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(54) **LIQUID METAL CONTACT AS POSSIBLE ELEMENT FOR THERMOTUNNELING**

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Related U.S. Application Data

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H01L 29/08 (2006.01)
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(52) **U.S. Cl.**
USPC **257/30; 257/324; 257/411; 257/E29.165; 257/E29.166**

(58) **Field of Classification Search**
USPC 257/30, 324, 411, E29.165, E29.166
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,169,200 A 2/1965 Huffman
4,135,067 A * 1/1979 Bitko 200/61.52

(Continued)

FOREIGN PATENT DOCUMENTS

WO WO-99/10688 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.

(Continued)

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(57) **ABSTRACT**

The use of liquid metal contacts for devices based on thermotunneling has been investigated. Electric and thermal characteristics of low wetting contact Hg/Si, and high wetting contacts Hg/Cu were determined and compared. Tunneling I-V characteristics for Hg/Si were obtained, while for Hg/Cu, I-V characteristics were ohmic. The tunneling I-V characteristic is explained by the presence of a nanogap between the contact materials. Heat conductance of high wetting and low wetting contacts were compared, using calorimeter measurements. Heat conductance of high wetting contact was 3-4 times more than of low wetting contact. Both electric and thermal characteristics of liquid metal contact indicated that it could be used for thermotunneling devices. To reduce the work function and make liquid metal more suitable for room temperature cooling, Cs was dissolved in liquid Hg. Work function as low as 2.6 eV was obtained.

19 Claims, 3 Drawing Sheets

