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High-Performance Near-field Thermophotovoltaics for Waste Heat Recovery

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Abstract

The US industries reject nearly 20%-50% of the consumed energy into the environment as waste heat. Harvesting this huge amount of heat can substantially improve the energy usage efficiency. For waste heat in the medium temperature range (~500-900 K), traditional solid-state waste heat recovery techniques like thermoelectric generators and thermophotovoltaics (TPVs) are still suffering from relatively low efficiency or power density. In this work, we analyze a near-field TPV system consisting of a plasmonic emitter (indium tin oxide) and a narrow-bandgap photovoltaic cell (InAs) that are brought to deep sub-wavelength distances for high-efficiency and high-power-density waste heat recovery. We show that despite the inclusion of realistic nonradiative recombination rates and sub-bandgap heat transfer, such a near-field TPV system can convert heat to electricity with up to nearly 40% efficiency and 11 W/cm² power density at a 900 K emitter temperature, because of the spectral reshaping and enhancement by the thermally excited surface plasmons and waveguide modes. Thus, we show that for waste heat recovery, near-field TPV systems can have performances that significantly exceed typical thermoelectric systems. We propose a modified system to further enhance the power density by using a thin metal film on the cell, achieving a counterintuitively “blocking-assisted” heat transfer and power generation in the near-field regime.

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