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(54) **METHOD OF INCREASING EFFICIENCY OF THERMOTUNNEL DEVICES**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,169,200 A * 2/1965 Huffman 310/306

4,747,698 A * 5/1988 Wickramasinghe et al. 374/6
6,064,137 A * 5/2000 Cox 310/306
6,365,912 B1 * 4/2002 Booth et al. 257/39
6,417,060 B2 7/2002 Tavkhelidze et al.
6,720,704 B1 4/2004 Tavkhelidze et al.
2001/0046749 A1 11/2001 Tavkhelidze et al.
2002/0171078 A1 * 11/2002 Eliasson et al. 257/25
2003/0168957 A1 * 9/2003 Sung 313/311

FOREIGN PATENT DOCUMENTS

WO WO99/10688 A1 3/1999
WO WO 99/13562 A1 3/1999

OTHER PUBLICATIONS

Tavkhelidze et al., "Electron tunneling through large area vacuum gap", Thermoelectrics, 2002. Proceedings ICT '02., Aug. 25, 2002, pp. 435-438, Piscataway, NJ, USA.

Hishinuma et al., "Refrigeration by combined tunneling and thermionic emission in vacuum: Use of nanometer scale design", Appl Phys Lett, Apr. 23, 2001, pp. 2572-2574, vol. 78, No. 17.

* cited by examiner

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(57) **ABSTRACT**

The present invention comprises a tunneling device in which the collector electrode is modified so that tunneling of higher energy electrons from the emitter electrode to the collector electrode is enhanced. In one embodiment, the collector electrode is contacted with an insulator layer, preferably aluminum or silicon nitride, disposed between the collector and emitter electrodes. The present invention additionally comprises a method for enhancing tunneling of higher energy electrons from an emitter electrode to a collector electrode, the method comprising the step of contacting the collector electrode with an insulator, preferably aluminum or silicon nitride, and placing the insulator between the collector electrode and the emitter electrode.

20 Claims, 3 Drawing Sheets

