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The MRF-Stimulated Quasi-Periodic Superlattice type characteristics in High Temperature Superconductor Bi2212

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The electric and magnetoconductivity in HTS Bi_{2212} have been experimentally observed under magneto-radio-frequency (MRF) excitations. The I-V characteristics, differential conductance dI/dV-V and second derivative d^2I/dV^2-V plots confirm the resonant tunnelling and the superlattice stimulations in HTS Bi_{2212} under MRF perturbations.

Keywords: HTS Bi_{2212}, MRF stimulated conductivity, Quasi-Periodic superlattice; resonant tunnelling, differential conductance.

1. INTRODUCTION

The anisotropic magnetoresistance in thin films for ferromagnetic (Fe, EuS) and anti-ferromagnetic materials such MnF_2, Ta/NiFe , FeC, Au/Co/Au etc had become of prominent interest for the researchers dealing with the advances in the technology of small scale devices and the multilayered structures [1,2,3]. The magnetostatic modes studied in multilayered structures exhibit deterrministic disorders. More recently, a new kind of structure namely the quasi-periodic superlattices in nanostructures is tempting scientists of both the theoretical as well as experimental fields [4,5]. It is known from magnetostatic theory that the multiple surface branches can occur even when the thickness of non-magnetic material is larger than the magnetic ones. The experimental results of present investigation reveal a few signatures of the characteristics associated with superlattice type behaviour in HTS Bi_{2212} under MRF excitation. The sleeping state multilayered superlattice structures seems to be activated under MRF excitations in HTS Bi_{2212}, getting rid off the cumbersome processes like MBE, hot electron spectroscopy techniques and the lift off processes etc [6].

2. THEORY

In magnetic thin films, the Hall voltage V_H is the sum of ordinary Hall voltage due to Lorentz force and extraordinary Hall voltage, generated from the asymmetric scattering of the conduction carriers from the magnetic moments of the thin films. In high temperature superconductors, under MRF perturbations the tunnelling between negative and positive type electrical regions (may be in the form of electrons, holes or the ions of any electrical polarity positive or negative) of varying dimensionality starts in the shape of tunnel currents between permutations of one, two and three dimensional regions. The mixed dimensional tunnelling theory for HTS crystals considering 2D-3D tunnelling, 2D-

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2D tunnelling and 1D-2D tunnelling has been presented. The net tunnelling current density J can be written as

$$J=\int \frac{q n_c(E) n_v(E)}{n_c(E)+n_v(E)} \{F_c(E) - F_v(E)\} T_t \left(\frac{2}{\hbar}\right) \frac{dE}{dK} dE \qquad \text{-(1)}$$

where q is change, $n_c(E)$ and $n_v(E)$ are the conduction band and valence band density of states at energy E respectively, $F_c(E)$ and $F_v(E)$ are the occupation probabilities for the conduction band and valence band respectively. The integration is over the range of overlapping conduction band and valence band states. A reduced density of states term also appears in eq. (1) which really describes tunnelling between bands of differing density of states compared with the conventional treatment. The energy components parallel with the barrier are neglected. The tunnelling transmission probability, T_t is given by

$$T_t = \frac{exp - \pi {m_t}^{1/2} {E_g}^{1/2}}{2\sqrt{2}\hbar q F}$$

where Franz's two-band model is applied to a WKB approximation with constant mass, E_g being the band gap, m_t, the tunnelling (dominated by highest effective mass states) effective mass and 'F' is the mean effective field. The MRF excitation seems to impose the abrupt doping spikes (delta layer) of positive and negative electric carriers electrons/holes/ions in HTS separated by the distance of the order of a few nanometers like modulation doping by MEE. The nanobehaviour of HTS Bi_{2212} under MRF excitation seems evident from the experimentally observed curves [7,8].

3. SYNTHESIS AND PREPARATION

The Bi-Ca-Sr-Cu-O oxide sample was prepared by solid state reaction using Bi_2O_3, $SrCO_3$, $CaCO_3$ and CuO as starting reagents. The powder mixture was thoroughly ground and heated at 820°C & 840°C for 12 hours each with intermediate grinding. Then reacted material palletized at 4.5 tonnes (Kbar) pressure. Then pellet put in furnace and brought to a partially melton state at different temperatures between 900°C and 940°C for 2-3 min, then furnace was turned off and cooled to room temperature.

The superconducting transition was observed using standard four probe resistance technique and the measurement current 5mA in the temperature range 70 K to 300 K. Air drying silver paste was used for making electrical contacts on the sample. The sample temperature was monitored within an accuracy of +-0.1 K using a standard 100 Ohm platinum sensor in conjunction with the Keithley 224 programmable constant current source and Keithley 181 nanovoltmeter.

4. EXPERIMENTAL STUDY

The samples were experimentally analysed by taking in 4 or 6 probe Hall geometry under magnetic field H-8 KG under radio frequency excitation 6 MHz due to RF oscillator alongwith transverse Hall potential measuring digital millivoltmeter. The RF-stimulated magnetoconductivity in HTS have been studied.

The experimental results have been presented in Figure 1, Figure 2 and Figure 3 as I-V characteristic, differential conductance characteristic (dI/dV-V) along with (d^2I/dV^2-V) respectively. In this way it has been possible to interpret the feature of d^2I/dV^2 data for tunnelling amongst electrons/holes/ ions confined in a two dimensional electrons gas and a bulk three dimensional region.

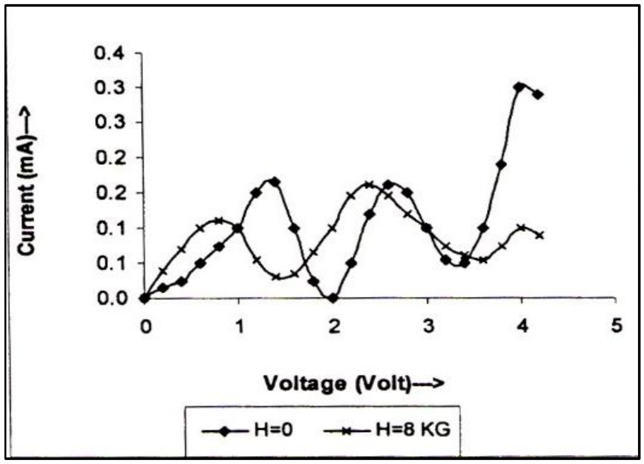

Fig. 1: I-V Characteristic.

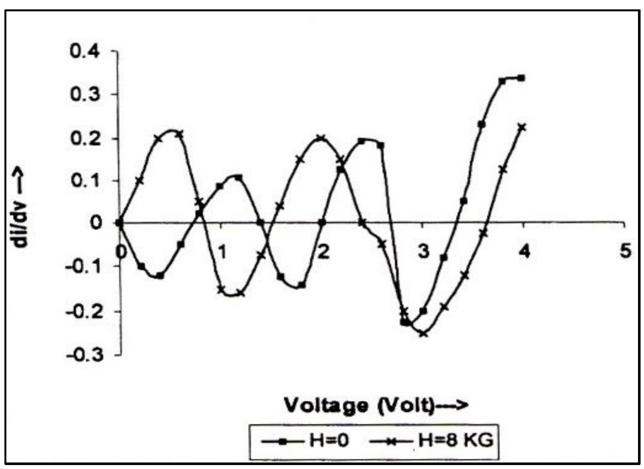

Fig. 2: Differential conductance characteristic.

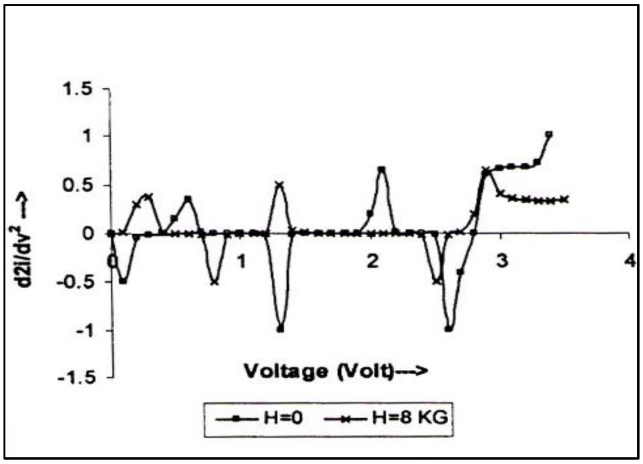

Fig. 3: d^2I/dV^2-V characteristic.

5. RESULTS, DISCUSSION & CONCLUSION

The features, which would not be apparent in the theoretical treatment of Prechtal et al. together with the spikes in the d^2I/dV^2 are evident in the current experimental findings. Theoretically, these features could be simulated only after using reduced density of states. The MRF stimulation thus seems to excite the sleeping nanostructures confined within the HTS and the cumbersome doping processes to achieve these characteristics may be avoided.

The I-V characteristic, derivative I-V characteristics have been obtained for HTS Bi_{2212} under MRF excitations. The d^2I/dV^2 data has been generated from the experimental functions obtained in present findings.

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