U.S. Patent No. 6,497,193, "Scanned Focus Deposition System", Hans M. Christen (December 24, 2002).

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