ELECTRON EMISSION THERMAL ENERGY CONVERSION

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ABSTRACT

Electron emission from a surface can be achieved via two mechanisms: tunneling and thermionics. Converting thermal energy to electrical power using these mechanisms is achieved by generation of an electron current from the emitter to the collector, and production of a voltage potential between electrodes due to the potential energy difference between the electrodes. Efficient low temperature energy conversion is investigated in this thesis utilizing these two emission mechanisms.

Two device concepts were developed based on thermal field (a form of tunneling) and thermionic emission that incorporate nontraditional design elements and novel implementations of existing technologies. These device concepts were developed with the intent to help mitigate some of the common downfalls of this solid state energy conversion.

In addition to the novel implementation and device concepts, a unique system level modeling approach is taken that combines a more detailed thermal network with the emission modeling. Advantages of this method include a better estimate for boundary conditions and emission temperatures. Typically emission models assume constant temperature boundary conditions which can over estimate device performance.

Modeling of a magnetically enhanced thermionic diode illustrated significant reductions in thermal radiation exchange between emitter and collector. This reduction is attributed to the ability to spatially reorient the electrodes due to the magnetically altered electron trajectories, and was shown to have a substantial effect on the energy conversion efficiency. Efficient low temperature thermionic energy conversion is currently not viable due to the high temperatures required to excite electrons above the material work function. With lower material work functions low temperature thermionic energy conversion would be achievable.

The second design concept investigated in this thesis utilizes the transition region between field emission and thermionic emission known as thermal-field emission. This type of emission uses a high electric field produced by a gate electrode to increase the probability of electron tunneling. High electric fields at relatively low gate voltages are achieved by concentrating the field around nanowire tip emission sites. Unlike field emission the electrode is heated by a heat source which further increases the probability of electron emission. Unlike thermionic devices which suffer poor emission rates at low temperature, the thermal-field nanowire converter can produce appreciable emission at low temperatures. Modeling showed promising conversion efficiencies for this device at low temperature. However, the model does not account for gate leakage currents which will likely be the primary obstacle of this technology. Initial steps towards fabrication of this device have been taken including the growth of Si nanowires.