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Observation of flicker 1/f noise in $YBa_2Cu_3O_7$ and GaAlAs diode

Abstract

Polycrystalline $YBa_2Cu_3O_{7-x}$ near T_C (70-95 K) and GaAlAs semiconductor diode in the temperature range 50-300 K has been studied. The measured dc voltages in these systems show fluctuations and the standard deviations of the voltage values show the statistics of flicker 1/f noise. In $YBa_2Cu_3O_{7-x}$ the measured dc voltages showed increased noise near T_C which is possibly related to the 1/f noise due to the motion of vortex lattice. The 1/f noise in GaAlAS diode is found to be temperature independent but current dependent. It is found to increase with decrease in forward current below 0.01 mA.

Key Words

1/f noise; $YBa_2Cu_3O_{7-x}$; GaAlAs diode.

There have been a great deal of interest in the study of noise in recent past. There are three kinds of noise which are shot[1], thermal[2,3] and flicker 1/f noise[4-7]. The thermal noise is frequency independent and 1/f noise is frequency dependent. The 1/f noise has been observed in several systems[4-7]. Here the observation of 1/f noise in polycrystalline $YBa_2Cu_3O_{7-x}$,and GaAlAs diode is reported.

Electrical resistance measurement was carried out by an automated d.c. four probe method. The setup is automated using GPIB-IEEE-488 interface and the instrument interface program is written in MSDOS GWBASIC in a 80386 PC. The setup is built around a Leybold closed cycle refrigerator. A calibrated type-D silicon diode thermometer was used as the sensor for a Leybold model LTC60 temperature controller to control and monitor the temperature of the sample holder. The current was varied in steps using Keithley model 224/2243 programmable current source. The dc voltage was measured using a Keithley model 182 sensitive digital voltmeter. The electrical leads from PCS and SDV are taken through a specially fabricated low thermal connection to the cryo-refrigerator. It minimizes the thermal e.m.f. as follows. The thermal e.m.f. due to temperature difference is minimized as the opposite polarity leads are anchored to the copper plate maintained at a constant temperature. The electrical leads are crimped to the copper lug which are fixed to the copper plate with nylon screws. The electrical isolation with thermal contact of these copper lugs are obtained using mica sheet fixed with thermal conducting grease. The electrical leads (insulated copper wire) are thermally anchored to the cold parts in the cryo-refrigerator in order to reduce the stray thermal emf. Using this setup a typical voltage resolution of 10 nV and residual thermal emf less than μV is obtained. A temperature resolution better than 0.1 K is obtained.

For HTSC the electrical contacts were made using silver paste had a resistance of 30 Ω for the two current leads. The electrical resistance of the sample at 100 K was nearly 0.1 Ω. For the GaAlAs diode the diode in the CU package configuration is epoxied into a flat cylindrical disc and the sensor leads are thermally anchored to the same disc. The metal encapsula-

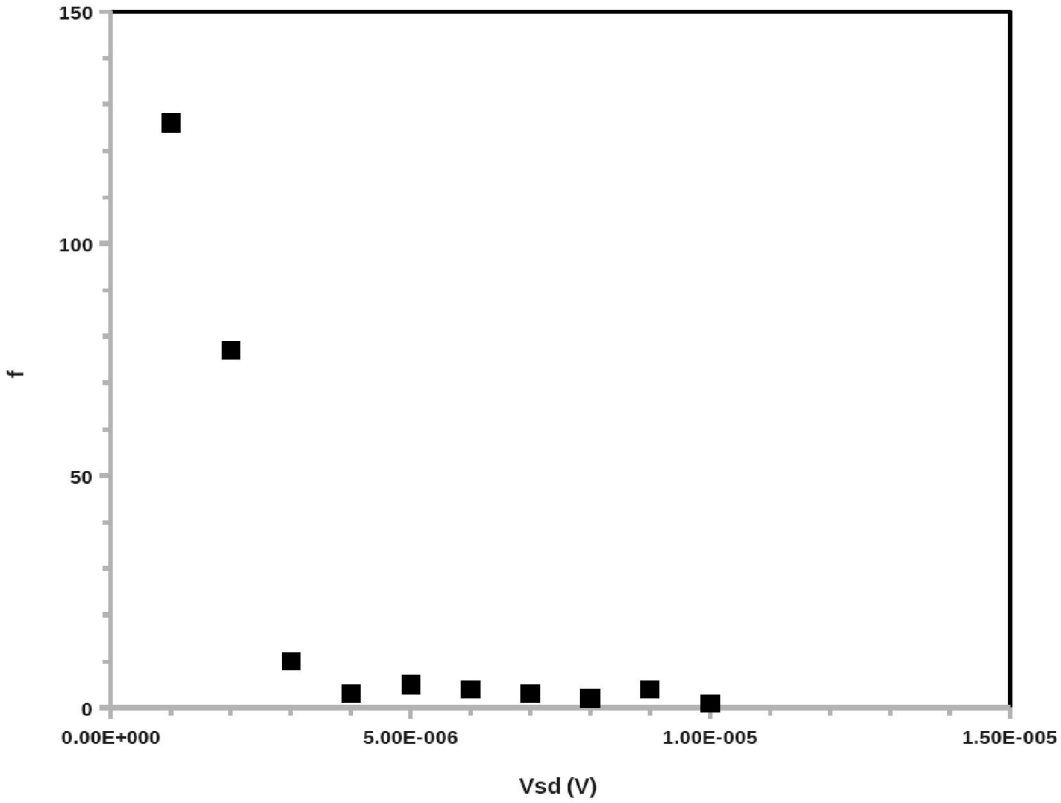

Figure 1 : The frequency distribution of V_{sd} for polycrystalline $YBa_2Cu_3O_7$ near T_C. The current was varied from 1 mA to 100 mA in steps. The ordinate represents the number of times out of 235 values that the V_{sd} is in the corresponding voltage bin of width 1 μV. The solid line through the data points is to guide the eye. It is seen that low noise voltages occur with high probability and high noise voltages occur with low probability.

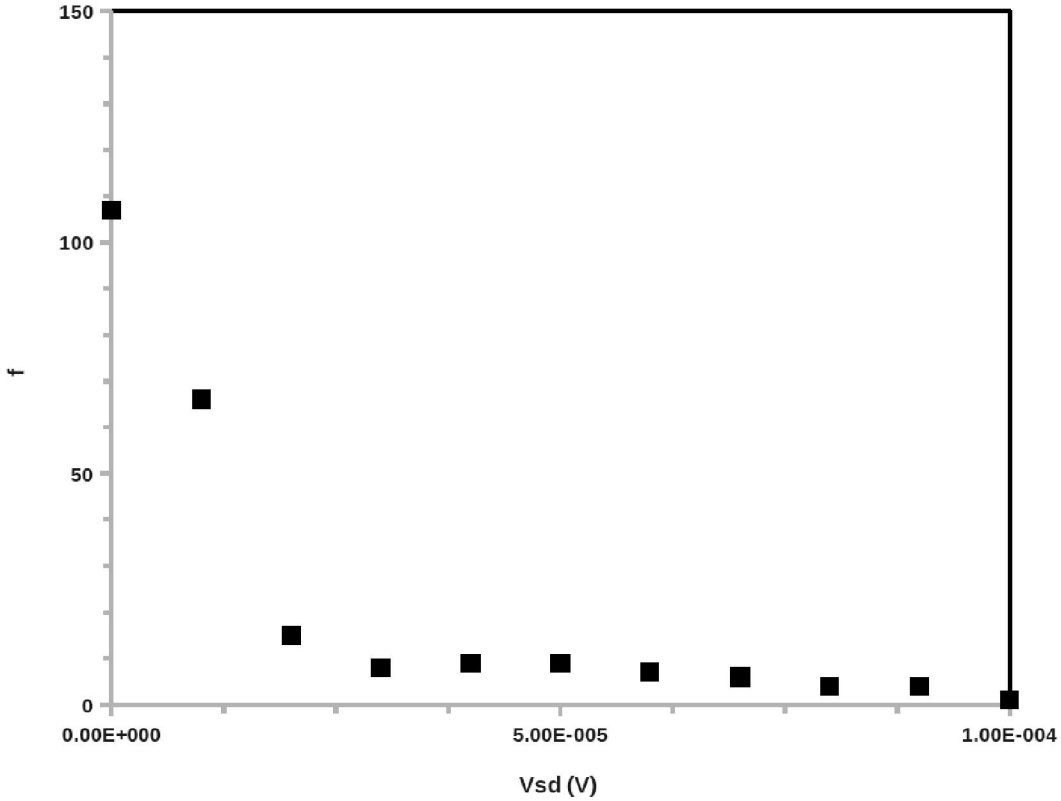

Figure 2 : The frequency distribution of V_{sd} for GaAlAs semiconductor diode in the temperature range 50 – 300 K. The forward current was varied from 10 nA to 450 μA in steps. The ordinate represents the number of times out of 236 values that the V_{sd} is in the corresponding voltage bin of width 10 μV. The solid line through the data points is to guide the eye. It is seen that low voltages occur with high probability and high voltages occur with low probability.

tion of the diode was fixed to the sample space of the closed cycle helium refrigerator with 0.2 mm thick indium foil and a thin layer of Apiezon-N grease by clamping with an aluminum disc and screws using moderate pressure.

If noise is assumed to consist of random 'pulses' with time of both polarity (not necessarily simultaneously) and has a probability distribution with respect to amplitude then V_{sd} has a distribution which is the characteristic of 'noise'. The measured voltage is given by:

$$V_m = V_f + V_n \quad (1)$$

where V_m is the measured voltage, V_f is the forward voltage of the diode and V_n is the noise voltage. The V_f is equal to $< V_m >$ and r.m.s. V_n is equal to the standard deviation (V_{sd}) of V_m. From the analysis of voltage standard deviation of a measured dc voltage (V_{sd}) it is possible to identify the presence of noises. If noise voltages is assumed to occur with equal probability, then low noise voltages occur with high probability whereas high noise voltages occur with low probability for flicker 1/f noise.

In case of polycrystalline $YBa_2Cu_3O_7$ the distribution of nearly 235 V_{sd} values in the temperature range 70-95 K was studied[8]. The current was varied between 0.1 mA and 100 mA in steps. The frequency distribution of V_{sd} is shown in figure 1. It is seen that low voltages occur with high probability as is expected for 1/f noise. The 1/f noise was found to occur in a few Kelvin temperature range around T_C. This has been predicted theoretically using the BKT theory[9]. Similarly for GaAlAs diode the distribution of nearly 236 values of V_{sd} in the temperature range 50-300 K and for current values 10 nA-450 μA is studied[10]. The frequency distribution of V_{sd} is shown in figure 2. It is seen that low noise voltages occur with high probability as is expected for 1/f noise. $< V_{sd} >$ is found to increase with decrease in current unlike V_f which decreases with decrease in current. This indicates that $< V_{sd} >$ arises from a source that is different from V_f.

In conclusion polycrystalline $YBa_2Cu_3O_7$ and GaAlAs diode have been studied. The measured dc voltages in these systems show fluctuations and the standard deviation of the voltage show statistics of 1/f noise. In $YBa_2Cu_3O_7$ the measured dc voltages showed increased noise near T_C which is possibly related to the 1/f noise due to fluctuation of vortex lattice. The 1/f noise in GaAlAs diode is found to be temperature independent but current dependent. The 1/f noise in these systems can be understood as due to thermal fluctuations from modified thermal equation[11,12].

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