Nanostructured Spacers: Creating Micron-Sized Gaps for Conductive Plates in Thermionic and Thermophotovoltaic Energy Converters

Josué León (SEAS 2023)

Advised by Matthew Campbell and Igor Bargatin; Funded by PURM

Department of Mechanical Engineering and Applied Mechanics at the University of Pennsylvania

Introduction

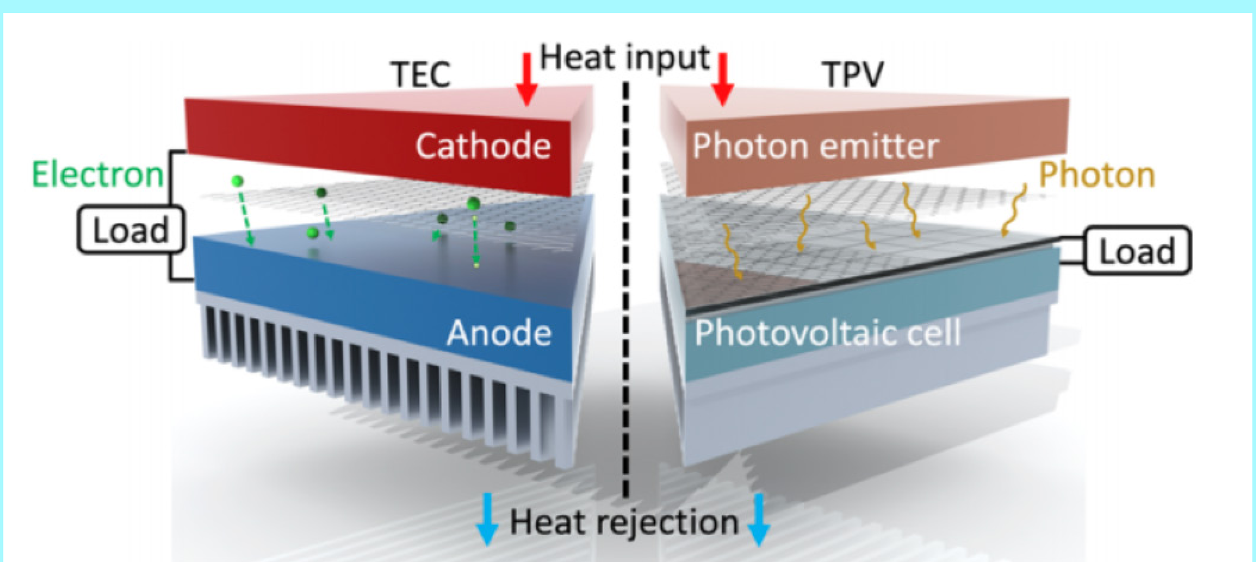
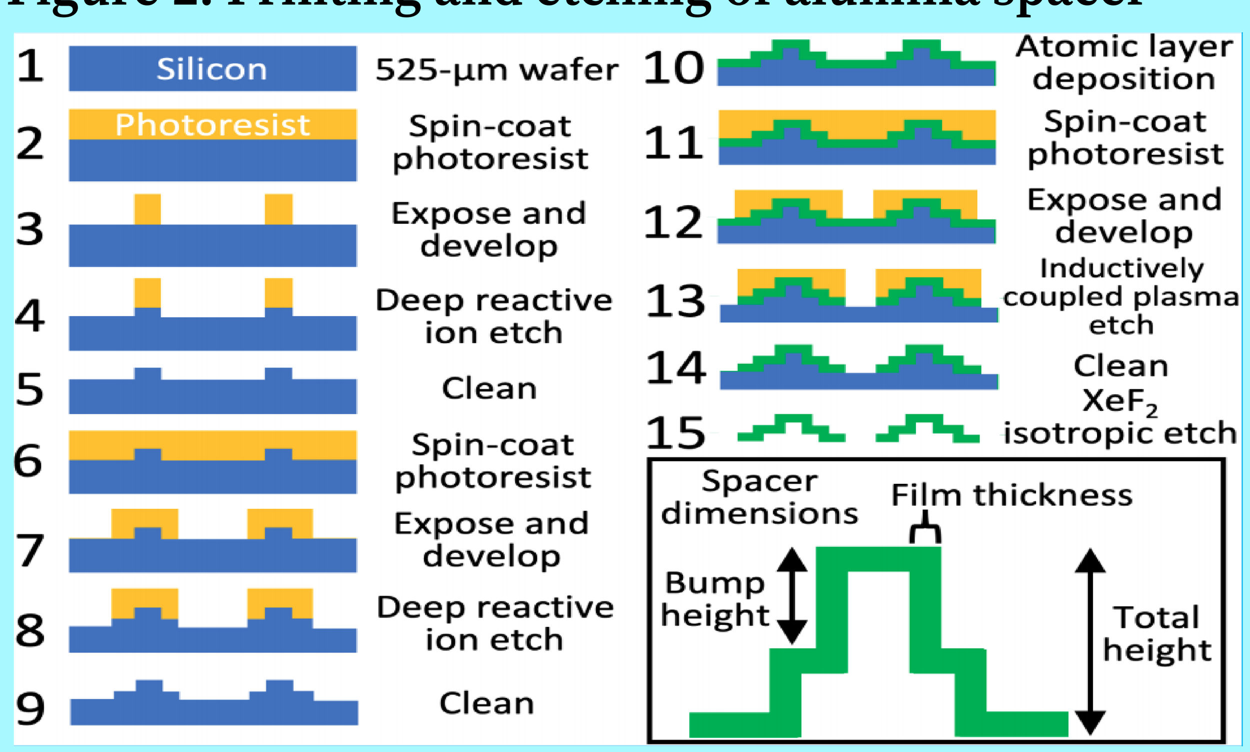


Figure 1. TEC's and TPV's transform heat into electricity

- Thermionic Energy Converters (TEC's) and Thermophotovoltaic devices (TPV's) are both energy producing technologies that have the potential to power everyday needs in the future.
- Micron-sized gaps are necessary in TEC's to reduce the electric field that opposes flow of electrons, while in TPV's they enhance radiative heat transfer. The gaps are separated by spacers that must be thermally (and electrically) insulating, withstand high temperatures, and be mechanically robust.
- Spacer masks are designed and structured using MATLAB (Figure 4), which are then used to fabricate the spacers using four cycles of photolithography as shown in Figure 2.

Figure 2. Printing and etching of alumina spacer



Thin alumina robust spacer with bumpy surface yields ultrahigh thermal resistance

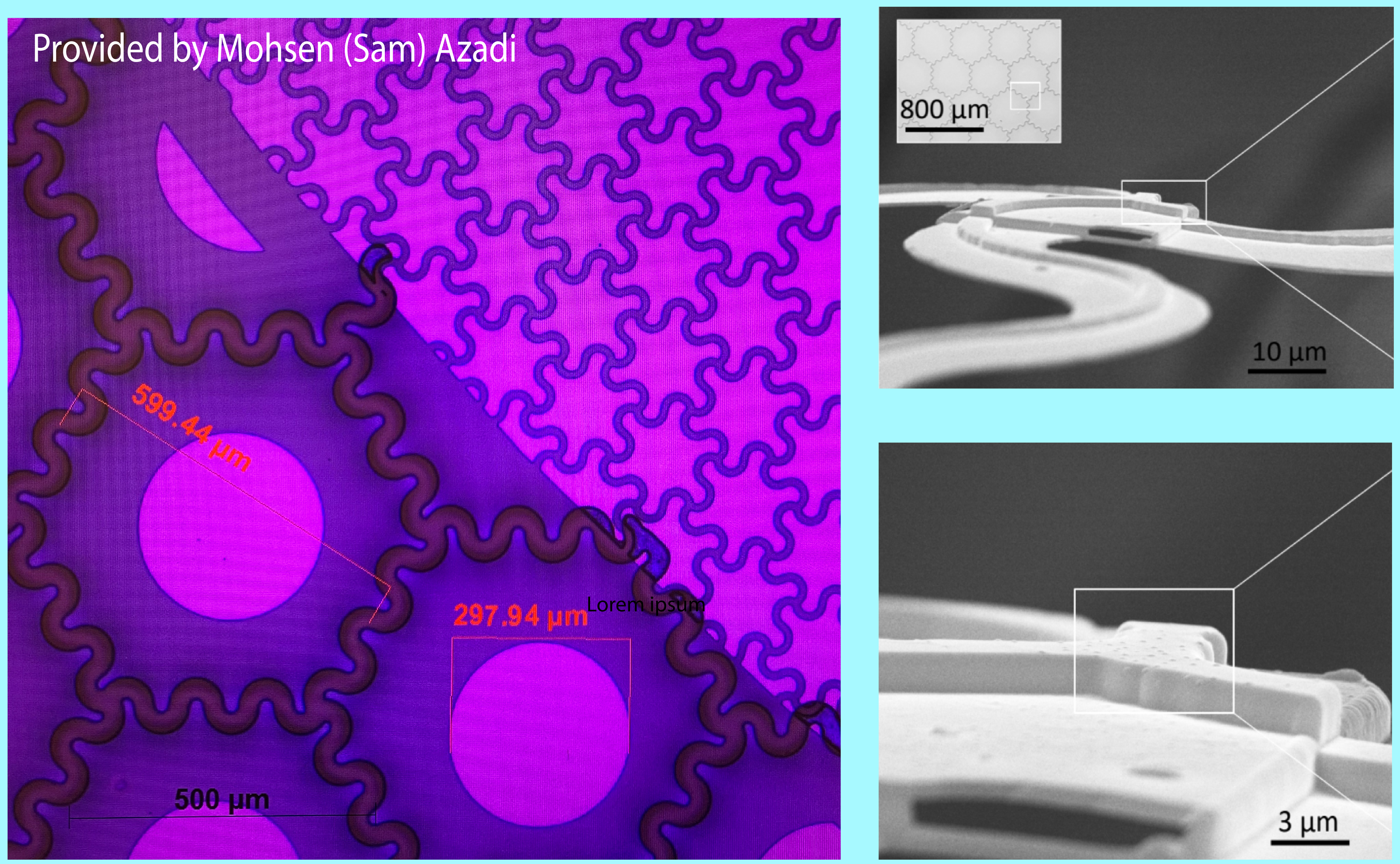


Figure 3. Spacer design and structure at three different microscale magnifications

The result is a thin spacer made of aluminum oxide (alumina) with a bumpy surface arranged into honeycomb structures. Each unit cell was approximately 600 [um] in heigth and 400 [um] in width. The design produced the highest thermal (and electric) resistivity out of different designs that were tested and optimized using COMSOL simulations. The most recent development of the spacer design is shown in Figure 3.

Discussion

Efficiency of the TEC's and TPV's can be increased by decreasing the gap distance between conductive plates, therefore, it would be favorable to shrink the spacers. However, current technology in nanofabrication still limits the size of the smallest spacers that can be physically fabricated. There is potential for smaller sized gaps in the future, as well as different spacer designs allowing greater efficiency and thermal resistivity.

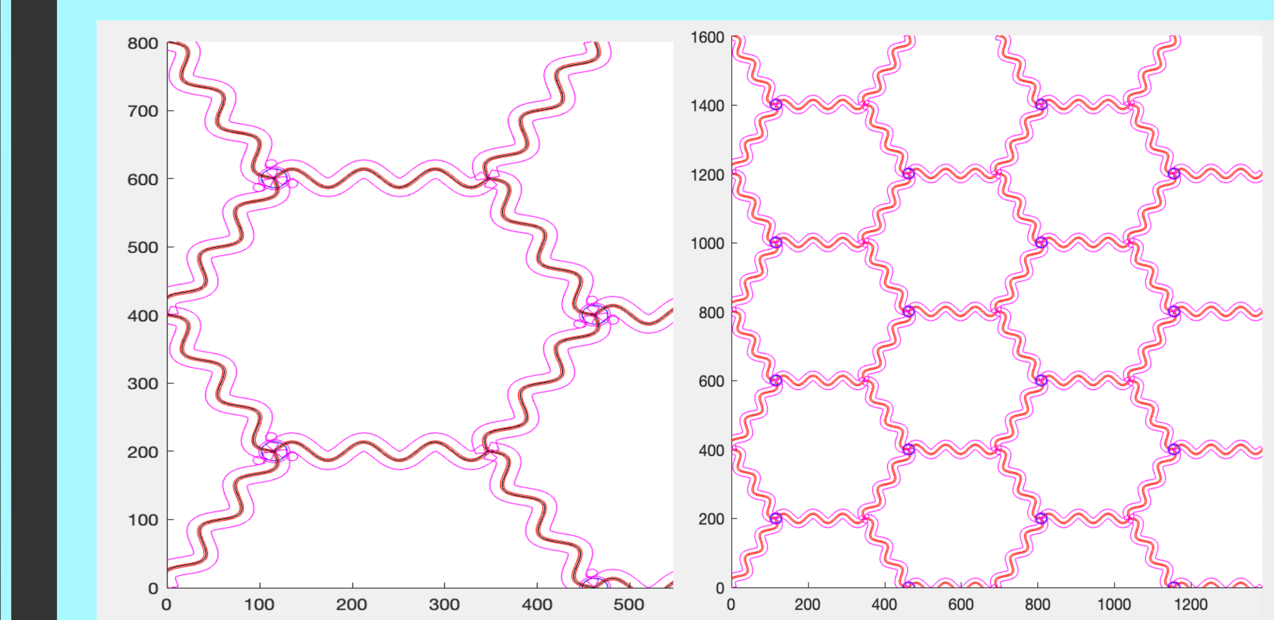


Figure 4. MATLAB spacer designs

MATLAB is efficient at calculating micro-scale coordinates or the spacer design; however, it fails to repeat structures in a short and productive amount of time. Different software such as LayoutEditor have reduced the patterning time. Additionally, because the spacers are fabricated using 2-D layers that build or etch upon each other, the masks must work perfectly in conjunction. Small issues within the MATLAB script can later arise that may cause problems in the rest of the fabrication process.

References

- Campbell et al. "Nanostructured Spacers for Thermionic and Thermophotovoltaic Energy Converters" (2019)
- Nicaise et al, "Micron-gap spacers with ultrahigh thermal resistance and mechanical robustness for direct energy conversion," Microsyst. (2019)