Making a $BaTiO_3$ Electrode with E-Beam Lithography

First 5-minute REU update • focus: my fabrication task

The larger project is a voltage-controlled circuit. My part is smaller: learn how to pattern $BaTiO_3$ thin films into usable electrodes.

MAIN SLIDE 1

The project

I am building a small $BaTiO_3$ electrode that can connect to a larger circuit.

My part

$BaTiO_3$ thin film
+ small electrode pattern
+ electrical test

Not my part

Full circuit layout
+ packaging
+ final device design

First proof of success

Clean coating
+ clean e-beam pattern
+ measurable electrode w/ tunable optical properties

What is BTO? Why BTO?

$BaTiO_3$ is useful because an applied voltage can change its refractive index — how strongly it bends or slows light.

Voltage-tunable index
Voltage can change the way light travels through BTO.
(Tunable refractive-index)

Lead-free material
Avoids lead-based piezoelectric materials.
(Non-toxic)

$BaTiO_3$
BTO

Electroactive ceramic
It responds to electric fields, not just electrical contact.

Electrode role
Small electrodes apply voltage locally to the BTO film.

Simple version: we are making electrodes so the circuit can apply voltage to BTO and change its optical behavior. (Possible applications are photonic-computing devices)

Overall process: from film to electrode

Grow the BTO film → pattern it with e-beam lithography → test the electrode.

1

PLD thin film

Grow a blanket $BaTiO_3$ layer on the chip.

Output: BTO film

2

E-beam lithography

Clean, spin coat resist, expose, and develop small patterns.

Output: electrode pattern

3

Electrode + test

Turn the pattern into a usable electrode and check its electrical contact.

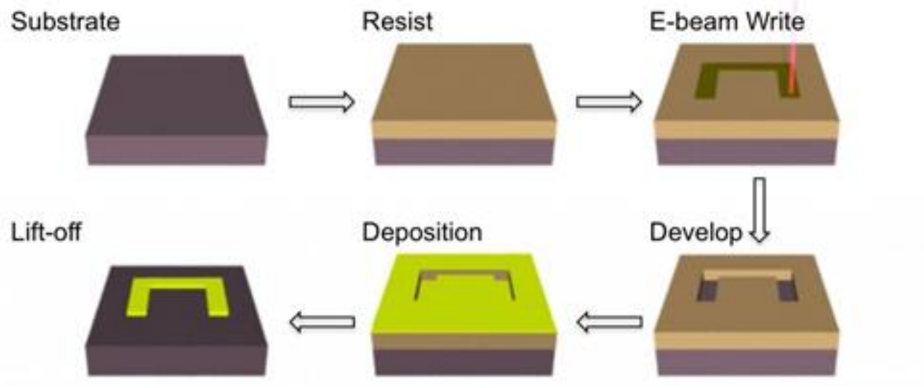
Output: testable device

Today's zoom-in: e-beam lithography on tiny 5×5 mm chips. The current issue is sample prep/spin coating before moving to BTO.

How e-beam lithography fits

E-beam lithography is like direct-write printing: an electron beam writes a pattern into a thin resist layer.

- **clean + dry** — prepare the surface
- **spin coat resist** — make a thin coating
- **bake** — set the resist
- **e-beam write** — draw the pattern
- **develop** — reveal the pattern
- **metal + liftoff** — make the electrode



Why spin coating matters?
If the resist coating is uneven, the e-beam pattern can fail before we reach BTO.

Near-term challenge: 5×5 mm samples

BTO thin films by PLD have been made before, including in our lab. The hard new step is patterning much smaller samples.

1. **Known starting point**
   BTO thin films can be grown
2. **Test first on silicon**
   Use simple 5×5 mm Si pieces
3. **Current bottleneck**
   Too small for our spin-coat setup
4. **Fix the prep**
   Make coating and cleaning reliable
5. **Then transfer**
   Run e-beam patterns on BTO film
6. **Electrode goal**
   Contact and test small electrodes

First milestone: prove we can clean, spin coat, expose, and develop patterns on 5×5 mm samples.

What success looks like next

A good first result is a reliable process, not the final full circuit.

1

Small-chip prep works

The 5×5 mm samples can be cleaned, mounted, spin coated, and baked without obvious coating failure.

2

EBL pattern works on silicon

Simple lines and pads expose and develop cleanly on a test wafer.

3

Same process moves to BTO

The pattern can be written on BTO films without major charging or distortion.

4

Electrode can be measured

Metal contacts or patterned electrode features can be electrically tested.

Current next step: fix the small-chip spin-coating workflow, then use that workflow for BTO thin-film e-beam lithography.

Take-home message

Summary:

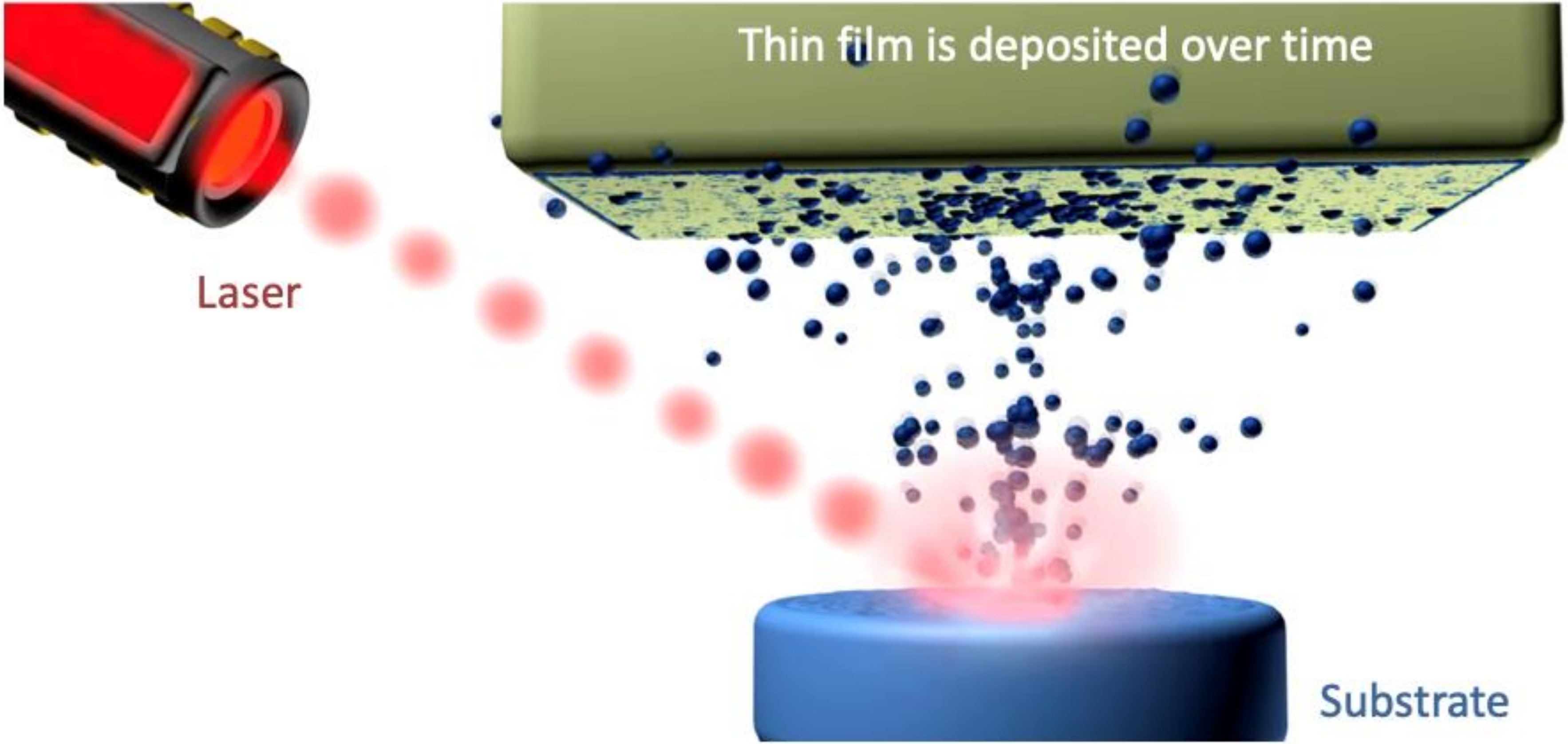
BTO	voltage-tunable optical material
PLD	already lets us make the thin film
EBL	lets us make much smaller electrode features
Current bottleneck	5×5 mm sample preparation and spin coating
Goal	a measurable BTO electrode for the larger circuit

Yay

Backup slides

Use only if someone asks for more detail.

Pulsed Laser Deposition



Backup: PLD knobs I can tune

Temperature

Helps the film crystallize, but too high can limit substrate choices.

Oxygen pressure

Affects oxygen vacancies, leakage, and composition.

Laser fluence

Controls ablation; too high can increase droplets or roughness.

Target-substrate distance

Affects plume density and growth rate.

Backup: BTO vocabulary

Voltage-tunable refractive index: applied voltage can change how light travels through BTO.
Electroactive ceramic: responds to electric fields.
Ferroelectric: has internal polarization that can be switched by an electric field.
Piezoelectric: electrical and mechanical responses are coupled.
Project scope: this talk focuses on making the small-pattern electrode process work.

Backup: why EBL on BTO may be harder than on silicon

The beam is tiny, but the pattern can still fail because the sample and resist change what the electror

Charging

Oxide-rich or insulating surfaces can build up charge, which can bend the beam and distort the pattern.

Scattering

Electrons spread inside the resist and substrate, so the exposed area can be wider than the drawn line.

Dose tuning

The right exposure dose depends on the exact resist, thickness, sample stack, and pattern size.

Practical answer: run a dose test, inspect the pattern, and add a charge-control layer if needed.

Backup: small-chip preparation checklist

Confirm how the 5×5 mm chip will be held during spin coating.

Clean and dry the sample before resist coating.

Spin coat resist and check that coverage is even across the chip.

Bake the resist so it is ready for e-beam exposure.

Expose a dose matrix before writing the real electrode pattern.

Develop and inspect: look for missing lines, swollen features, residue, or edge-bead problems.

Backup: what each test tells me

SEM / optical microscope	Did the small pattern actually print cleanly?
AFM	Is the film/coating surface smooth enough?
XRD	Is the BTO film crystalline?
Electrical test	Can the electrode be contacted, and is leakage reasonable?

For the 5-minute talk, translate tests into plain questions: Did it print? Is it smooth? Is it BTO? Can we measure it?

Backup: what is not the novelty claim

I should not claim that $BaTiO_3$ thin films by PLD are brand new.

1990s
PLD BTO films in literature

Later
high-quality films and device examples

Our lab
BTO films have already been made

Now
small-sample e-beam patterning for electrodes

Better claim: we are developing a functioning device via PLD-synthesized-BTO films