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CURRENT FLUCTUATIONS IN THIN a-SiC:H FILMS

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In a-SiC:H films of about $1\mu m$ thickness with 2.25eV bandgap an approximately 1eV potential barrier containing a high density of localized states determines the electron flux across the interfaces to metal and n- type silicon contacts. We observed irregular structures in the I-V characteristics at room temperature and at 77K. At a fixed voltage random telegraphic noise (RTN) was observed with amplitudes of up to 30% of the mean current and switching times between milliseconds and minutes. At constant voltages we measured the current distribution function and found the RTN levels to exhibit a remarkably weak dependence on voltage. To interpret these phenomena we propose hopping transport along a few isolated transport paths, selected by an exponentially high contribution to the conductivity in a sample of limited contact area. In this picture RTN is caused by random charging and discharging of individual localized states close to the channels dominating conductance.

1. INTRODUCTION

Within the last decade several experimentalists reported irregular structures in the I-V characteristics of semiconductor devices in connection with a characteristic abrupt random switching of the current signal in time between two or some few discrete levels. This type of noise with amplitudes usually below a few percent of mean current was called random telegraphic noise (RTN). It was usually observed in small area devices ($A \approx 1\mu m^2$) such as tunnel junctions[1] , MOSFETs[2,3] and superconducting tunnel junctions[4] . Especially in MOSFETs correlations between the existence of an RTN signal and I-V characteristics were studied[3] . Recently Arce et al.[5] reported RTN in amorphous silicon/amorphous silicon nitride tunnel junctions of cross section areas more than $0.25mm^2$.

On the theoretical level the work of Tartakovskii et al.[7] is concerned with conduction through barriers in the intermediate range between direct tunneling (high field) and Mott conduction (low field) in doped crystalline and amorphous semiconductor films.

Compared to similar experimental observations mentioned before, we investigated the phenomena not only with a different material, namely a-SiC:H, but chose a contact area of one order of magnitude larger than in previous experiments. We measured up to room temperature and investigated the RTN-signal with the help of a current distribution function that was measured at a constant voltage. We found much higher amplitudes of the RTN-signal than usually observed and analyzed the voltage dependence of the RTN-levels.

2. EXPERIMENTAL

The a-SiC:H films were deposited in a plasma-CVD chamber. Details about the metal/a-SiC:H/substrate samples are described elsewhere[6] . The thickness of the samples ranged between $0.7\mu m$ and $1\mu m$. A carbon content of about 38% resulted in an optical bandgap of 2.25eV determined by transmission measurements and a midgap density of states of about $10^{18} eV^{-1} cm^{-3}$. The samples were grown either on glass substrates covered with a thin ITO film and n^+-doped a-Si:H or on n-type c-Si substrates. Ni-Cr contacts with an area of $2mm \times 2mm$ were evaporated on top of the film.

The current-voltage (I-V) characteristics were measured using a computer controlled DAC as the DC voltage source and a current preamplifier (Ithaco 1211). The output voltage of the current preamplifier was read by computer via an ADC. For the most accurate measurements the voltage was swept with a rate of 5mV per

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gular shape. Since the material has a defect density of about $10^{18} eV^{-1} cm^{-3}$ at the Fermi energy hopping assisted tunneling has to be considered besides the well known direct tunneling and thermionic emission processes.

From measurements at different temperatures we estimate an activation energy of 50meV, a value far too small to consider thermionic emission as a relevant process.

On the other hand, considering a thermally activated tunneling process one finds that at room temperature this contribution to the current can be neglected compared with thermionic emission. We are therefore led to believe that hopping assisted tunneling through the barrier is the dominating transport mechanism in our samples. As shown in fig. 5 one or more defects situated at the right positions in the barrier can increase the tunneling probability compared to the case with no defects or, in other words, lower the effective barrier height.

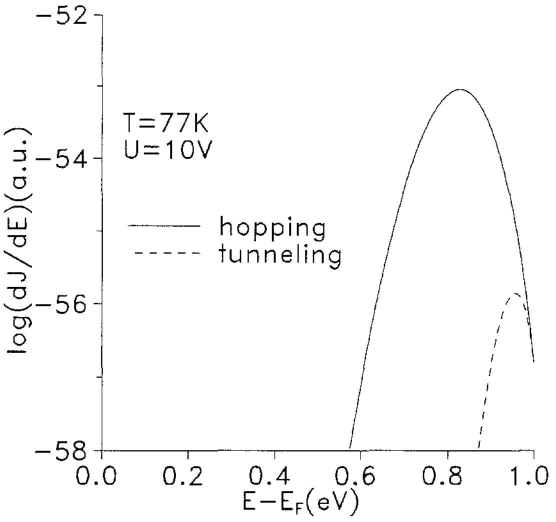

Figure 5: Hopping assisted tunneling in the barrier increases the transmission probability and lowers the activation energy compared to pure tunneling.

However, one has to keep in mind that a defect state can only increase the tunneling probability for electrons within a small area on the contact below which the site is situated thus leading to a transport path with high transmission probability. Since defect states are supposed to be randomly distributed throughout the film there is a certain probability that a transport path with a certain conductivity exists in a sample of finite contact area.

The existence of RTN signal supports the idea that the transport paths are indeed isolated rather than connected by branches of high conductivity. Furthermore the observation of RTN makes evident that only one or a few most conductive paths determine the total conductivity of the sample.

Applying the theoretical treatment of Tartakovskii[7] we found that our samples fit well into their model of statistical selection of isolated transport paths. From this model we estimated a number of about 5 sites forming one most conductive path.

The conductivity of a path can be changed by Coulomb interaction of individual traps near the path with path defects. Therefore a temperature activated statistical capture and release of electrons from such a 'modulator' can switch the conductivity of the path randomly. This accounts for the observation of the RTN signal.

The weak voltage dependence of single current levels on one hand and the rapid redistribution of the peak intensities on the other hand suggests that the main reason for the change of current with voltage is the change in the occupation of the 'modulators' and not a change of tunneling probabilities.

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