Enhancement of TPV power density with surface-engineered emitters

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TPV-15 Conference
3 Oct 2024

Massachusetts Institute of Technology

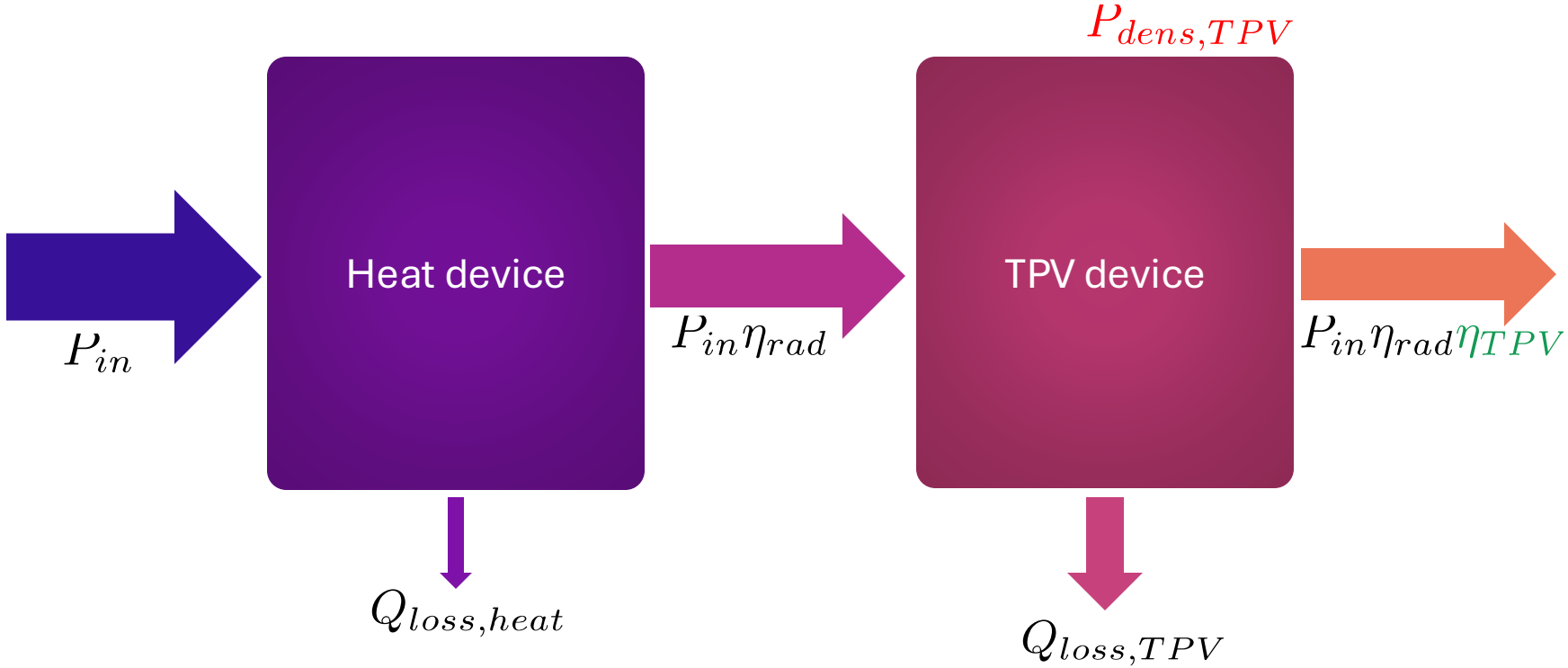
1. When does TPV power density matter?

2. How can we create high-emissivity materials?

3. How do TPV cells perform with these emitters?

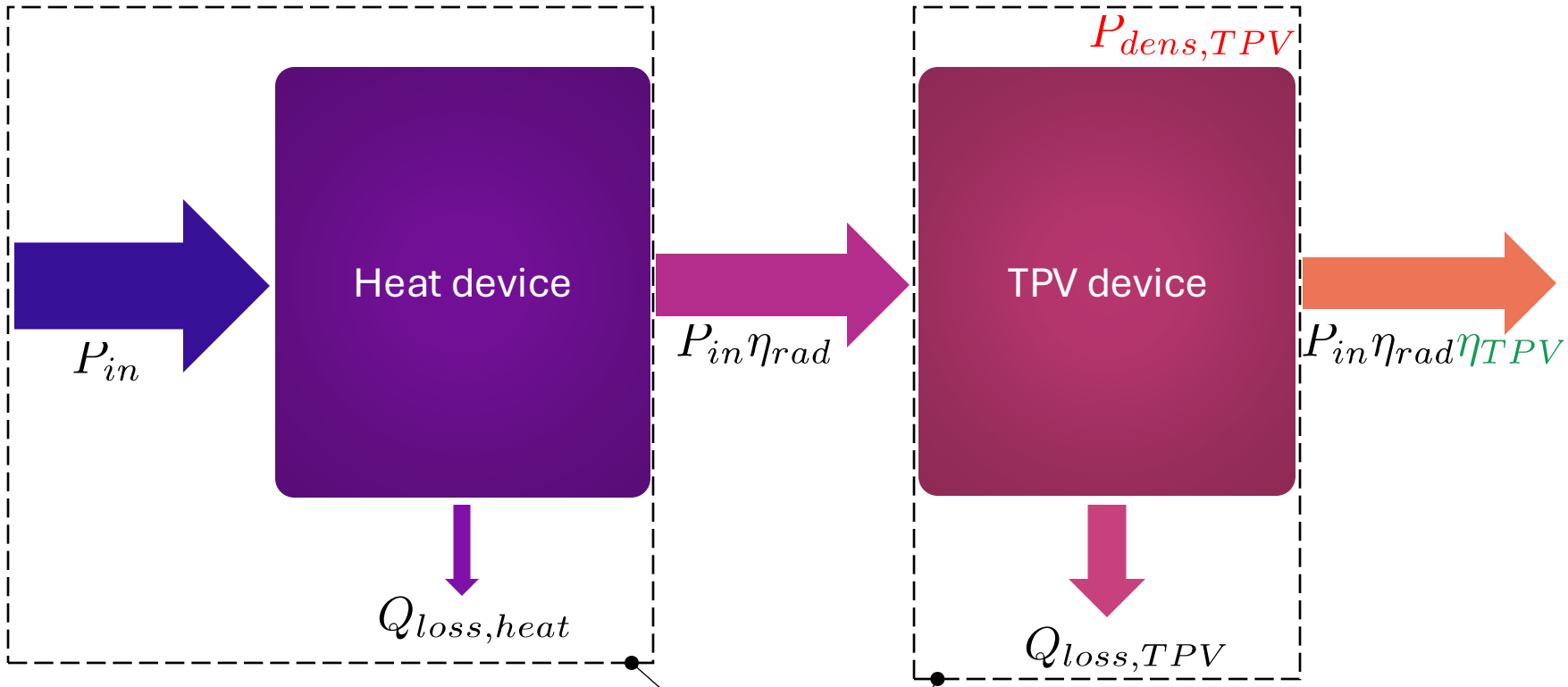
4. How long do the emitters last?

TPV performance metrics: power density and efficiency



Verma et al. *arXiv* (2024)

We can evaluate the cost of TPV with LCOE



$$LCOE = \frac{LCOH}{\eta_{TPV}} + \frac{CPA \cdot CRF/t_{out}}{P_{dens,TPV}}$$

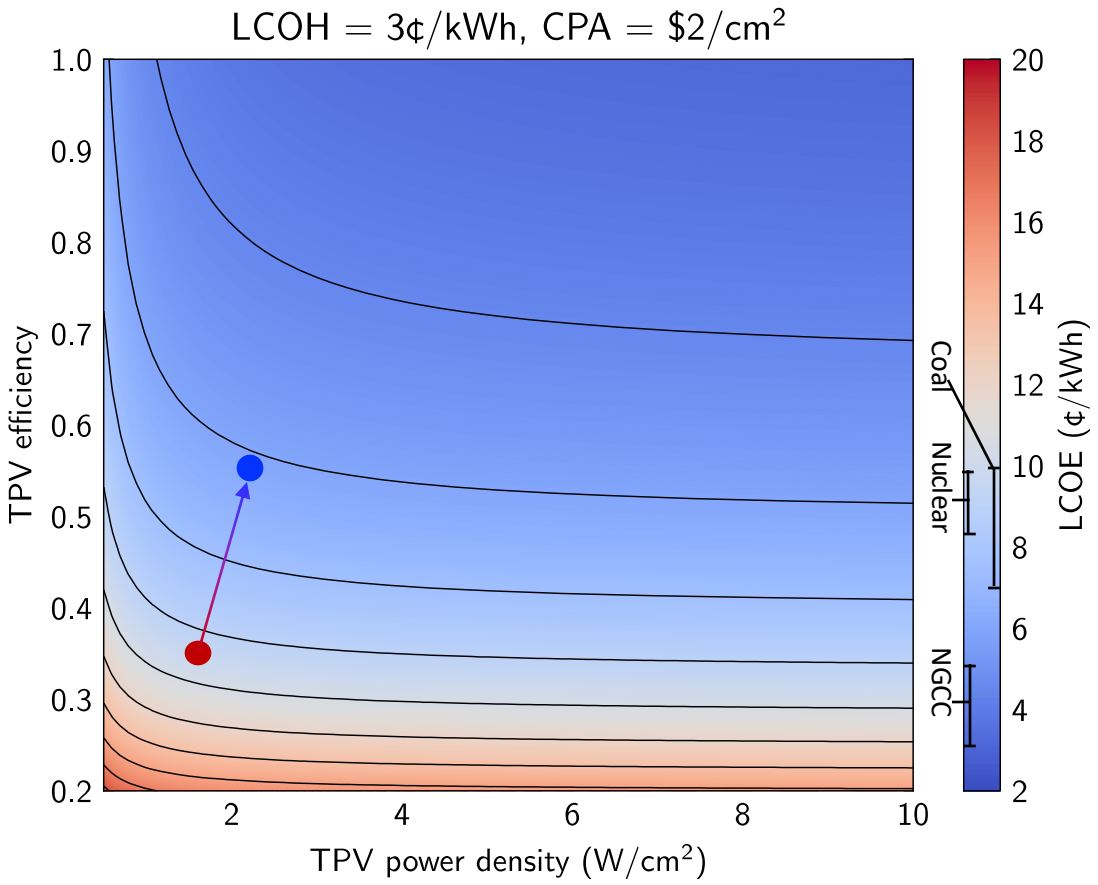
Heating term Cell term

Verma et al. *arXiv* (2024)

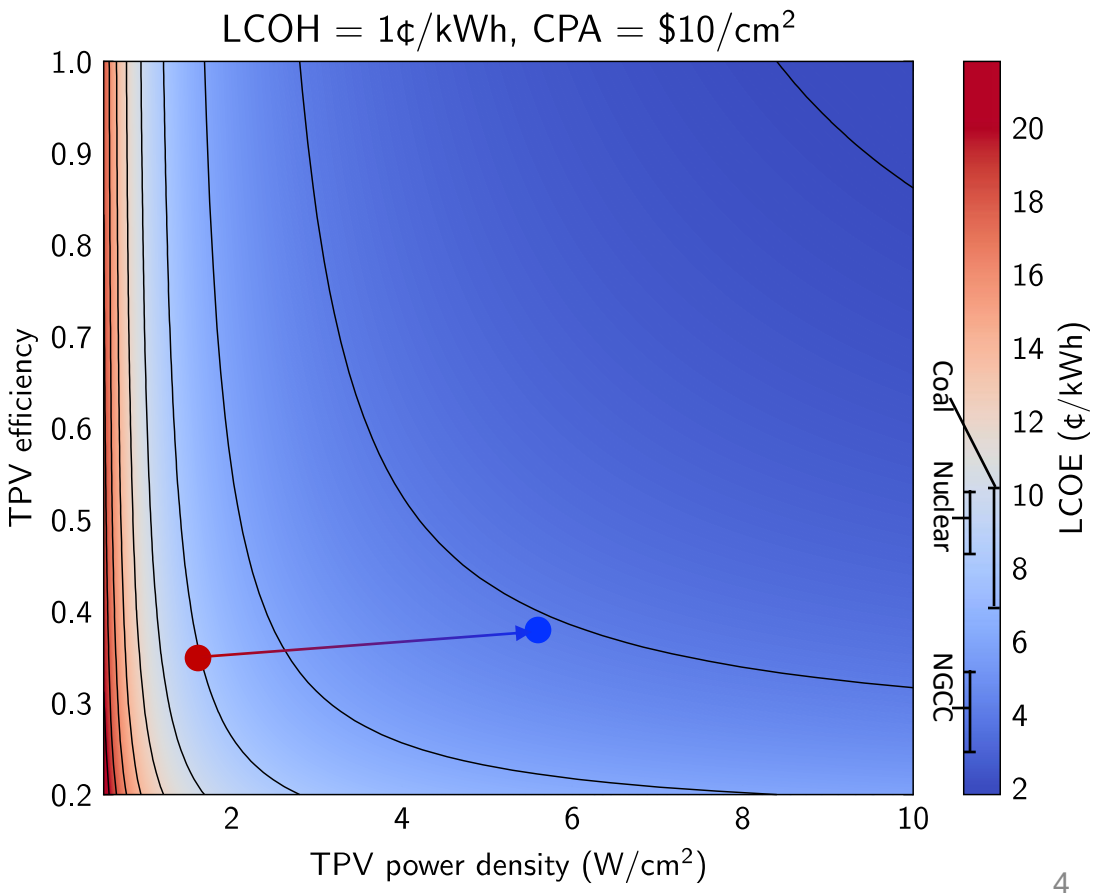
Power density matters when cell term dominates

$$LCOE = \frac{LCOH}{\eta_{TPV}} + \frac{CPA \cdot CRF/t_{out}}{P_{dens,TPV}}$$

Case 1: Heating cost dominates

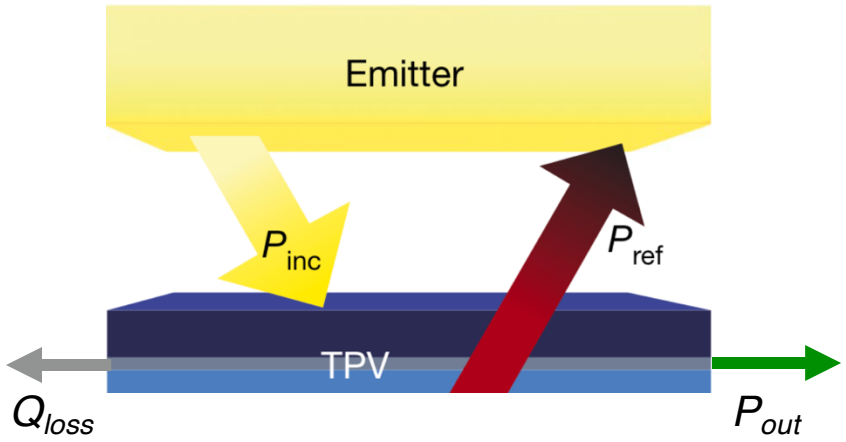


Case 2: Cell cost dominates

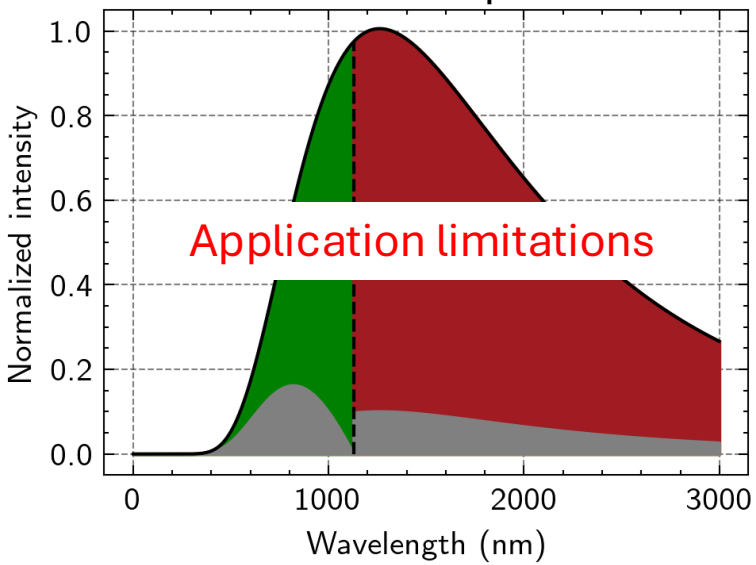


Verma et al. *arXiv* (2024)

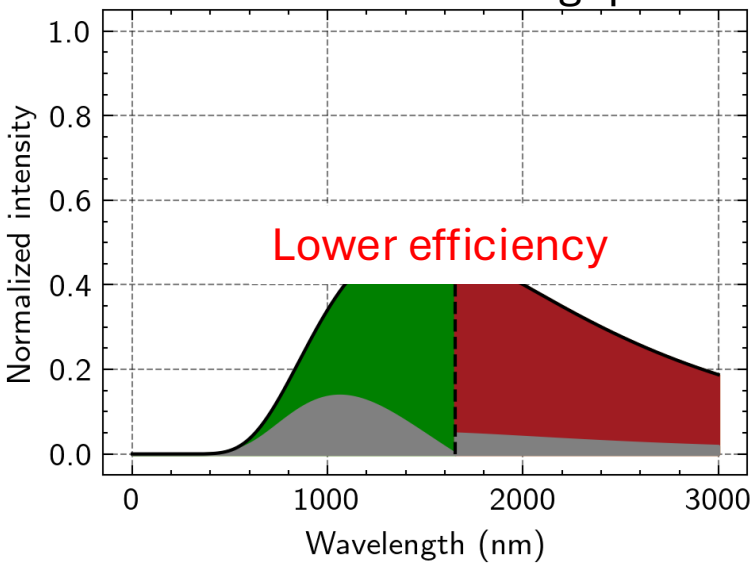
Options for increasing TPV power density



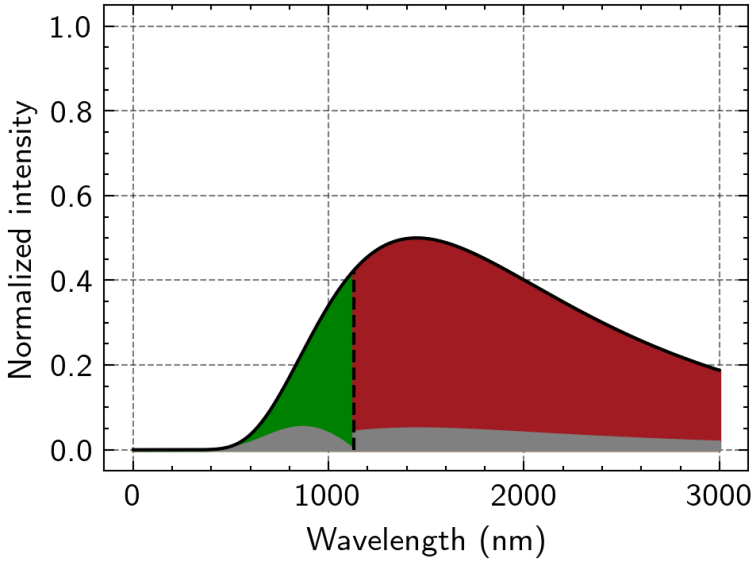
Increase temperature



Decrease bandgap



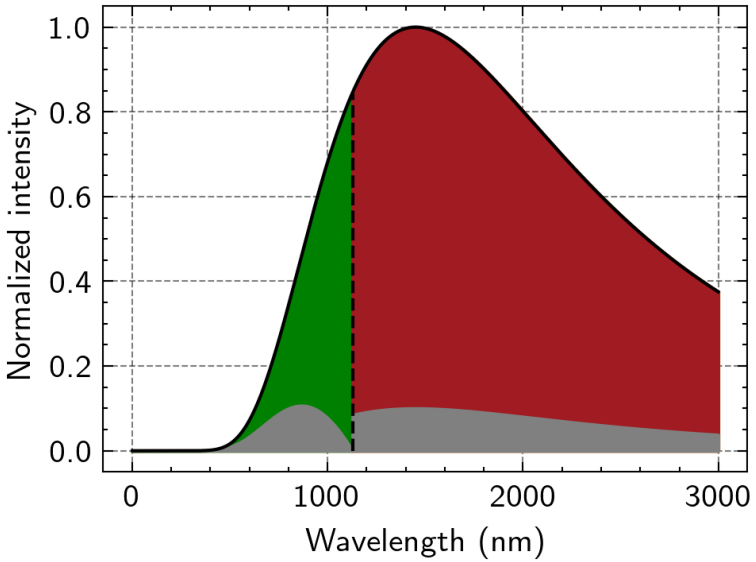
Base case



Application limitations
Increase view factor
Limited impact
Add ARC

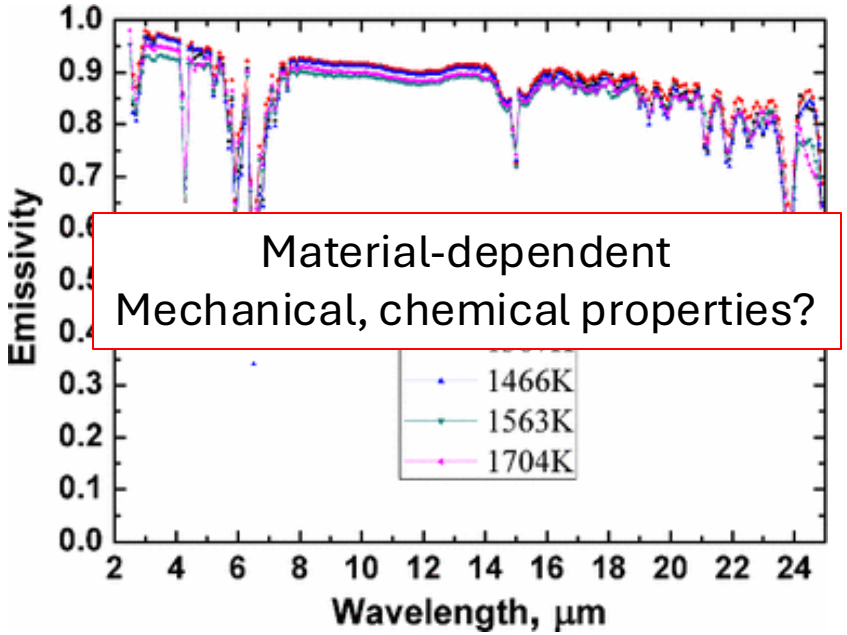
Increase emissivity

(Similar eff ensures higher light intensity ⇒ higher electric intensity)



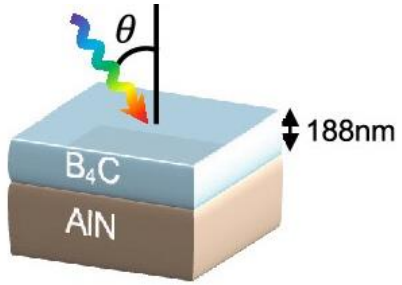
Options for improving emitter emissivity

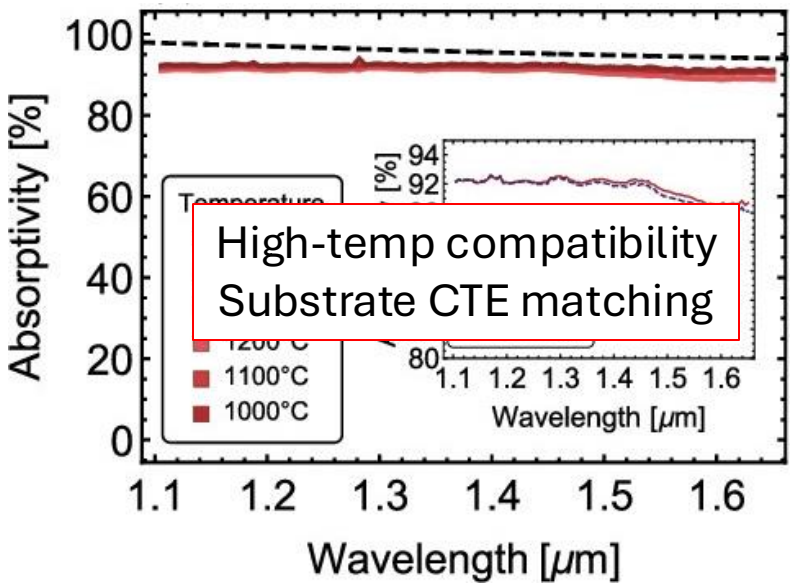
High-emissivity materials



Material-dependent
Mechanical, chemical properties?

Coatings





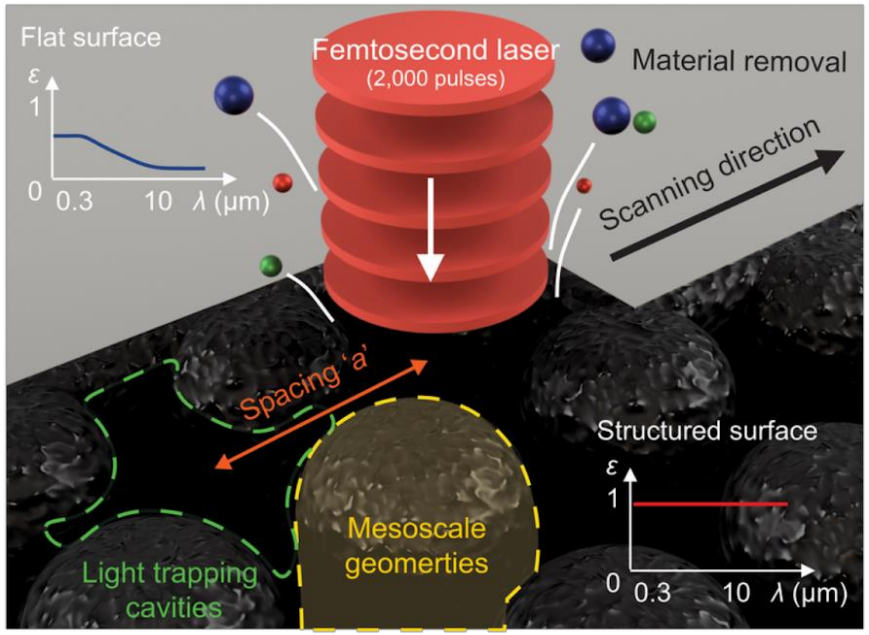
High-temp compatibility
Substrate CTE matching

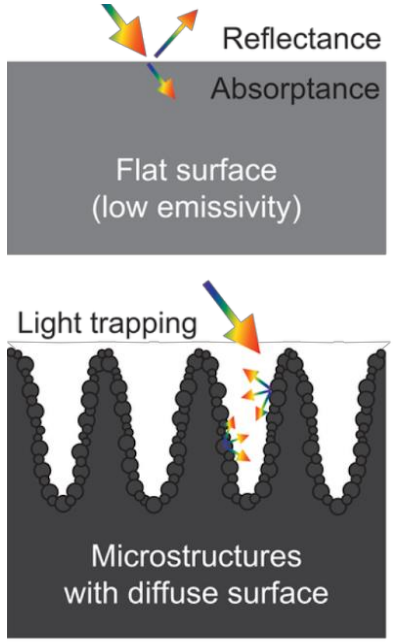
Surface engineering?

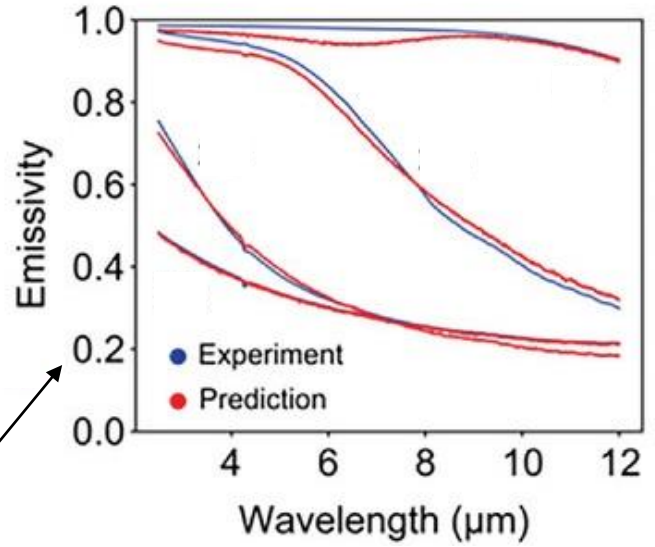
Gong et al. *ACS Applied Optical Materials* (2023) *1* 9, 1615-1619

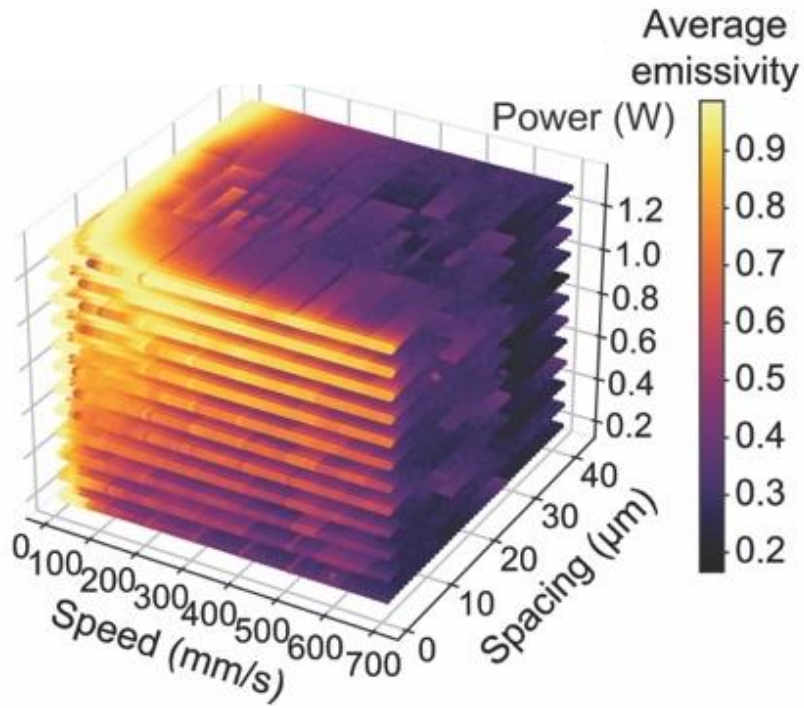
Graphite emissivity, metal cubes

Laser ablation can tune emissivity



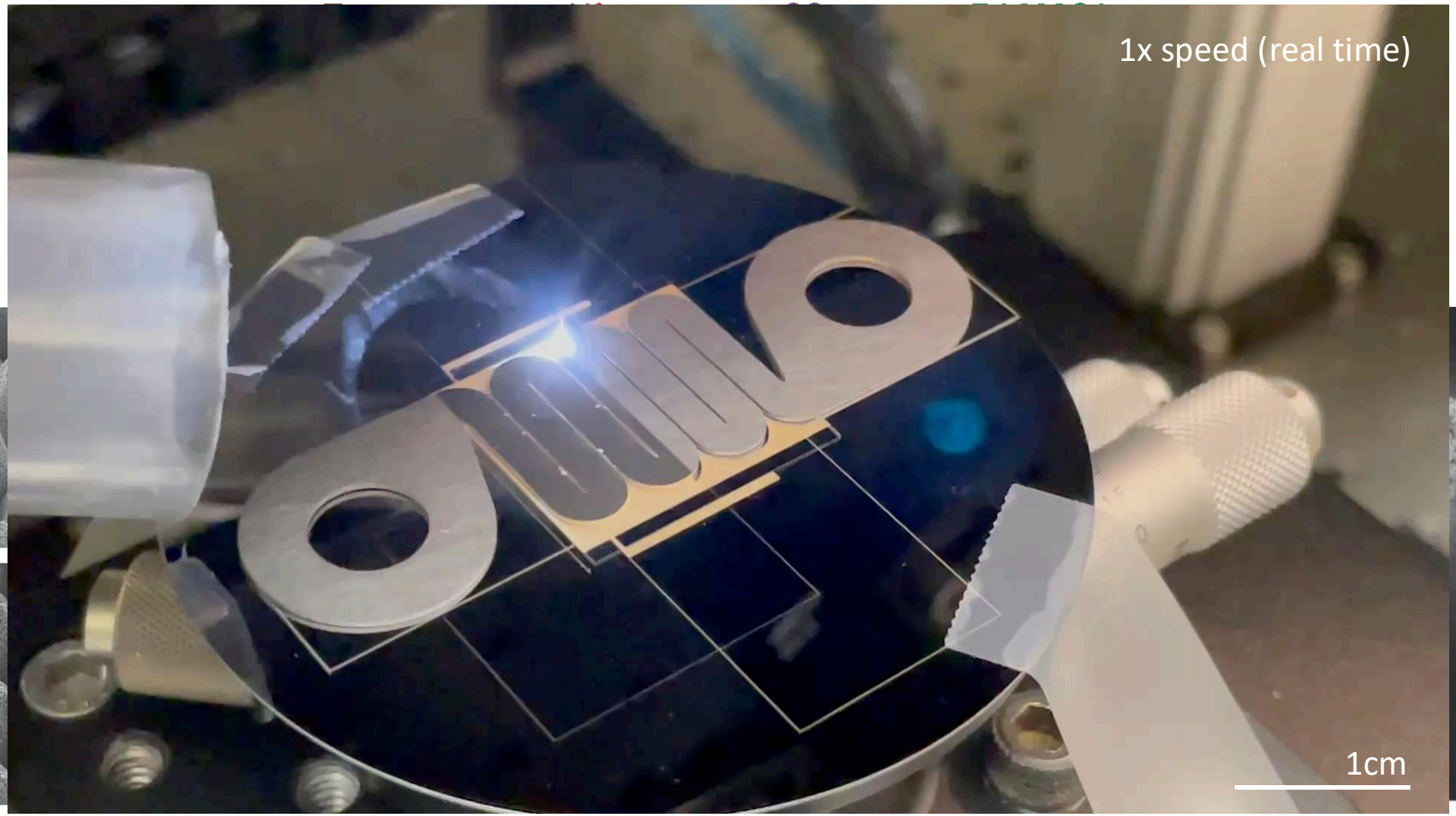


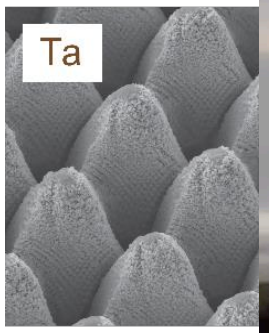


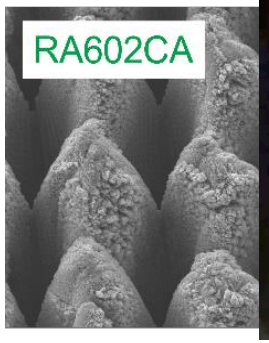


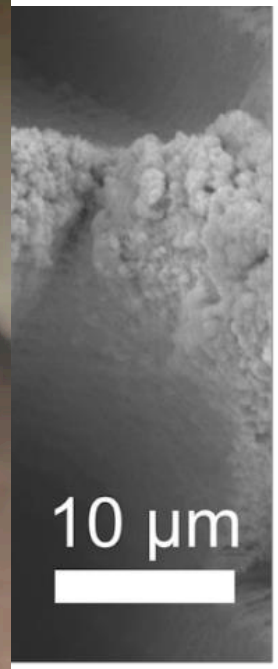
Park et al. *Advanced Science* (2024)

We can make any surface black



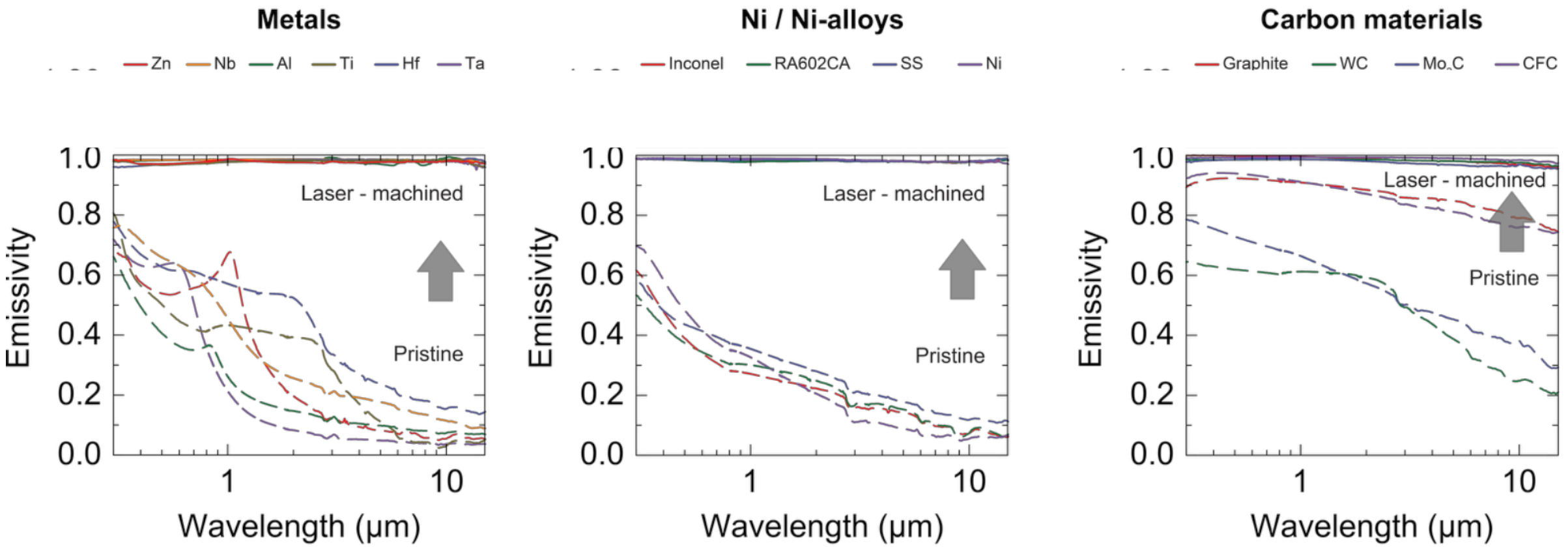






Park and Verma et al. *Submitted* (2024)

Emissivity before vs. after laser processing



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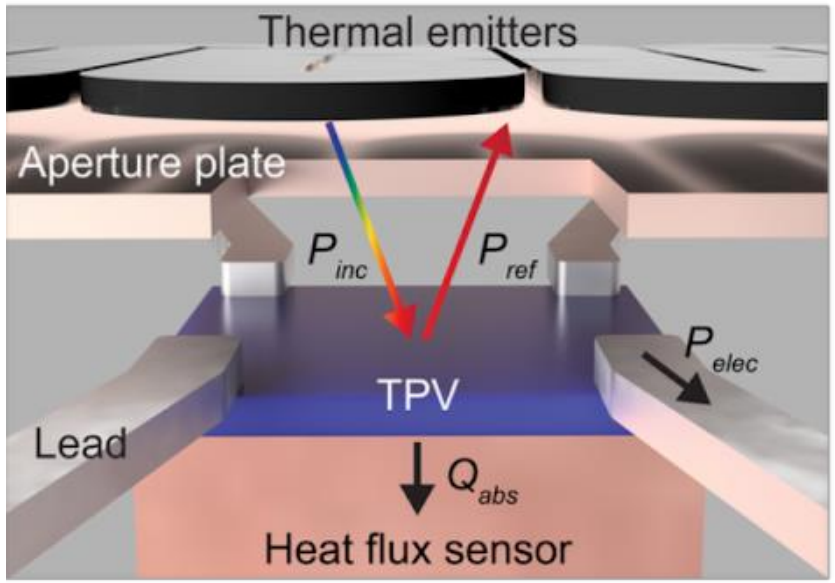
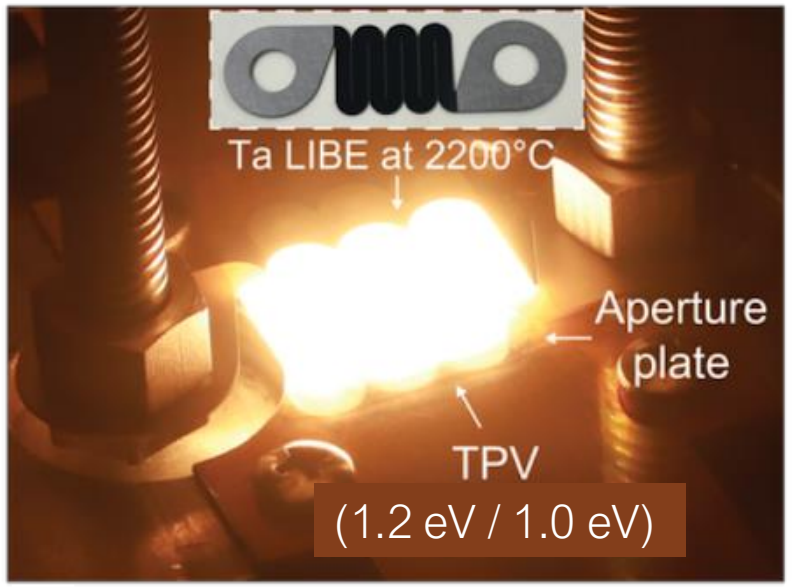
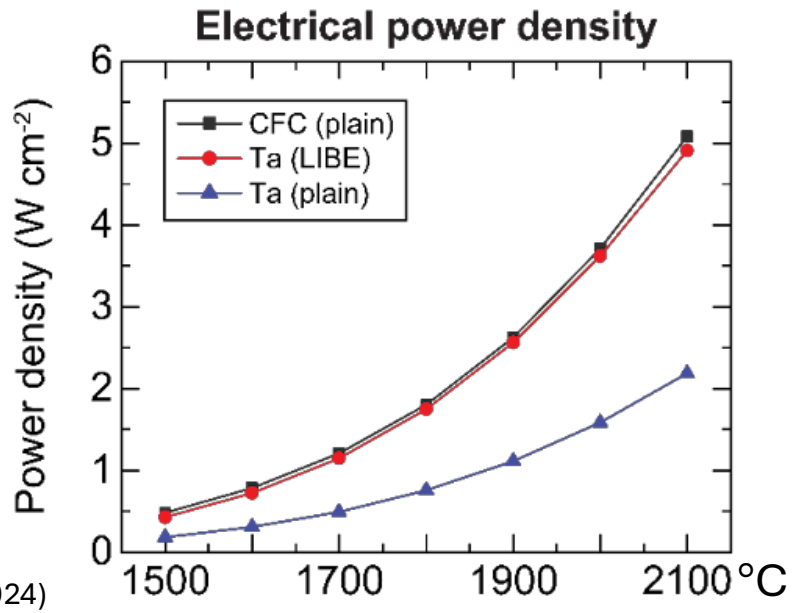
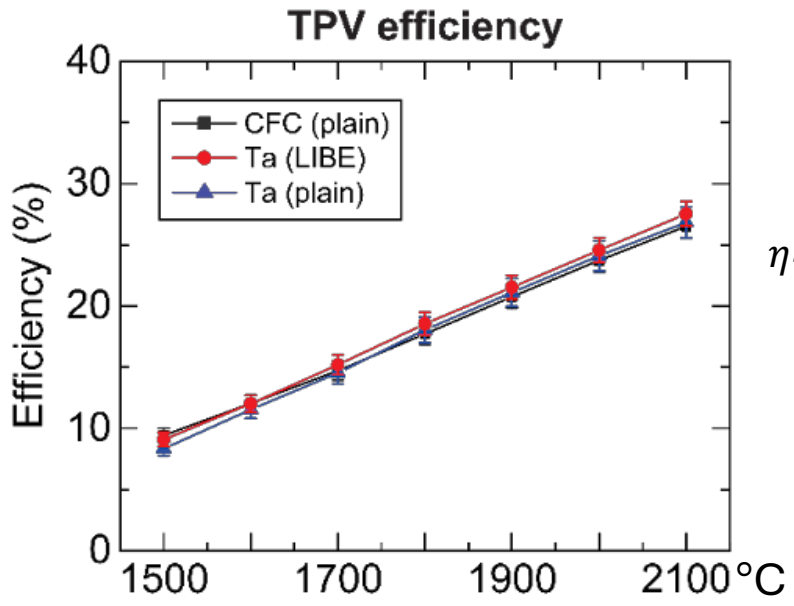
Laser processed emitters and TPV power density





AlGaInAs / GaInAs
+ Au BSR





$$\eta_{TPV} = \frac{P_{elec}}{P_{elec} + Q_{abs}}$$

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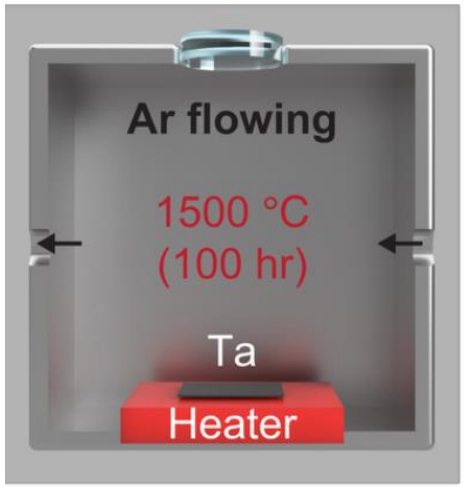
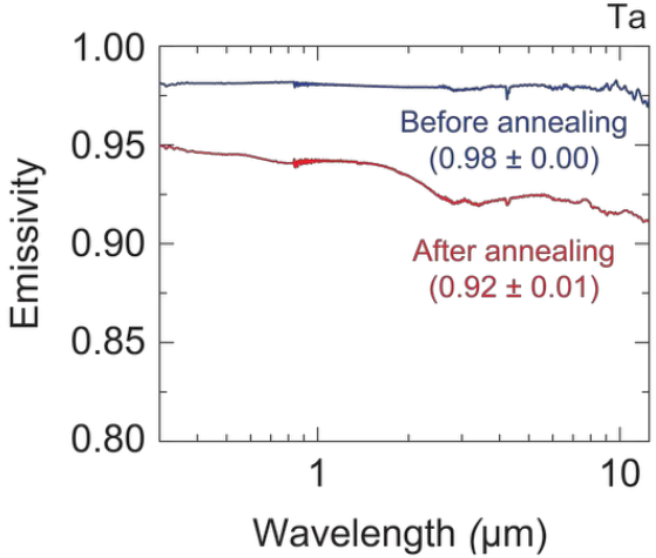
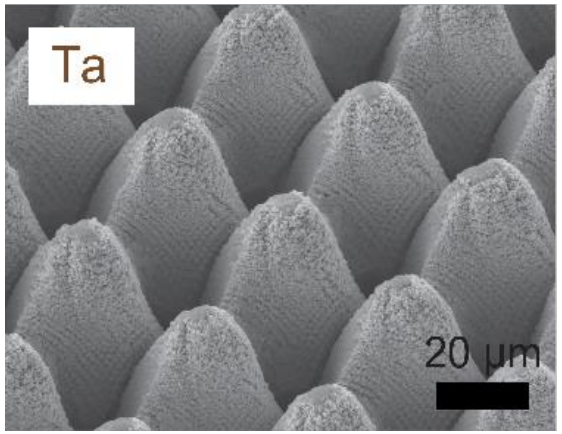
Durability of laser processed emitters

Low-temp, long-duration, oxidizing

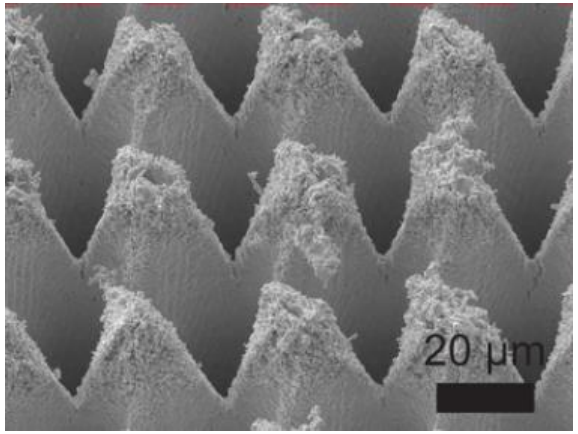




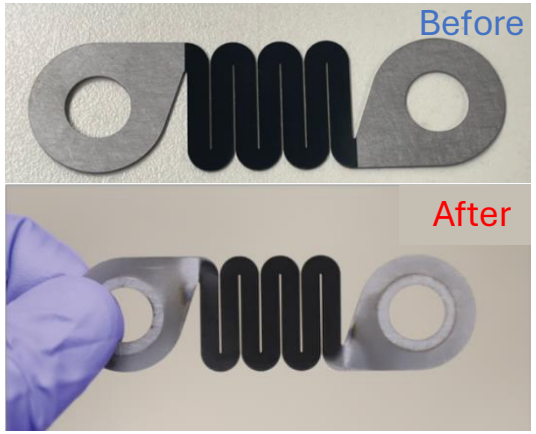
Before



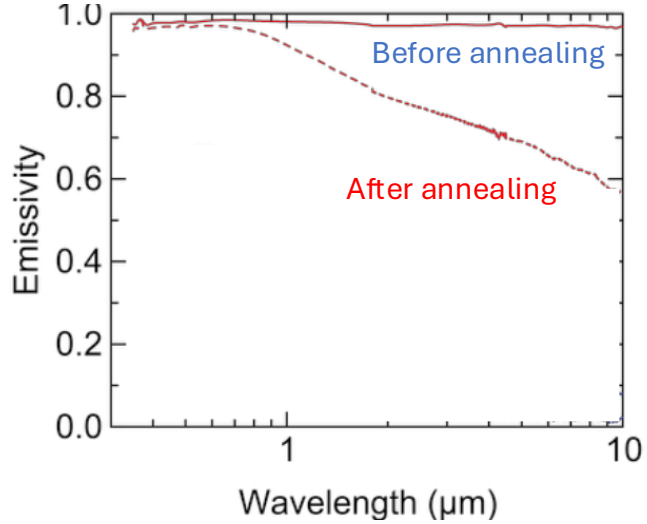
After



High-temp, short-duration, reducing



1500-2100C step heating
10 min each



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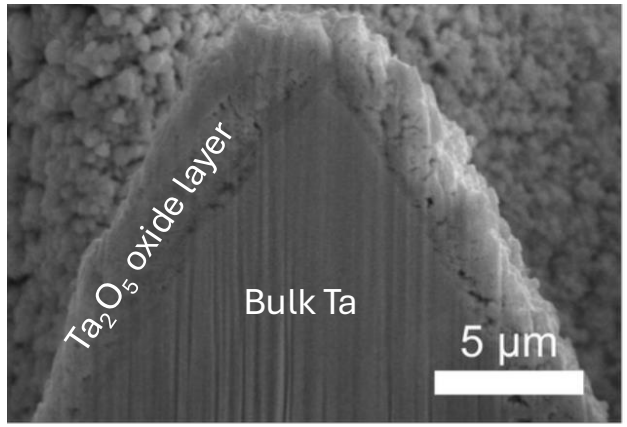
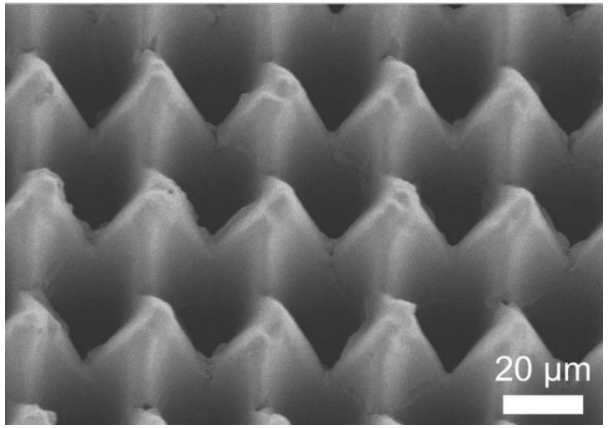


After



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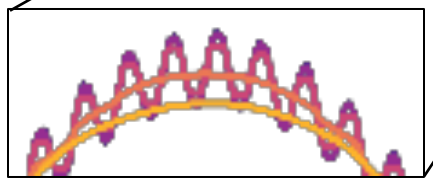
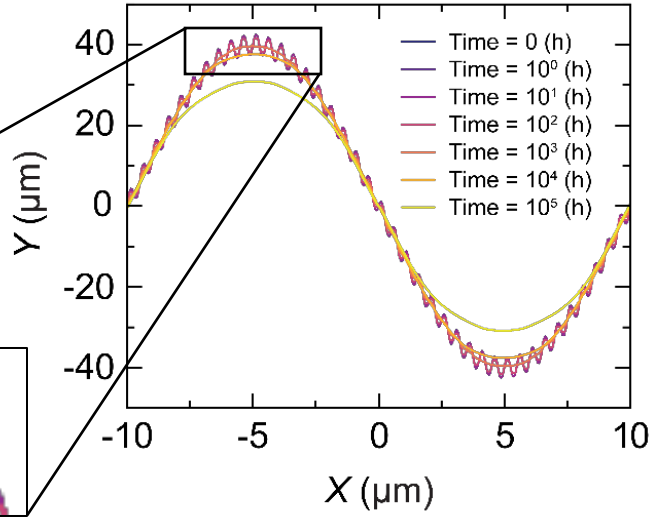
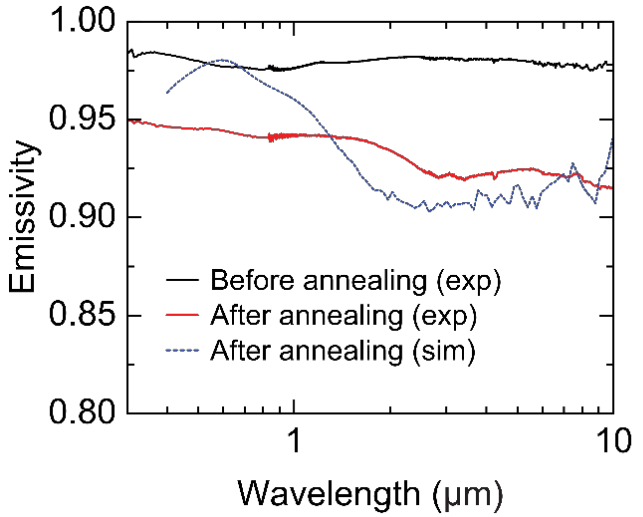
Modeling sintering to extrapolate durability testing

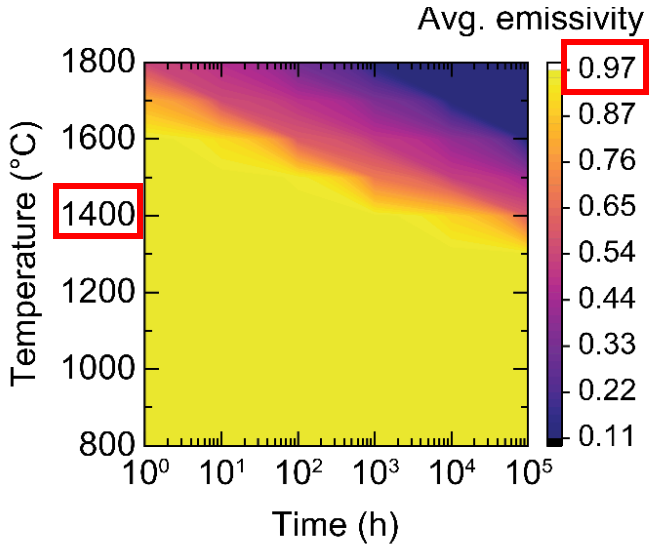
(Including surface diffusion + vapor pressure effects)

Low-temp, long-duration, oxidizing

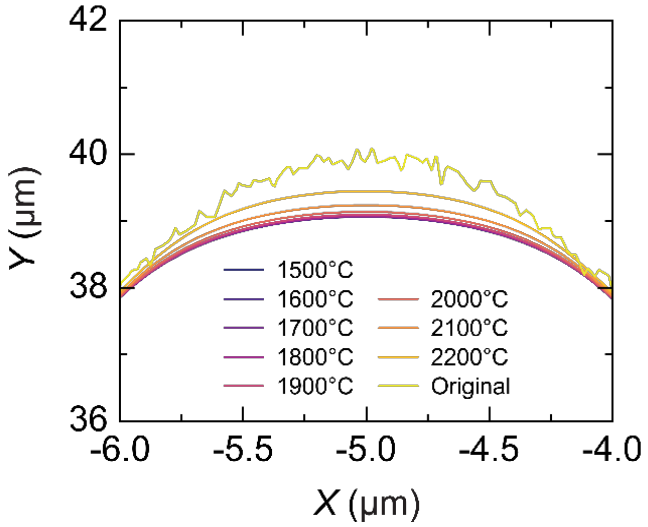


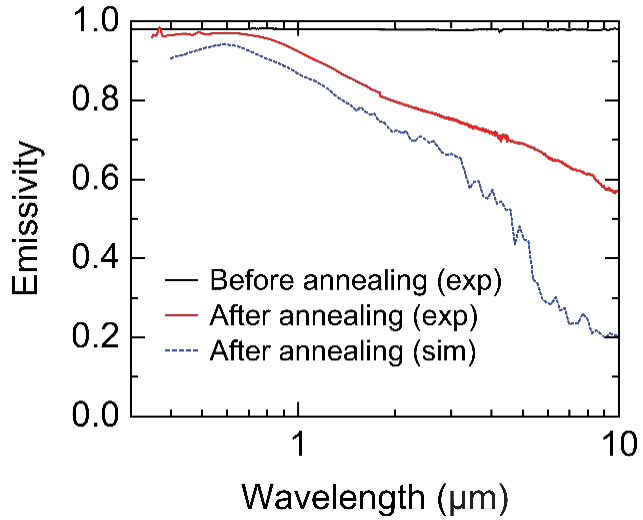


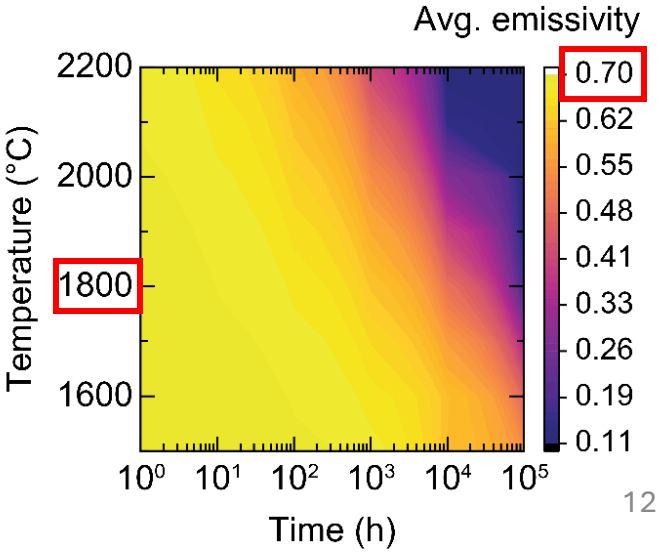




High-temp, short-duration, reducing







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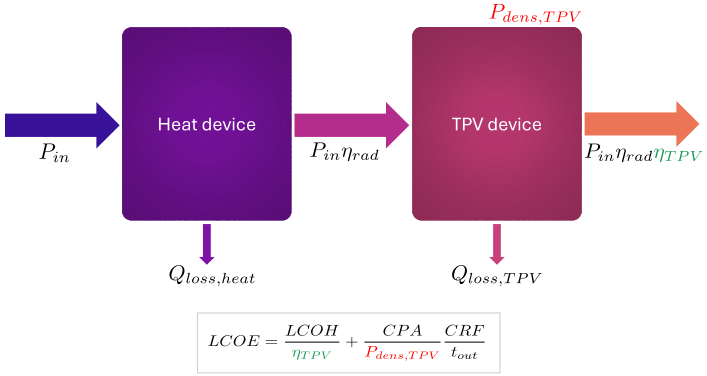

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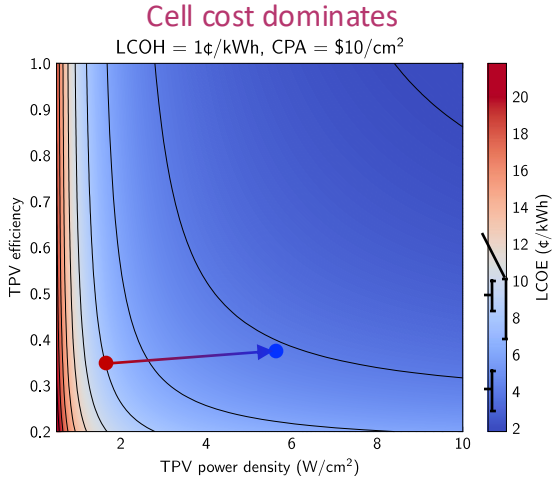

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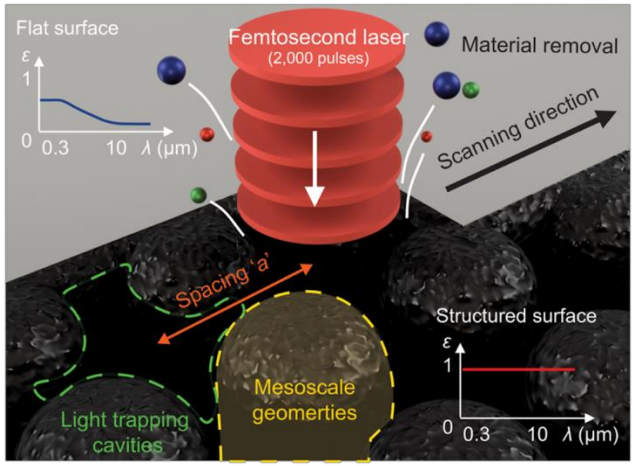

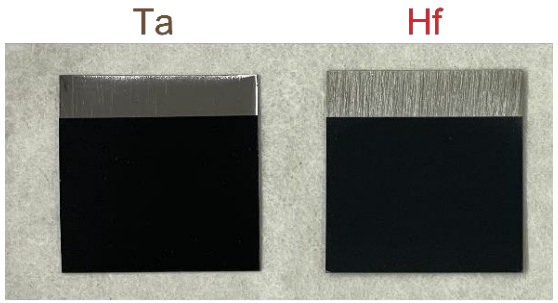

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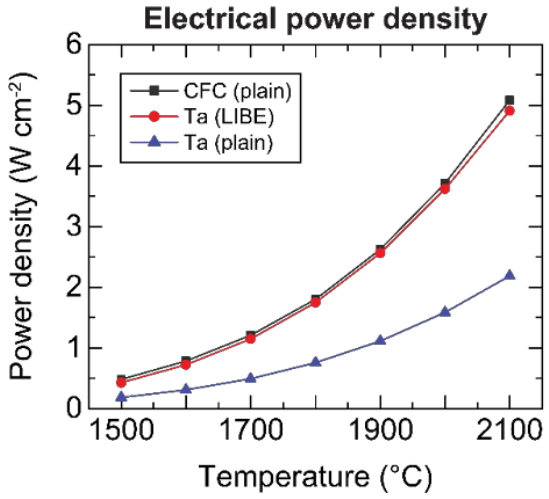

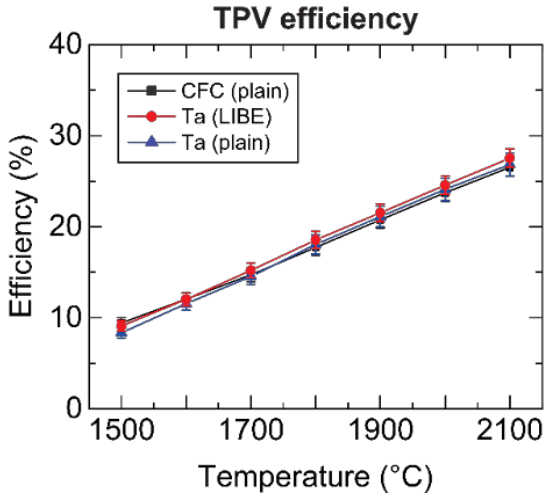

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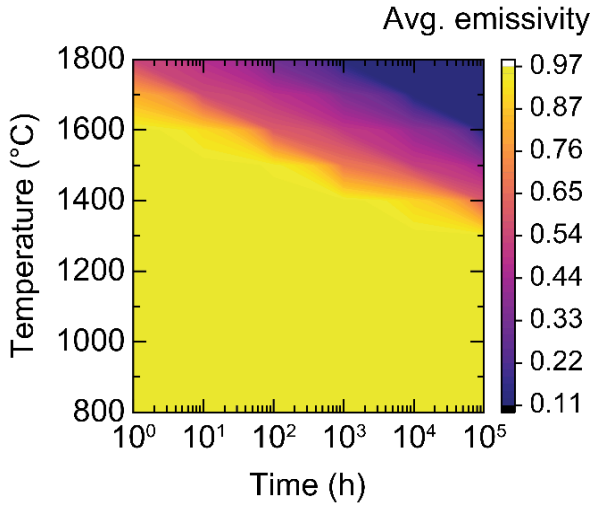

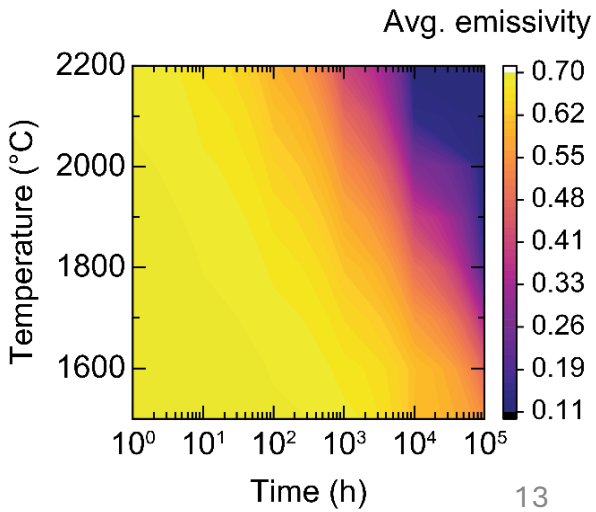

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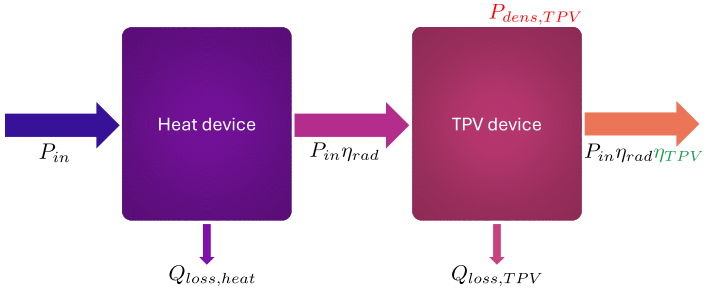

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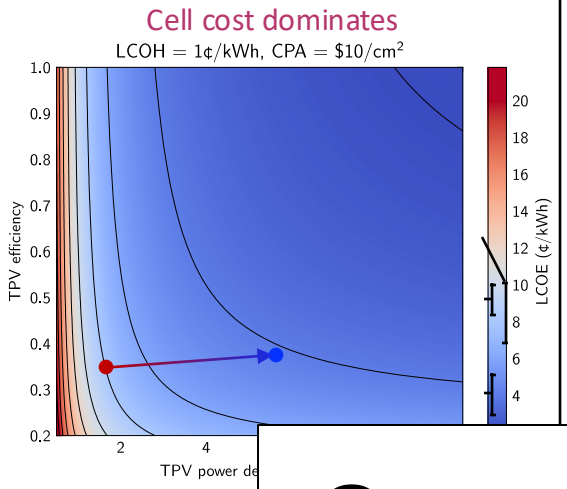

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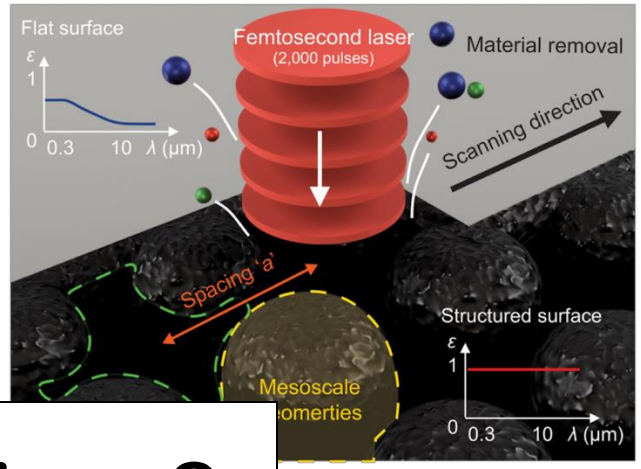
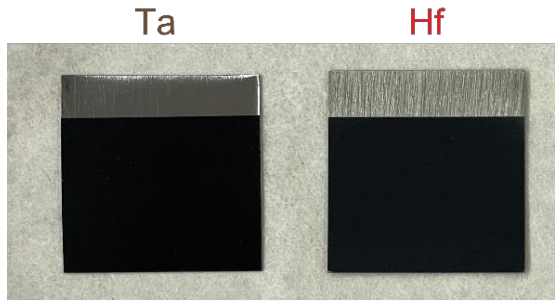
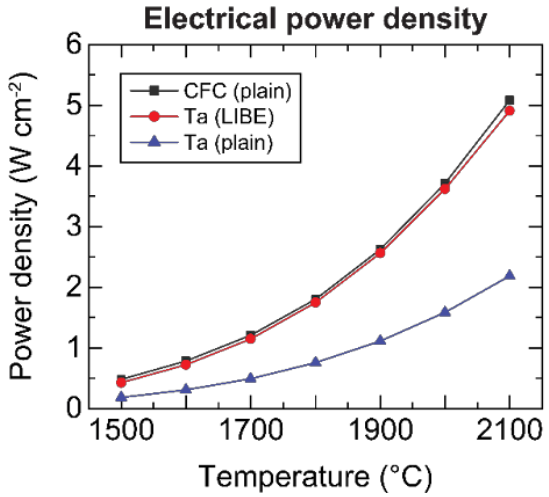
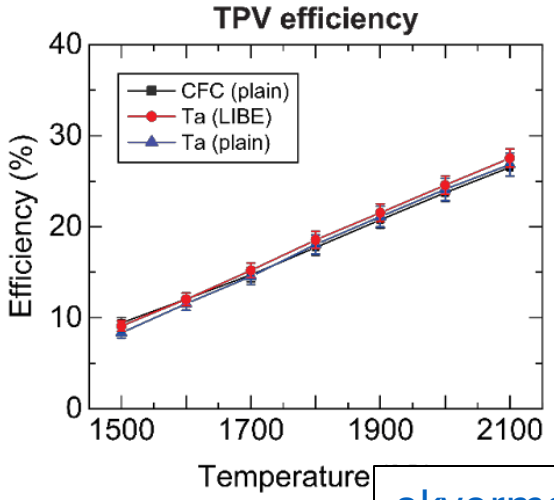




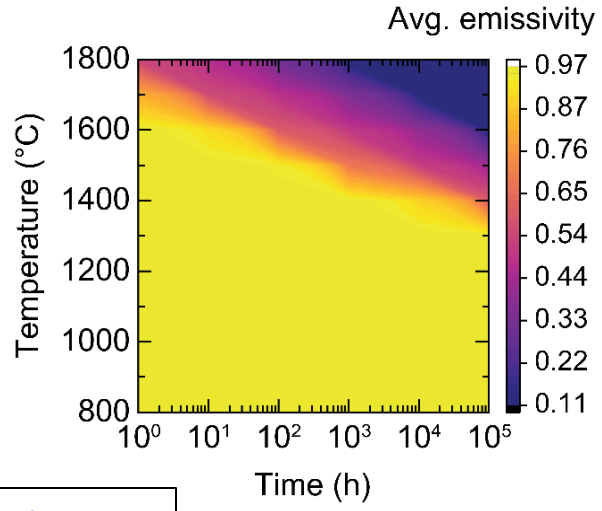
Questions?

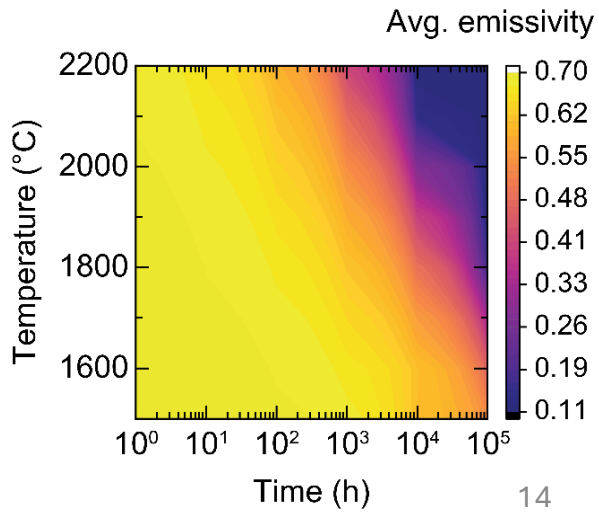
3. How do TPV cells perform with these emitters?





4. How long do the emitters last?





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