LOW TEMPERATURE ELECTRONIC TRANSPORT IN POROUS SILICON NANOSTRUCTURES

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Electrical conductivity of electrochemically etched porous silicon are studied in the temperature range from 300 K to 15K. Three different conduction mechanisms are found in different temperature ranges. Berthelot type conduction over 180 - 280 K, Mott's hopping conduction for 140 - 180 K and Efros-Shkloviskii hopping conduction below 120 K are observed.

Electronic transport properties in porous Si (PS) are quite complex . So far there is no clear understanding of current conduction mechanisms in PS[1]. Considering the disorder induced density of states (DOS) within the band gap, similar to amorphous semiconductors, hopping conductivity has been proposed at lower temperatures. It has also been proposed that current conduction in PS may be of Berthelot type because of fractal structure of PS. These proposals were based on the results over a limited temperature range. In order to investigate the current transport mechanisms in PS, we report the results of dc conductivity measurement over a wide temperature range from 450K to 15 K.

Thick PS layers were made by electrochemically anodizing p-Si(100) wafers having resistivity of 6-10 Ω.cm. The current-voltage (I-V) characteristics, measured in co-planner configuration, show a non-linear but symmetric behavior over a large voltage range. However the I-V for smaller voltages shows quasi-linear behavior. This linear region increases as temperature decreases.

Two separate activation energies(E_a) were estimated for two different temperature regions. E_a of around 50 meV is obtained in the temperature range from 280 K to 180 K. On the other hand, lower temperature range from 100 K to 50 K gives E_a of 10 meV. Below 50 K, σ becomes almost independent of temperature. These values of E_a are very low compared to the above room temperature E_a of around 0.5 eV. The low values of E_a in our samples indicate that the tunneling of carriers may be the dominant form of current conduction mechanism. We fitted our data to Mott's hopping model ($\ln(\sigma) \propto (T_o/T)^{0.25}$) and obtained T_o equal to 2 $X10^6$ K in the temperature range 300K to 170K. In the low temperature range (115K to 15K), the value of T_o becomes ~ 9K, which is unreasonably low. Such a low value of T_o (which results in unrealistic high DOS at the fermi level) suggests that the current transport mechanism of higher temperatures may not be applicable to the lower temperatures. There may exist different current transport mechanisms in the different temperature ranges. We also analyzed our low temperature data for Berthelot type, which results T_B =540K, which is very high, compared to the reported value[1]. Further analyzing the data using Zabrodskii method which suggests that the type of conduction mechanism may be of Efros-Shklovskii(ES) hopping conduction, as recently observed in micro granular metal films[2].

References

[1] R.M. Mehra, V. Agarwal, V.A. Singh, and P.C. Mathur, J. Appl. Phys. 83, 2235 (1998)

[2] S.K. Mandal, S. Chaudhury, and A.K. Pal, Thin Solid Films 357, 102 (1999)