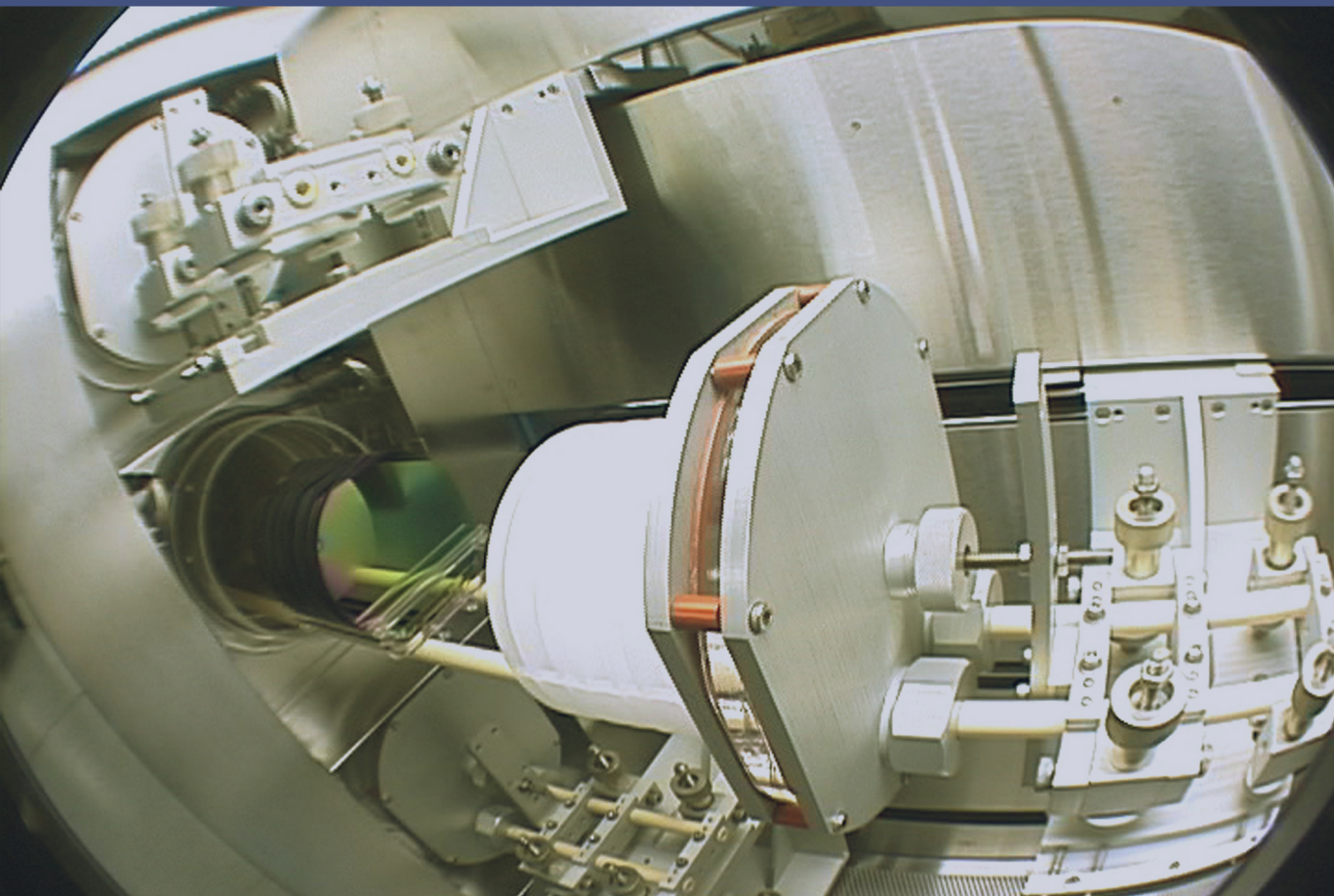


 **TYSTAR** LECTURE SERIES

LPCVD & Related Processes



From Fundamentals to Advanced Process Optimization

LPCVD Fundamentals

Learn about the basic principles of LPCVD

LPCVD Advanced Topics

Master advanced topics for applications in semiconductor, MEMS, and photonic device manufacturings

Table of Contents

Letter from the CEO	2
Table of Contents	3
Overview of LPCVD Processes	4
Silicon LPCVD	5
Silicon Nitride LPCVD	6
Low Stress Silicon Nitride for MEMS	7
Stoichiometric Silicon Nitride for Photonics	8
Oxidation vs. Oxide LPCVD	9
TEOS Oxide LPCVD Challenges	10
In-Situ Doped Silicon LPCVD	11
Solid Source Diffusion for Doping	12
Oxidation Processes	13
Ge & SiGe LPCVD	14
CNTs, Graphenes, and Nanowires	15
AI-Assisted Process Recipe Design	16

Duration of each lecture is 30 minutes

Letter From the CEO

Dear Tystar partners,

Tystar Corporation is pleased to offer our new Lecture Series on Mastering LPCVD Processes for applications in Semiconductor, MEMS, and photonic devicemanufacturings.

This catalog contains a series of lectures on fundamentals and advanced topics for engineers and researchers interested in thin-film deposition and related technologies.

Each lecture is carefully crafted to deliver practical insights and real-world applications.

Thank you for continued partnership with Tystar. We look forward to welcoming you to these lectures and supporting your success in your LPCVD careers.

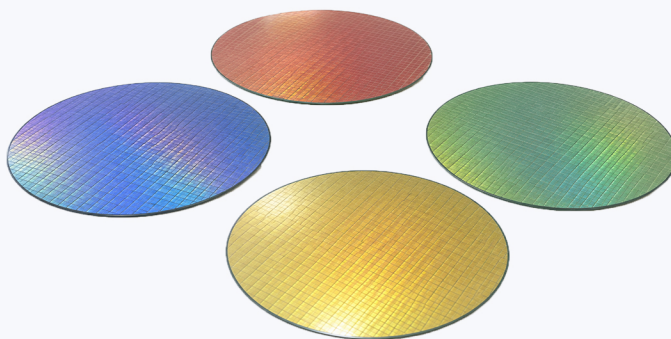
Sincerely,

Wayne H. Choe, Ph.D.
Tystar Corporation



Overview of LPCVD Processes

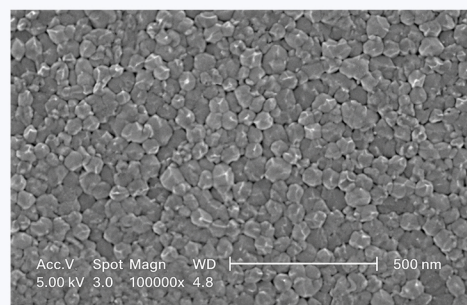
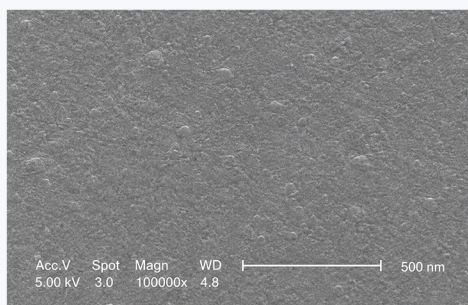
LPCVD remains one of the most widely used techniques for depositing high-quality films in semiconductor, MEMS, and photonic device manufacturing. This lecture provides a foundational overview of the science and engineering principles that govern LPCVD processes. The presentation begins with the definition of LPCVD and its operating regimes, then examines the key physical and chemical phenomena that control film growth: gas-phase kinetics, surface reactions, mean free path effects, and Knudsen diffusion. Special attention is given to how reactor geometry, pressure, temperature, and gas flow rates influence deposition rate, thickness uniformity, step coverage, and residual stress. Using real process data from, the lecture illustrates how these fundamentals apply across major film families. The goal is to equip attendees with a clear conceptual framework that will make the subsequent specialized lectures more effective and immediately applicable.



Silicon LPCVD

Silicon LPCVD is one of the most fundamental and widely studied LPCVD processes in nano/micro fabrication. Because the process involves only a single precursor species, silane (SiH_4), it provides an excellent platform for understanding the underlying principles that govern many other, more complex LPCVD processes. The insights gained from studying Si deposition are directly applicable to a broad range of thin-film deposition technologies.

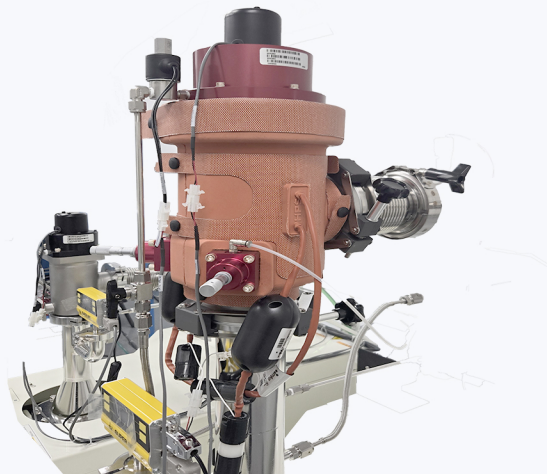
This lecture examines the mechanisms that control Si film growth, crystallinity, deposition rate, and film uniformity. Particular emphasis is placed on understanding how process variables influence film properties. The course also introduces fundamental transport and reaction models that describe LPCVD behavior.



Silicon Nitride LPCVD

This lecture provides a comprehensive overview of silicon nitride LPCVD processes and their critical role in MEMS, silicon photonics, oxidation/ionic barriers, and etch stops. It covers foundational chemistry, Knudsen number regimes for wafer/trench uniformity, and optimization of key parameters (pressure, temperature, NH_3/DCS ratio) affecting deposition rate, stress, refractive index, hydrogen content, and step coverage.

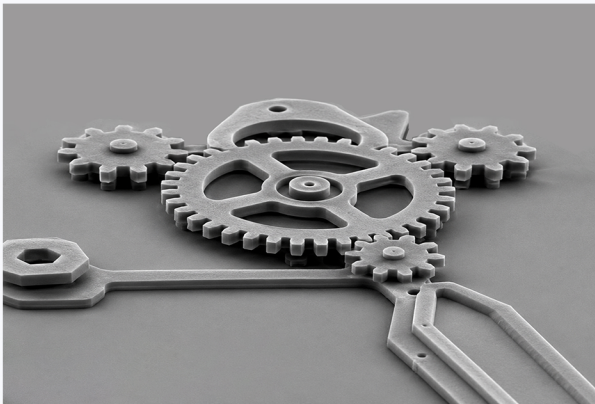
The presentation sets the stage for two follow-on lectures focused on Low-Stress Silicon Nitride (MEMS applications) and Stoichiometric Thick Silicon Nitride LPCVD (optoelectronics/photonics), addressing practical challenges like particle generation, annealing, and uniformity enhancements using data from Tystar's extensive process database.



Low Stress Silicon Nitride

This follow-on lecture focuses on engineering low-stress silicon nitride (Si_xN_y , $x/y > 3/4$) films by LPCVD for MEMS applications such as membranes, resonators, and sensors. It contrasts stoichiometric Si_3N_4 with low-stress compositions and details how key parameters—DCS/ NH_3 ratio (>1), deposition temperature, and post-annealing—control residual stress ($|\sigma| < 250 \text{ MPa}$), refractive index, hydrogen content, and surface roughness.

The presentation covers temperature and gas-ratio effects on deposition rate and zero-stress crossover points, strategies for minimizing hydrogenation (high-temperature N_2 annealing), particle/haze mitigation, and uniformity improvements (temperature tilting, boat turnaround). Practical process guidelines and data from Tystar's extensive database provide attendees with reliable recipes for near-zero-stress films that maintain excellent mechanical and electrical properties.



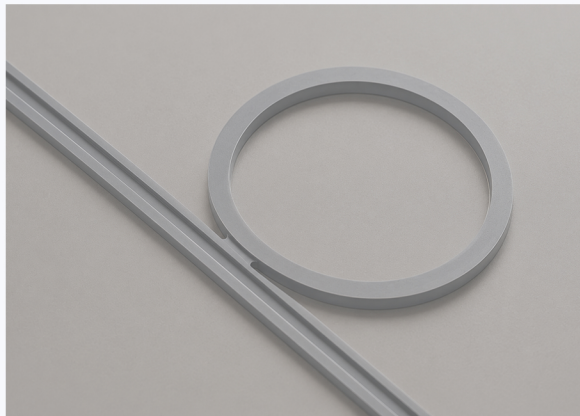
Stoichiometric Silicon Nitride

This lecture explores the deposition of stoichiometric Si_3N_4 films by LPCVD as the cornerstone platform for ultra-low-loss photonic integrated circuits (PICs).

It addresses the key challenges limiting industrial adoption—residual stress, cracking, hydrogen content, refractive index control, thickness uniformity ($>1\text{--}2\text{ }\mu\text{m}$), and sidewall/surface roughness.

Topics include process parameter optimization, annealing strategies for stress relief and H-removal, multi-stacking techniques, and SACBO (Surrogate-Assisted Constrained Bayesian Optimization) for efficient exploration of the high-dimensional parameter space.

Ideal for researchers and engineers developing high-performance waveguides, resonators, and nonlinear photonic devices.



Oxidation vs. Oxide LPCVD

This lecture provides a clear comparative overview of thermal oxidation and the three primary oxide LPCVD processes—LTO ($\text{SiH}_4 + \text{O}_2$), TEOS, and HTO (DCS + N_2O)—and their roles in semiconductor, optoelectronic, MEMS, and sensor manufacturing. It highlights fundamental differences in chemistry, by-products, conformality, and temperature requirements.

Special attention is given to practical challenges and proven solutions: uniformity issues in LTO (addressed via caged boats and distributed gas injection), TEOS-related particle generation and organic by-products (vapor delivery, cooled traps, heat tape), and HTO loading effects/chlorine corrosion. Process details, precursor properties, and optimization strategies from Tystar systems equip attendees with actionable insights for high-quality oxide films.

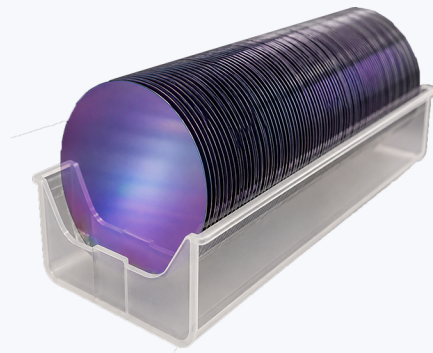
Ideal for process engineers seeking to select and optimize the right oxide deposition method for their application.



TEOS Oxide LPCVD Challenges

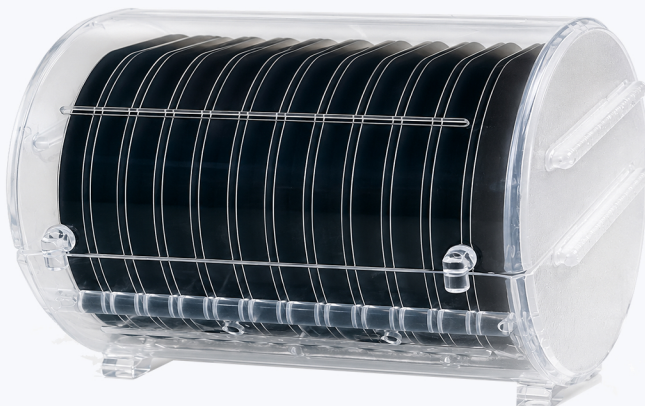
This lecture examines tetraethyl orthosilicate (TEOS)-based oxide LPCVD, a widely used process for conformal SiO_2 films in semiconductor, optoelectronic, MEMS, and sensor applications. It compares TEOS with LTO and HTO processes, highlighting TEOS-specific challenges including vapor generation/delivery, unreacted radicals, 192 organic by-products (siloxanes and SiO_x particles), and related particle/haze issues.

Optimized vapor delivery systems, water-cooled particle traps (pre- and post-pump), heat tape/sub-atmospheric pressure control, dry scrubbers, and exhaust line heating. The talk also covers process details, conformality advantages, impurity control, temperature effects, and current industry best practices for high-quality, low-particle TEOS films.



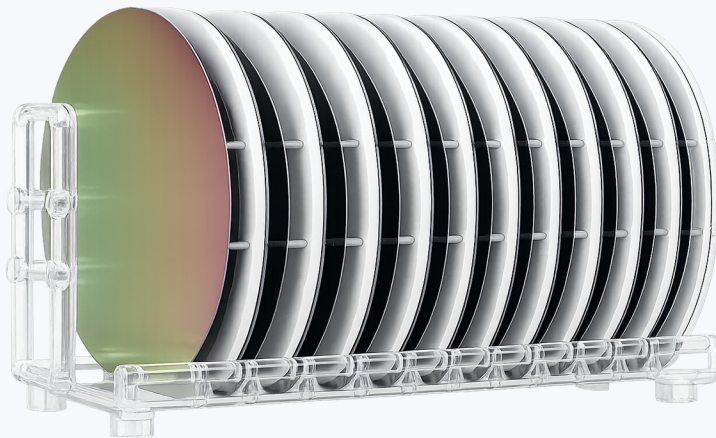
In-situ Doped Silicon LPCVD

This lecture focuses on in-situ liquid-source doping techniques (e.g., POCl_3 , BBr_3 , and related precursors) for precise and efficient introduction of dopants during semiconductor, optoelectronic, MEMS, and sensor fabrication. Topics include process chemistry, vapor delivery systems, temperature and flow optimization, junction formation, and integration with thermal processes. Practical challenges such as uniformity, loading effects, and by-product management are addressed with proven solutions and Tystar system data. Ideal for engineers seeking high-throughput, controllable doping alternatives to implantation or solid sources.



Solid Source Diffusion for Doping

This lecture covers solid-source diffusion using dopant disks (e.g., Saint-Gobain PH/PhosPlus and BN series) for applications including pinched resistors, junction/MOS capacitors, ohmic contacts, and doped optical cladding. It details the two-step predeposition + drive-in process, thermodynamics of P and B reactions, glass layer (PSG/BSG) formation for sustained dopant supply and gettering, stoichiometry, kinetics, and optimization for dose control, junction depth, and wafer uniformity. Real process data and best practices provide actionable insights for reliable, low-cost doping.

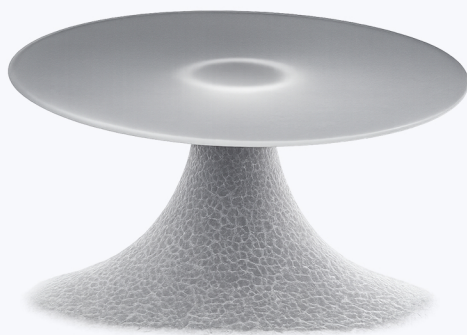


Oxidation Processes

This lecture provides a comparative overview of dry and wet oxidation for growing silicon dioxide layers in semiconductor, MEMS, and photonic applications. It begins with the fundamental principles of thermal oxidation and the Deal-Grove model.

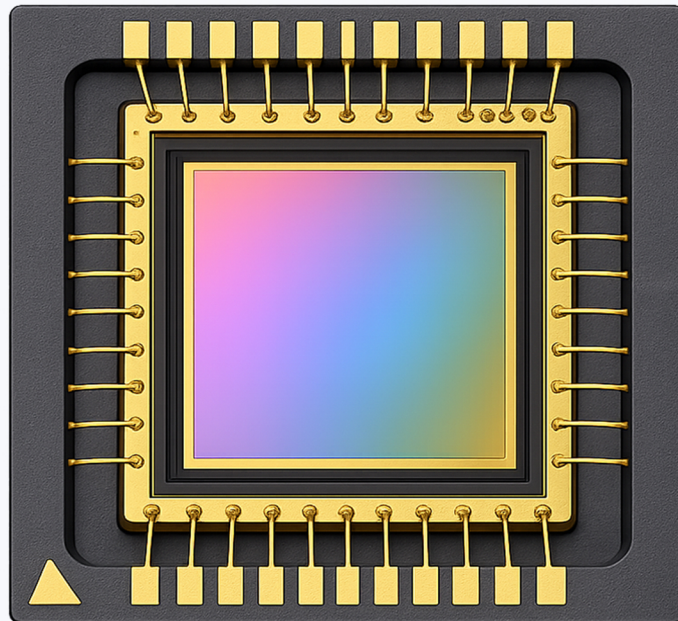
Dry oxidation is highlighted for producing dense, pinhole-free films. The presentation covers its slower growth mechanism, typical parameters, uniformity data, and Tystar's TLC bubbler option for enhanced purity and slight rate improvement.

Wet oxidation follows for thicker oxides (up to a demonstrated 30 μm record), comparing pyrogenic, DI-water bubbler, and flash vaporizer methods along with their advantages, disadvantages, and suitability for a variety of different applications.



Ge and SiGe LPCVD

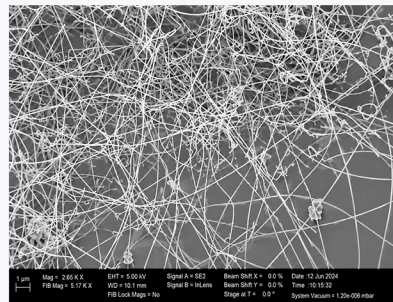
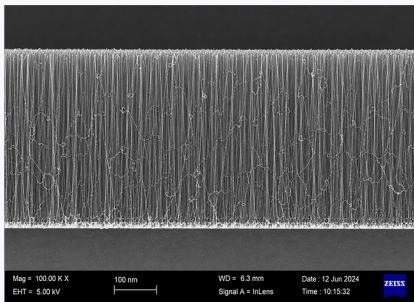
This lecture covers solid-source diffusion using dopant disks (e.g., Saint-Gobain PH/PhosPlus and BN series) for applications including pinched resistors, junction/MOS capacitors, ohmic contacts, and doped optical cladding. It details the two-step predeposition + drive-in process, thermodynamics of P and B reactions, glass layer (PSG/BSG) formation for sustained dopant supply and gettering, stoichiometry, kinetics, and optimization for dose control, junction depth, and wafer uniformity. Real process data and best practices provide actionable insights for reliable, low-cost doping.



CNTs, Graphenes, and Nanowires

Carbon nanotubes (CNTs), graphene, and semiconductor nanowires are among the most important nanostructured materials for next-generation electronic, photonic, sensing, and energy devices. This lecture introduces the standard deposition recipes used for producing these nanostructures and explains how catalyst selection, precursor chemistry, temperature, gas composition, and growth conditions determine the nucleation and evolution of nanoscale structures.

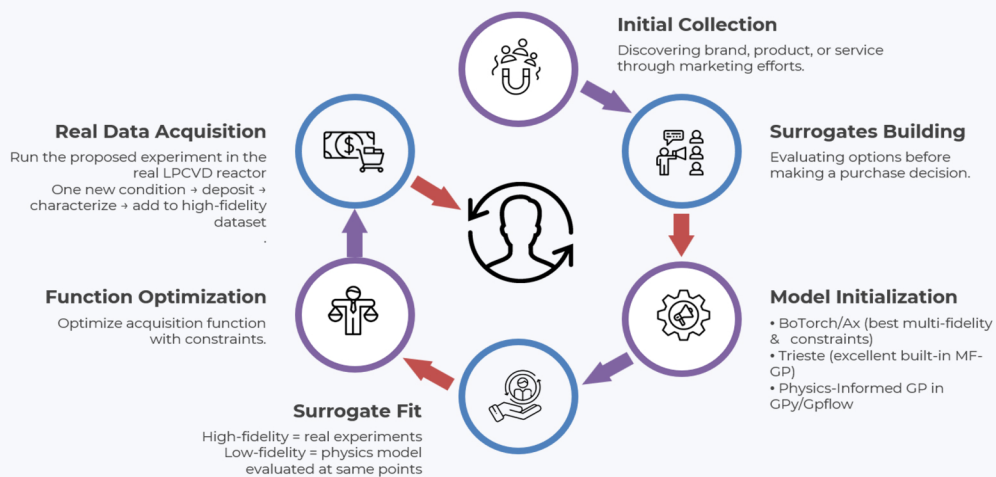
The lecture emphasizes the mechanisms responsible for nanostructure formation and the relationship between processing conditions and material properties. The attendees will learn how growth parameters influence morphology, crystallinity, alignment, diameter, layer thickness, density, and overall process uniformity.



AI-Assisted Process Recipe Design

This lecture highlights the power of data-driven approaches in LPCVD process development, featuring Tystar's extensive 40+ year process database (>2,000 datasets) and the SACBO (Surrogate-Assisted Constrained Bayesian Optimization) algorithm for efficient exploration of high-dimensional parameter spaces.

Attendees will learn how AI and machine learning transform traditional trial-and-error methods into intelligent optimization, reducing the need for thousands of experimental runs while accelerating recipe development for low-stress, stoichiometric, and thick Si_3N_4 films. The talk also introduces plans for an AI-driven expert system and data-sharing initiatives that empower customers with predictive analytics, real-time insights, and best-practice recommendations.



TYSTAR CORPORATION



7050 Lampson Avenue
Garden Grove, CA 92841
U.S.A.
www.tystar.com