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The Radioactivity Induced MRF-Fluctuations in High Temperature Superconductors $YBa_2Cu_3O_7$ and Geo-rock BPY-4

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ABSTRACT

The study on the high-T_c superconductors $YBa_2Cu_3O_7$ as well as geo-rock BPY-4 had been made for their magneto-potentials behaviours as transport-properties under radioactivity influence. The Hall effect measurement had been investigated using six-probe Hall geometry under radio-frequency (RF) signaling at room temperature T. The magneto-potentials (V_H) having oscillatory nature had been recorded with changing frequencies upto 7 MHz using magnetic fields H = 0 Gauss, 4000 Gauss and 6000 Gauss without and with α-radioactivity exposure using isotope $_{241}Am^{95}$ ($5f^4$, $7S^2$). The radioactivity exposure increases the transverse potentials which seems to be oscillatory in nature. These magneto-potentials have been employed to compute the various physical parameters such as Hall coefficient (R_H), electrical carrier density (N_H), electron concentration (n), plasma frequency (ω_p) at the magnetic field H = 6000 Gauss. All these physical parameters are deeply influenced by the α-radioactivity exposure in geo-rocks as well as above said superconductors.

KEY WORDS: High-T_c superconductors, transport properties, magneto-potentials, α-radioactivity and RF-perturbations

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INTRODUCTION

The discovery of high-T_c superconductors were surprising and exciting, not simply because of large increase in T_c, but also it revealed that oxides formed due to an unsuspected new class of superconducting materials with great potential. In high-T_c superconductors, the copper oxide planes form a common structural element which is thought to dominate the superconducting properties. Depending on the choice of stoichiometry, the crystallographic unit cell contains varying number of CuO_2 planes. In addition, the $YBa_2Cu_3O_{7-\delta}$ the compound commonly renamed as 123, contain CuO chains. Even though there is no consensus on the mechanism causing the high-T_c and the electromagnetic properties which can be well described by the familiar BCS / GL criteria and concepts.

Structure and mechanism of superconductivity in YBCO:

$YBa_2Cu_3O_{7-\delta}$ (YBCO) is one of the most actively studied HTS materials and it is widely utilized in various fields of research. It is the only known stable four-element compound with a T_c above 77 K and it is relatively easy to make single-phase YBCO, in contrast to other HTS materials. Furthermore, this material includes no toxic elements (e.g., Hg) or volatile compounds.[1, 2] However, one clear disadvantage of the compound is that it degrades in humid environment, even in the ambient air. YBCO can be considered as a perovskite type structure. The name perovskite has no special scientific meaning: it is only a label for a family of structure whose generic class is represented by $SrTiO_3$ and a derived one by K_2NiF_4 (La_2CuO_4 structure). The actual name, perovskite, is a name of a small village in Russia where over the years the crystallographers have found many oxides with similar structures. A Single unit cell of YBCO is shown in Fig. 1.

The dimensions of the cell are a = 3.8227 $\overset{o}{A}$, b = 3.8872 $\overset{o}{A}$, and c = 11.6802 $\overset{o}{A}$ [3]. The lattice is composed of double perovskite layers, separated by CuO chains. The term 7-δ in the chemical formula appears because the CuO plane between the adjacent BaO layer is imperfect in the sense that there is a slight deficiency of oxygen[4]. One reason for that kind of behaviour is the mobility of the oxygen atoms. Mobility increase with increasing temperature, which means that, δ is also a function of temperature. When δ = 0, the Cuo-chains are perfectly ordered and the lattice is in the orthorhombic phase. When the temperature is higher, δ=1 and YBCO has a tetragonal structure.[1]

Only the orthorhombic structure is superconducting but, it is stable only at temperatures below 500^0C. This complicates the deposition of thin films. Since the deposition has to be performed at high temperatures, a post annealing is required so that the high-temperature tetragonal structure undergoes a phase transition to the orthorhombic structure.

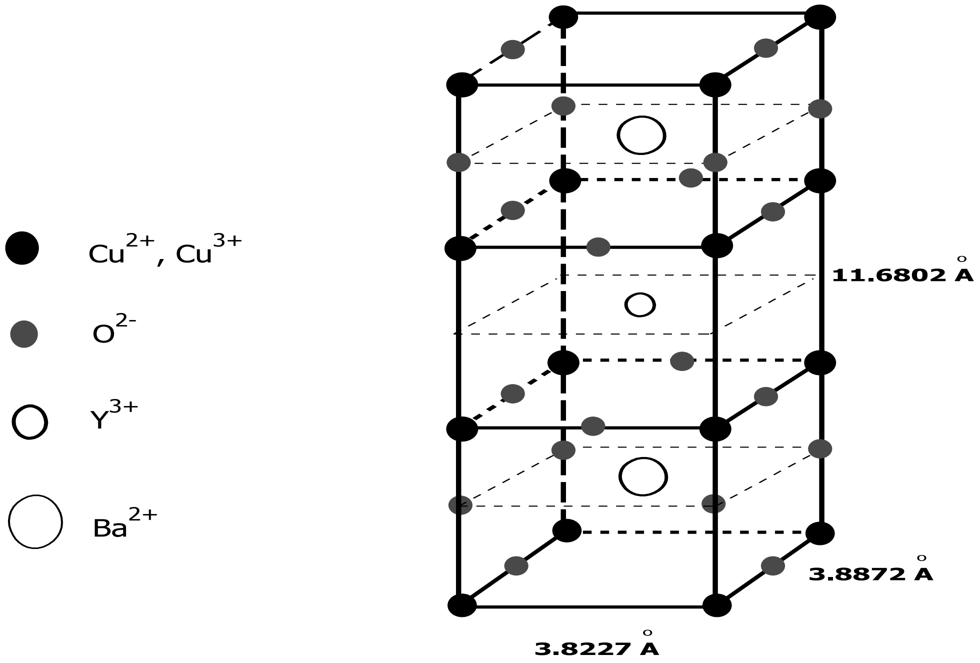

Fig. 1: Structure of the ideal $YBa_2Cu_3O_{7-\delta}$ lattice

The transition temperature slightly depends on how much oxygen is present during the post-annealing step: at 0.5 m bar, the temperature is 480^0C and at 500 m bar, it is approximately 570^0C[4]. In the Pr-doping of high-T_c superconductor YBCO, the Pr atoms occupy Y sites in the same proportion of doping. The structure remains orthorhombic, but the changes in lattice parameters a, b and c, are occurring accordingly with doping.

In the present investigation, we have studied the magneto-radio-frequency (MRF) stimulated conduction process in high-T_c superconductors $YBa_2Cu_3O_7$ observing the magneto potential (V_H) records with changing both the frequency and magnetic fields at room temperature without and with radioactivity (${}_{241}\mathrm{Am}^{95}$) exposure. This data had been used to compute the various physical parameters such as Hall coefficient, electrical carrier density, electron concentration and plasma frequency of interest.

EXPERIMENTAL DETAILS

Synthesis and preparation

The superconducting properties, e.g. T_c and J_c of high–T_c cuprates are crucially found to depend on the preparation techniques, viz. solid state reaction method[5], co-precipitation technique[6], sol-gel technique,[7] freeze drying technique[8] and melt texturing.[9-12] The samples of $YBa_2Cu_3O_7$ have been prepared by using the solid state reaction method. The preparation and characterization of $YBa_2Cu_3O_7$ samples were made at superconductivity and cryogenic division, National Physical

Laboratory (NPL), New Delhi. These HTS prepared for the present investigations were followed by the processes given below.

The ingredients used for making the samples of $YBa_2Cu_3O_7$ have been taken in following manner:

Table No. 1

Constituents	**Molecular weight**	**Stoichiometric Ratio**	**Formula weight**	**Fractional weight**
Y_2O_3	225.81	1	112.905	0.7565
$BaCO_3$	197.35	2	394.7	2.6446
CuO	79.54	3	238.62	1.5989
				5.000 gm

The samples of pure HTS YBCO were prepared by using conventional ceramic processing techniques with Y_2O_3, $BaCO_3$, and CuO as the starting materials. The stoichiometric powder mixture was thoroughly grounded for 1 hour and thus subjected it to calcinations in a programmable furnace (Naberthenin model C-19) for 12 hours in air at 850^oC. Further calcinations were carried out at 875^oC, 900^oC and 920^oC for 12 hours each with intermediate grindings. The calcined powder was made in pellets form (5K bar) sweltered at 930^oC in flowing oxygen with schedule $(930^oC/24h/O_2) \rightarrow (750^oC/24h/O_2) \rightarrow (600^oC/24h/O_2) \rightarrow (400^oC/24h/O_2)$.

The rock crystals in rectangular shape were constructed by cutting and grinding technique. The natural rock samples were belonging to various Geo-graphical hierarchy of Indian geo-origin. The experimental findings[13] of one such rock sample collected from Bamhori-Lalitpur (U.P.) namely, BPY-4 respectively had been quoted in this paper.

After preparing the bulk samples of HTS YBCO and geo-rock BPY-4, A six-probe Hall geometry was employed having two electrodes for current density J_x in x-direction, two for magneto-potential field E_y in y-direction and two for RF signaling making an angle ~ 45^o with x-y direction. The magnetic field H being in z-direction. Air drying silver paste (paste was formed by isoamil acetate, which is in liquid form) was used to make electrical contacts on the surface of the samples.

RESULT AND DISCUSSION

The Hall potential V_H may be written as $V_H = R_H \frac{i_x}{b} Hz$, where longitudinal current i_x is in x-direction, Hz is the magnetic field in transverse z-direction, b is the thickness of sample. The term R_H is called Hall coefficient which is closely associated with the concentration of different electrical carriers having different polarities and their mobilities participating in electrical conduction in the material of Hall probe and may be written as $R_H = \frac{Ey}{Jx\ Hz}$. For single dominant electrical carrier, the Hall coefficients may be written as $R_H = -\frac{1}{nec}$. The plasma frequency $\omega_p = (4\pi ne^2/m)^{1/2}$ may also be computed using the experimental magneto-potential records (the terms having their usual meanings) in order to describe their characteristic behaviour changes under MRF-excitations.

The frequency dependent Hall potentials (V_H) of high-T_c superconductor YBCO and Geo-rock sample (BPY-4) were recorded using magnetic fields H = 0 Gauss, 4000 Gauss and 6000 Gauss without and with radioactivity which are depicted in Fig.1, Fig.2, Fig.3, Fig.4, Fig.5 and Fig.6 respectively at room temperature. One may observe that the frequency dependent Hall potentials without and with α-radioactivity ($_{241}Am^{95}$) for HTS YBCO which reveals a remarkable variation in frequency range upto 7 MHz with magnetic field H=0 Gauss, 4000 Gauss and 6000 Gauss. The radioactivity increases the Hall potentials $\Delta V_H = 1.7$ (f = 2MHz) at H = 4000 Gauss and $\Delta V_H = 1.4$ (f = 2MHz) at H = 6000 Gauss which as depicted in Fig.1, Fig.2, and Fig.3 respectively.

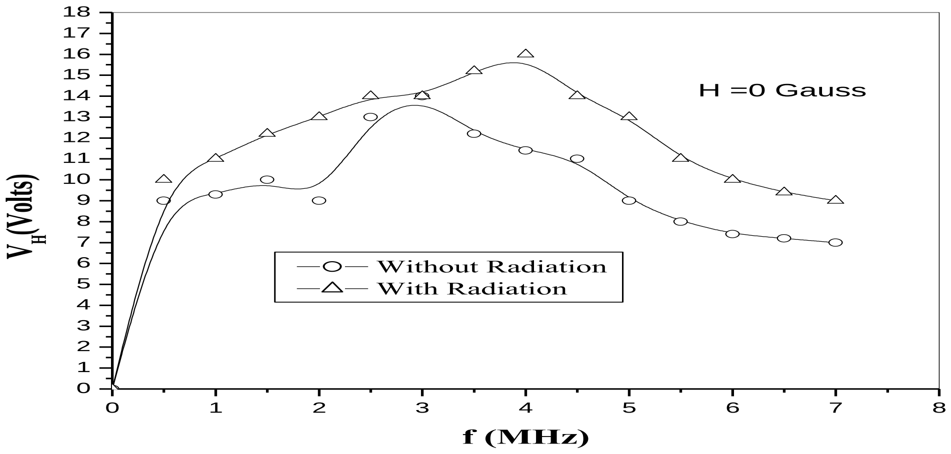

Fig. 1: The RF-Stimulated Hall Potential Records of Pure YBCO at T = 300K with and without radioactivity.

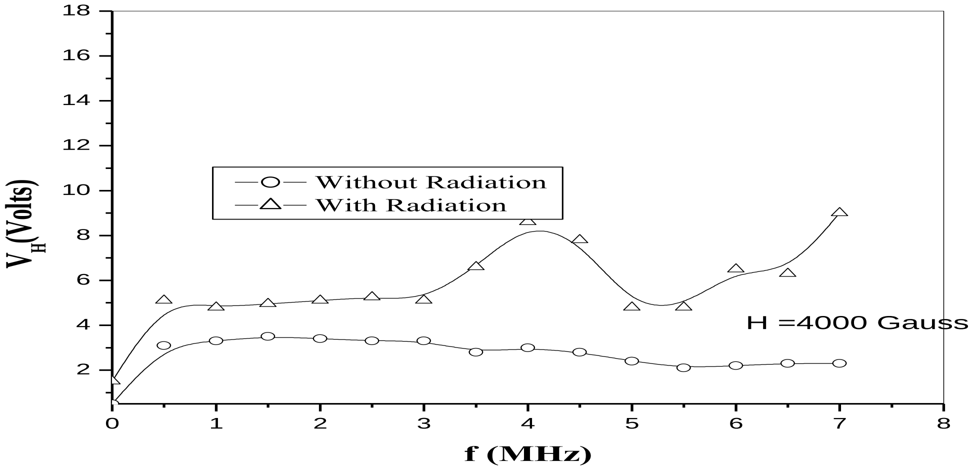

Fig. 2: The RF-Stimulated Hall Potential Records of Pure YBCO at T = 300K with and without radioactivity.

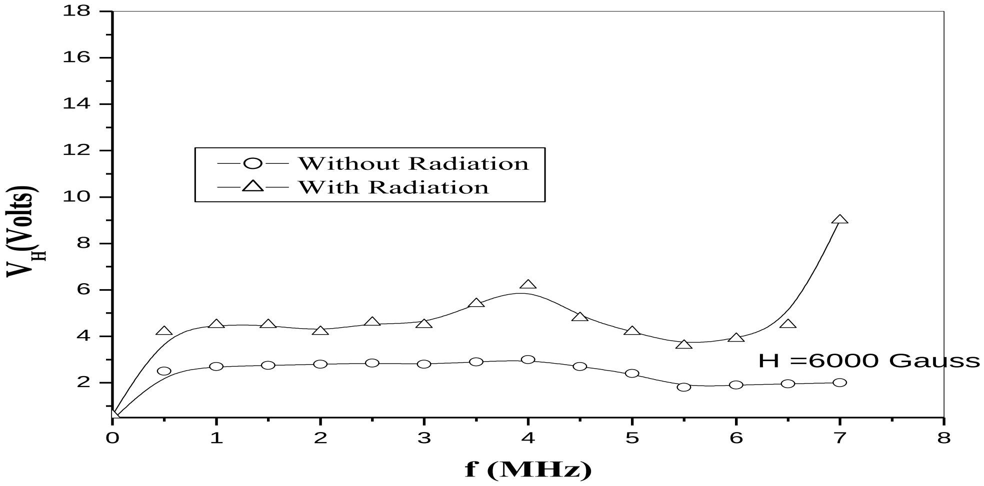

Fig. 3: The RF-Stimulated Hall Potential Records of Pure YBCO at T = 300K with and without radioactivity.

The frequency dependent Hall potentials without and with radioactivity for geo-rock sample BPY-4 had been shown in Fig.4, Fig.5 and Fig.6 respectively. This rock sample had been tried with magneto-radio-frequency (MRF) excitation without and with radioactivity which shows a striking variation upto 7 MHz frequency range with H = 0 Gauss, 4000 Gauss and 6000Gauss.

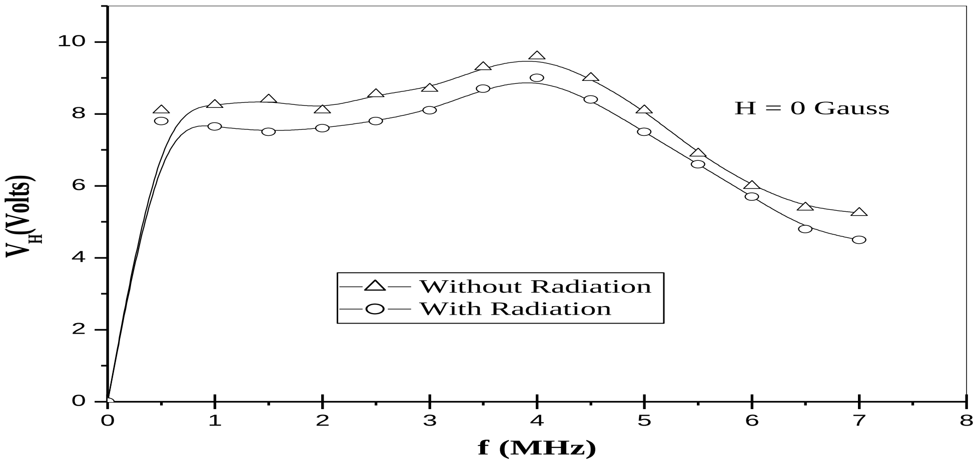

Fig.4: The RF-Stimulated Hall Potential Records of BPY-4 at T = 300K with and without radioactivity.

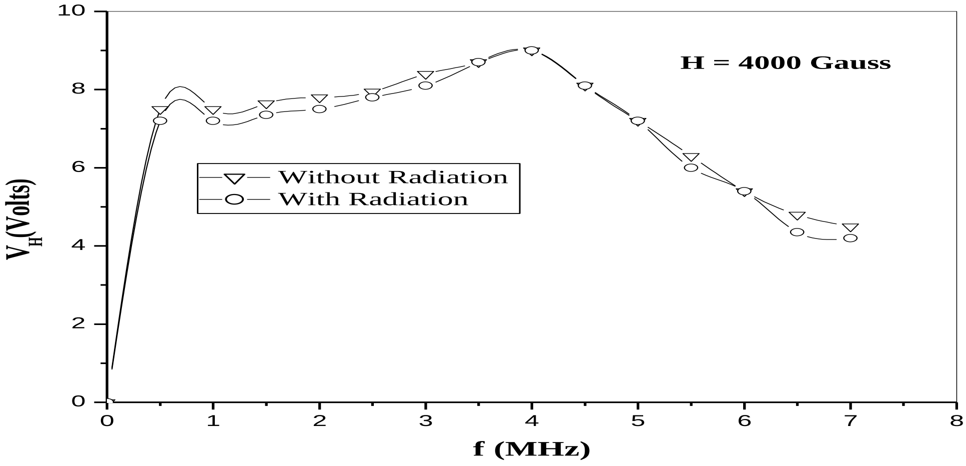

Fig. 5: The RF-Stimulated Hall Potential Records of BPY-4 at T = 300K with and without radioactivity.

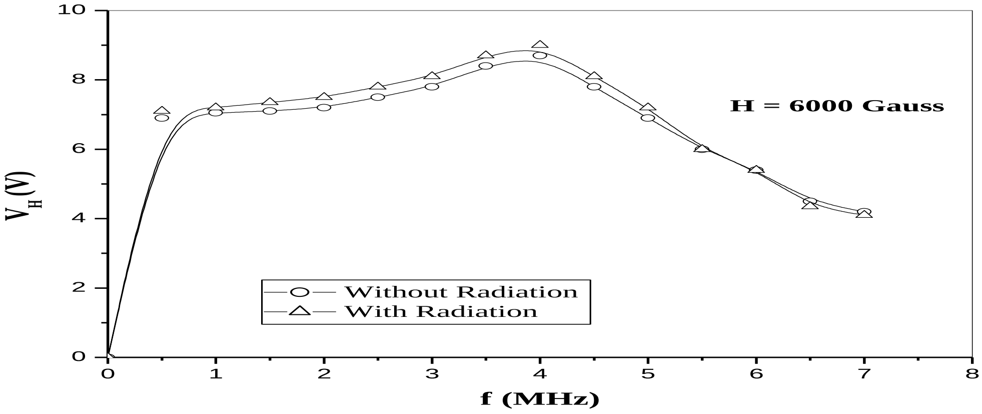

Fig. 6: The RF-Stimulated Hall Potential Records of BPY-4 at T = 300K with and without radioactivity.

By using the above mentioned relations, the magneto-potential records at H = 6000G have been employed to compute the various physical parameters such as Hall coefficient, electrical carrier density, electron concentration and plasma frequency. It is observed that the Hall coefficient vary with the rise (0-2.5) MHz and fall (3.5-6) MHz trends in frequency at H = 6000G and magnitude of R_H in the same order (10^{-15}) is increased with exposure of $_{241}Am^{95}$ radiation source in high-T_c superconductors YBCO, while in geo-rock sample (BPY-4) R_H vary with increase (0-4) MHz and fall (4.5 -7) MHz in frequency at H = 6000G and magnitude of R_H in the same order of 10^{-16} is varies in small amount with application of $_{241}Am^{95}$. The frequency dependent N_H~10^{13}, n ~10^{14} and ω_p~10^{10} varies in the same order with the rise of frequency of YBCO without and with radiation exposure while in Geo-rock crystal BPY-4 frequency dependent N_H~10^{14}, n ~10^{12} and ω_p~10^{10} varies in same order[14] for the rise of frequency without and with radiation exposure.

CONCLUSION

The Magneto-radio-frequency perturbation enforced upon high-T_c superconductors YBCO and Geo-rock crystal BPY-4 with the aim of having artificial hold over the physical character of these materials seem valid with the experimental observance and theoretical investigation as per ambition. The various physical parameters such as Hall coefficient, electrical carrier density, electron concentration, plasma frequency are deeply influenced by the exposure of $_{241}Am^{95}$ radiation source in high-T_c superconductors YBCO as well as geo-rock crystal BPY-4 which could be detected in terms of MRF-fluctuations in these matters.

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