UNIVERSITY OF CALIFORNIA, MERCED

SCIF CLEANROOM FACILITY

STANDARD OPERATING PROCEDURE (SOP)

Electron Beam Evaporation System

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1. PURPOSE

To provide a detailed, standardized, and safe procedure for thin film deposition using electron beam evaporation. This SOP defines both manual process development and automated deposition control to ensure reproducibility, equipment protection, user safety, and high-quality thin film fabrication.

This procedure ensures controlled operation of high-voltage and high-vacuum systems while minimizing contamination, variability, and equipment damage.

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2. SCOPE

Applicable to all trained and authorized users operating the SCIF electron beam evaporation system using:

- ebeam evaporator Manual Applicable to SCIF Cleanroom System
- Temescal CV-6SLX high-voltage power supply
- Temescal E-Beam Controller (EBC)
- SQC-310 thin film deposition controller (QCM-based monitoring)
- Manual for Shutter Control

Covers system startup, vacuum operation, manual and automated deposition, venting, shutdown, and documentation.

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3. RESPONSIBILITIES

3.1 Users

- Operate only within certified training limits
- Follow all safety and process guidelines

- Record process parameters and report issues
- Ensure material and substrate compatibility

3.2 Core Staff

- Provide training and certification
- Maintain calibration and system performance
- Approve advanced or non-standard processes

3.3 Facility

- Maintain utilities and safety compliance
- Ensure vacuum and gas system integrity

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4. REQUIRED SYSTEM CONDITIONS

4.1 Utilities

- Cooling Water: 10–25 °C (recommended 15–20 °C)
- Continuous, stable flow (no interruptions)
- Power: grounded, stable, no alarms
- Gas: Dry N_2 (2–7 psig), moisture-free

4.2 Interlocks (MANDATORY)

System must NOT operate unless:

- Cooling water flow is active
- Chamber is under vacuum
- Chamber is properly closed

Failure of any interlock requires immediate shutdown.

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5. SAFETY REQUIREMENTS

5.1 Hazards

- High voltage (lethal)

- Vacuum implosion risk
- UV/X-ray radiation
- Thermal hazards (hot components)
- Magnetic fields

5.2 PPE

- Cleanroom gloves
- Safety glasses (UV-rated recommended)
- Lab coat / cleanroom gown

5.3 Safety Practices

- Never bypass interlocks
- Never open chamber under vacuum
- Do not touch hot or energized components
- Do not leave system unattended during deposition
- **Ground the substrate holder and all internal chamber components before touching after venting**

6. OPERATION PROCEDURE

6.1 System Startup & Pumpdown

6.1.1 Start Cooling System

- Turn ON chiller
- Verify flow, temperature, and stability
- Confirm interlock

6.1.2 Power ON System

- Release emergency stop
- Turn ON main power and controllers
- Verify system initialization (gauges, controllers, no faults)

6.1.3 Chamber Preparation

- Clean chamber (IPA + lint-free wipes)
- Inspect O-rings, shields, and surfaces
- Load correct material and crucible

6.1.4 Load Substrate

- Clean substrate (solvent/plasma)
- Mount securely with correct orientation
- Ensure good thermal contact

6.1.5 Secure Holder

- Insert holder and align with source
- Verify rotation (if applicable)
- Set working distance

6.1.6 Close Chamber

- Inspect sealing surfaces
- Close and clamp securely
- Ensure no trapped cables or debris

6.1.7 Pump Down

- Start roughing + high vacuum pumps
- Reach $\leq 5 \times 10^{-5}$ Torr
- Verify stability and no leaks

6.2 Process Development (Manual Mode)

6.2.1 Manual Parameter Development

Purpose: Establish beam power → deposition rate relationship

- Set EBC to MANUAL
- Gradually ramp beam power

- Stabilize melt (shutter CLOSED)
- Perform trial deposition (shutter OPEN briefly)
- Monitor rate (SQC-310)
- Record: power, rate, pressure, stability

Goal: Identify stable, repeatable process window

6.3 Automation Setup

6.3.1 Automation Configuration

- Input material parameters into SQC-310
- Enable closed-loop rate control
- Set EBC to REMOTE mode
- Verify communication and interlocks

Process Sequence:
Pumpdown → Beam ramp → Stabilize → Open shutter → Rate control → Thickness control → Close shutter → Ramp down

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6.4 Automated Deposition

6.4.1 Pre-Run Check

- Vacuum stable
- Cooling active
- Recipe loaded
- QCM functional

6.4.2 Run Process

- Start process via SQC-310

System automatically controls:

- Beam power
- Deposition rate

- Thickness

6.4.3 Monitoring

- Rate stability
- Pressure
- Beam condition

6.4.4 Completion

- Shutter closes automatically
- Beam ramps down

6.5 Post-Deposition Operations

6.5.1 Cooldown

- Maintain vacuum
- Allow full cooling of source and substrate
- Do NOT vent hot system

6.5.2 Vent (CRITICAL STEP)

- Ensure system is at safe temperature
- Vent slowly to avoid turbulence and contamination

LL Vent Gas Selection (MANDATORY COMPLIANCE)

- If N_2 supply is connected → LL vent MUST be set to N_2
- LL vent to Air is permitted ONLY if N_2 is unavailable
- Operator MUST verify LL valve position prior to venting

Operational Guidance

- Vent gradually to prevent particle disturbance
- Avoid directing gas flow toward substrate
- Maintain clean vent pathway

⚠ Contamination & Oxidation Warning

- Air venting introduces oxygen and moisture
- May oxidize films
- May degrade adhesion and electrical properties
- May introduce particulates

✓ Always use N_2 vent when available

6.5.3 Unload

- Confirm atmospheric pressure and grounding
- Open chamber carefully
- Ground substrate holder and components
- Remove substrate with clean tools
- Inspect film quality

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7. POST-OPERATION

Record in logbook/iLab:

- Material
- Thickness
- Deposition rate
- Base pressure
- Issues/anomalies
- Operator and date

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8. TROUBLESHOOTING

Issue	Cause	Action

Issue	**Cause**	**Action**
No deposition	Beam misaligned	Adjust
Unstable rate	Poor vacuum	Re-pump
Arcing	Contamination	Clean
Low rate	Low power	Increase gradually

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9. KEY PRINCIPLE

- Manual Mode → Process Development
- Automated Mode → Controlled, repeatable deposition

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10. FORMAL SOP STATEMENT

Deposition parameters shall first be established under manual operation to determine the relationship between beam power and deposition rate. These parameters shall then be implemented in the SQC-310 controller and Temescal E-Beam system to enable automated, closed-loop deposition under predefined process conditions.

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11. CRITICAL DOs & DON'Ts

11.1 DO

- Verify interlocks
- Ramp power slowly
- Maintain cleanliness
- Use N_2 vent whenever possible

11.2 DON'T

- Operate at high pressure
- Run without cooling
- Vent rapidly
- Touch hot or energized components

12. APPROVAL

Director Name: ____________________
Signature: ________________________
Date: ____________________________

User Name: _______________________
Signature: ________________________
Date: ____________________________