Wafer-Scale Thermionic Energy Converters

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Thermionic energy converters were conceived in 1915, demonstrated in 1939, and were the focus of very large investments during the Cold War by the U.S. and the Soviet Union for space power applications. A 6 kW thermionic converter, fabricated using precision machining technology, was flown on a reconnaissance satellite in 1987 by the Soviet Union. Over recent decades, research on thermionic converters has lagged, due to the perception that the technology is impractical for commercial applications.

Thermionic converters can be fabricated using processes borrowed from micro electromechanical systems (MEMS). Advances in materials, micromachining, and vacuum encapsulation can be used to enhance performance and reduce manufacturing costs. Potential commercial applications for wafer-scale thermionics include small-scale co-generation and topping cycles for conventional heat engines. Recently, a new conversion concept has been demonstrated at Stanford, in which a semiconductor photocathode replaces the conventional metal cathode. This photon-enhanced thermionic energy (PETE) converter harvests photon energies above the bandgap, as well as broad-spectrum radiation through heating of the photocathode, making it attractive as a high-temperature topping cycle for solar-thermal power stations. Micro- and nano-structured cathodes and anodes and high-temperature materials are also essential to fabricating wafer-scale, cost-effective PETE converters. I will conclude by summarizing the remaining research challenges that must be surmounted in order to bring thermionic and PETE conversions into the mix of energy conversion options.

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