MicroSurf:

Guiding Energy Distribution inside **Microwave Oven with Metasurfaces**

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*Work conducted during internship at MSRA



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Even with rotating plates, microwave ovens suffer from non-uniform heating.



We investigated the heat distribution of *glass* plate and water of 10 different microwave ovens.



Related work: Feedback-enabled systems



MicroSurf: Open-loop heating control by a metasurface



Modeling the microwave ovens



MicroSurf fits the *temperature on the plate* with the simulated *dielectric loss*



Plate

Temperature distribution

SimulationSimulationBefore refinementAfter refinement

Standard metasurface design may be unsafe. Burning!



MicroSurf: High-power metasurface design

Safety

- Passive electronics-free
- Smooth edges
- Large gaps
- Programmability

Symmetry



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Metasurface optimization



Standing wave initialization



Standing wave criteria

$$\frac{d}{\lambda} + \phi = k\pi \qquad \begin{array}{c} d: \text{ Traveling distance} \\ \phi: \text{Tuned phase of metasurface} \end{array}$$

Optimize for different objectives

Maximize efficiency

Maximize uniformity $\max_{\mathcal{P}} \iiint_{V} L(x, y, z) \, \mathrm{d} v \qquad \max_{\mathcal{P}} \min_{n=1,2,\dots,N} \iiint_{V_{n}} L(x, y, z) \, \mathrm{d} v$





Result: Different microwave ovens



We experimented on 4 different microwave ovens with 1 same metasurface and 2 objectives for maximize power / uniformity with optimized placements.

02:33	E:0.97 02:27	£:0.97	02:23	£:0.97

Result: Different microwave ovens



Max efficiency objective:

- Temperature rise 2-4 °C.
- Sometimes STD increases.

Max uniformity objective:

- Temperature rises 1-2 °C.
- STD decreases by 25%-80%.

Result: Different food types



We evaluated on a wide range of food. The optimization models food as water sheets / cylinders.

Check the paper for detailed improvement numbers!

Result: Heating selective regions



Conclusion

- We propose MicroSurf, a metasurface to guide energy distribution inside microwave ovens. It includes:
 - Accurate modeling of microwave ovens.
 - High-power design of resonant metasurfaces
 - Coupling optimization of metasurfaces
- MicroSurf realizes improvement on multiple objectives:
 - Heating uniformity
 - Heating efficiency
 - Selective region heating



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	Group	Group	Center