

# Microchannel Fabrication on Silicon Wafer and Development of Heating Elements on Silicon and Sapphire

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*Primary CNF Tools Used: Lesker PVD75 Sputter, CVC SC4500 Odd-hour evaporator, MRL A1 General Anneal*

## Abstract:

This project reports on the fabrication and post-deposition treatment of a transparent heater using a 600 nm thick Indium Tin Oxide (ITO) film sputtered onto a sapphire substrate. Following ITO deposition, a thin metal contact layer composed of 2 nm titanium and 150 nm gold was evaporated to facilitate electrical probing. ITO was deposited using the Lesker PVD 75 sputtering tool at 100 degrees Celsius, and post-annealing was conducted in ambient air at 500 degrees Celsius for 45 minutes. The device is designed to retain high optical transmittance while enabling Joule heating and low-resistance contact.

## Summary of Research:

The objective of this project was to develop a transparent, electrically conductive heater using ITO on a sapphire substrate, integrated with metal contacts for reliable electrical interfacing. Transparent heaters are essential to study the bubble nucleation in boiling phenomena. Transparent heaters allow for both optical access and local heating, making them ideal for this study.

Sapphire substrates were selected for their desirable thermal properties, along with optical clarity and mechanical robustness. ITO was chosen as the heater material due to its high transmittance in the visible spectrum and relatively desirable sheet resistance when properly processed.

The ITO layer was deposited using the Lesker PVD 75 RF magnetron sputtering system. Deposition was carried out at a substrate temperature of 100 degrees Celsius under an argon ambient. The resulting film thickness was 600 nanometers.

Post-deposition annealing trials are being conducted in ambient air to improve crystallinity, reduce resistivity, and maintain high optical transmission. Annealing is to be performed in a tube furnace at 400 degrees Celsius

for 45 minutes. This air anneal condition is supposed to provide a good balance between transmittance and electrical performance. While forming gas anneals can further reduce sheet resistance, they were not used in this iteration.

To enable low-resistance electrical contacts, a bi-layer metal stack was deposited using the CNF Odd-Hour. A 2 nm titanium adhesion layer was deposited directly on the ITO, followed by 150 nm of gold. Titanium provides good adhesion to both ITO and the underlying sapphire, while gold serves as a chemically inert, low-resistance contact layer suitable for wire bonding or probing.

The annealed ITO films exhibited an estimated average visible transmittance of 80 to 85 percent, with peak transmittance near 550 nanometers. The sheet resistance was estimated to be between 10 and 15 ohms per square, depending on grain structure, carrier mobility, and stoichiometry. These values are within expected ranges for ITO processed under similar conditions. [1] [2] [3]

The completed heater consists of a transparent region for optical access and well-defined metal pads for electrical interfacing, please refer to Fig. 1. The heater is compatible with applications requiring simultaneous thermal and optical functions. Future work will include photolithographic patterning of heater geometries and optimization of contact pad layouts.

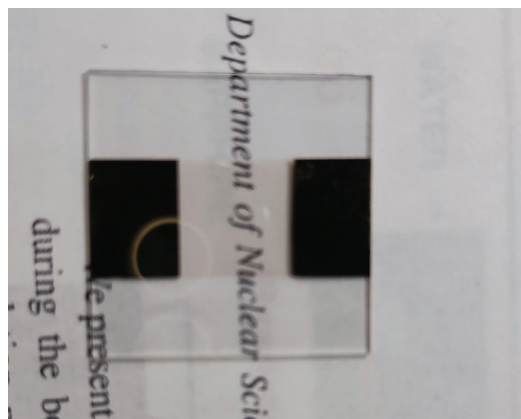


Figure 1: Fabricated prototype

**References:**

- [1] Hamberg, M., and Granqvist, C. G., “Evaporated Sn-doped indium oxide films: Basic optical properties and applications to energy-efficient windows,” *Journal of Applied Physics*, vol. 60, 1986.
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- [3] Sharma, A. K., et al., “Post-deposition annealing effect on ITO films,” *Journal of Materials Science*, vol. 45, pp. 1260–1266, 2010.