

Space Mirror Alignment System

NASA's Jet Propulsion Laboratory, Pasadena, California

An optical alignment mirror mechanism (AMM) has been developed with angular positioning accuracy of ± 0.2 arc-sec. This requires the mirror's linear positioning actuators to have positioning resolutions of ± 112 nm to enable the mirror to meet the angular tip/tilt accuracy requirement. Demonstrated capabilities are ± 0.1 arc-sec angular mirror positioning accuracy, which translates into linear positioning resolutions at the actuator of ± 50 nm.

The mechanism consists of a structure with sets of cross-directional flexures that enable the mirror's tip and tilt motion, a mirror with its kinematic mount, and two linear actuators. An actuator comprises a brushless DC motor, a linear ball screw, and a piezoelectric brake that holds the mirror's position while the unit is unpowered. An interferometric linear position sensor senses the actuator's position. The AMMs were developed for an Astrometric Beam Combiner (ABC) optical

bench, which is part of an interferometer development. Custom electronics were also developed to accommodate the presence of multiple AMMs within the ABC and provide a compact, all-in-one solution to power and control the AMMs.

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Thermionic Power Cell To Harness Heat Energies for Geothermal Applications

Possible uses include geothermal exploration, automotive, and renewable energy applications.

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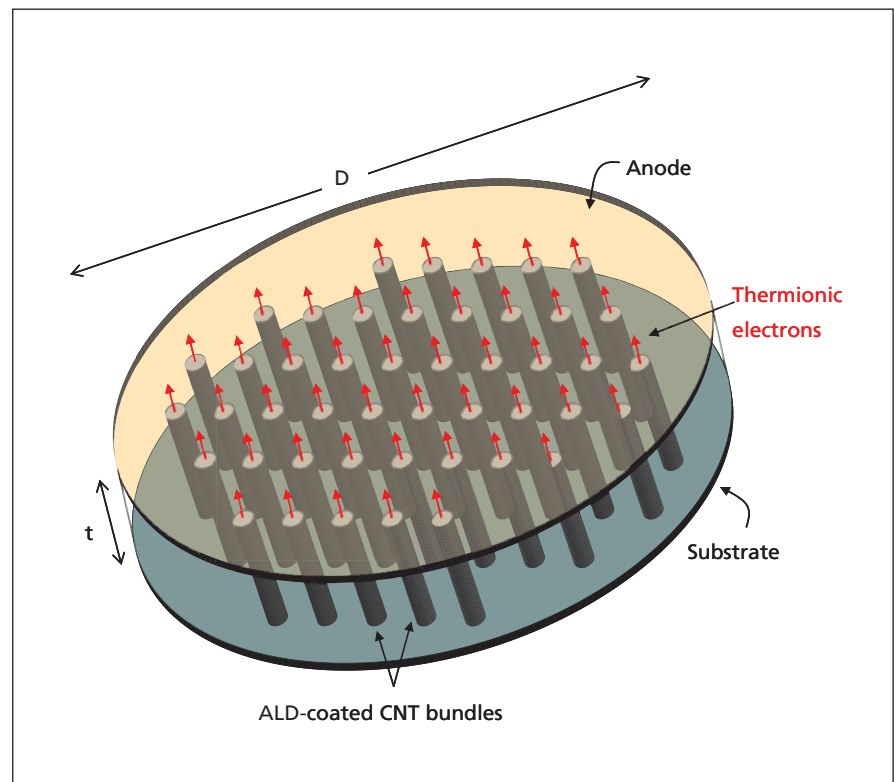
A unit thermionic power cell (TPC) concept has been developed that converts natural heat found in high-temperature environments (460 to 700 °C) into electrical power for *in situ* instruments and electronics. Thermionic emission of electrons occurs when an emitter filament is heated to "white hot" temperatures ($>1,000$ °C) allowing electrons to overcome the potential barrier and emit into the vacuum. These electrons are then collected by an anode, and transported to the external circuit for energy storage.

The thermionic emission current density (A/m^2) = $AT^2e^{(-\phi/kT)}$; where A = a constant, T = temperature (K), ϕ = work function (eV), and k = Boltzmann constant. The efficiency of emission increases with decreasing work function of the emitter material and increasing temperature. For example, the emission efficiency is much higher for cesium (ϕ = 2.4 eV) compared to pure carbon nanotube (CNT) (4.9 eV) and tungsten (4.5 eV). Additionally, the total current produced can be increased by enhancing the emitter surface area.

In this proposed approach, the higher emission efficiency of low-work function metal is combined with the enormous surface area achievable using CNT bundles to produce mA to A range current at lower temperatures of 460 to 700 °C range. This is achievable by conformally coating CNT (see figure) bundle arrays (or simply arrays of CNTs) with alkali metals such as potassium (ϕ = 2.3 eV) or

cesium using an atomic layer deposition process. Projected emission area of such an alkali metal-coated CNT bundle array (2- μ m diameter, spaced 2 μ m apart) over a 4-in. (≈ 10 -cm) diameter wafer is $\approx 3.0 \times 10^4$ cm². This leads to an estimated current production of ≈ 500 μ A (> 200

Wh/kg) at 460 °C to ≈ 1.3 A at 700 °C, which is comparable to standard high-temperature batteries (for example, for Na-NiCl₂ high-temperature batteries produce ≈ 90 –130 Wh/kg), and sufficient to power communication, computational and control electronics, as well as sensors



Schematic representation of the Thermionic Power Cell (TPC) with alkali-metal coated CNT bundles to enhance thermionic emission.