

Superconductors and Quantum Gravity

Ülker Onbaşı¹ and Zeynep Güven Özdemir²

¹University of Marmara, Physics Department

²Yıldız Technical University, Physics Department

^{1,2}Turkey

1. Introduction

The high temperature oxide layered mercury cuprate superconductor is a reliable frame of reference to achieve a straightforward comprehension about the concept of quantum gravity. The superconducting order parameter, ψ , that totally describes the superconducting system with the only variable of the phase difference, φ of the wave function, will be the starting point to derive the net effective mass of the quasi-particles of the superconducting system. The calculation procedure of the net effective mass, m^* , of the mercury cuprate superconductors has been established by invoking an advanced analogy between the supercurrent density J_s , which depends on the Josephson penetration depth, and the third derivative of the phase of the quantum wave function of the superconducting relativistic system (Aslan et al., 2007; Aslan Çataltepe et al., 2010). Moreover, a quantum gravity peak has been achieved at the super critical temperature, T_{sc} for the optimally oxygen doped samples via the first derivative of the effective mass of the quasi-particles versus temperature data. Furthermore, it had been determined that the plasma frequency shifts from microwave to infrared at the super critical temperature, T_{sc} (Özdemir et al., 2006; Güven Özdemir et al., 2007). In this context, we stated that the temperature T_{sc} for the optimally oxygen doped mercury cuprates corresponds to the third symmetry breaking point so called as T_{QG} of the superconducting quantum system. As is known that the first and second symmetry breaking points in the high temperature superconductors are the Meissner transition temperature, T_c , at which the one dimensional global gauge symmetry $U(1)$ is broken, and the Paramagnetic Meissner temperature, T_{PME} , at which the time reversal symmetry (TRS) is broken, respectively (Onbaşı et al., 2009).

2. $\text{HgBa}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+x}$ mercury cuprate superconductors

Hg-based cuprate superconductors exhibit the highest superconducting Meissner transition temperature among the other high temperature superconducting materials (Fig. 1).

The first mercury based high temperature superconductor was the $\text{HgBa}_2\text{CuO}_{4+x}$ (Hg-1201) material with the $T_c=98\text{K}$, which was synthesized by Putilin et al. in 1993 (Putilin et al, 1993). In the same year, Schilling et al. reached the critical transition temperature to 134K for the $\text{HgBa}_2\text{CaCu}_2\text{O}_{7+x}$ (Hg-1212) and $\text{HgBa}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+x}$ (Hg-1223) materials at the normal atmospheric pressure (Schilling et al., 1993). Subsequent to this works, Gao et al., achieved to increase the critical transition temperature to 153K by applying 150.10^8Pa pressure to the

HgBa₂Ca₂Cu₃O_{8+x} superconductor (Gao et al., 1993). Ihara et al. also attained the $T_c=156\text{K}$ by the application of 250.10^8Pa pressure to the superconducting material contains both Hg-1223 and Hg-1234 phases (Ihara et al., 1993). Afterwards, in 1996, Onbaşı et al. achieved the highest critical transition temperature of 138K at normal atmospheric pressure in the optimally oxygen doped mercury cuprates which contain Hg-1212 /Hg-1223 mixed phases (Onbaşı et al., 1996). Recently, the new world record of T_c at the normal atmospheric pressure has been extended to 140K for the optimally oxygen doped mercury cuprate superconductor by Onbaşı et al. (Onbaşı et al., 2009).

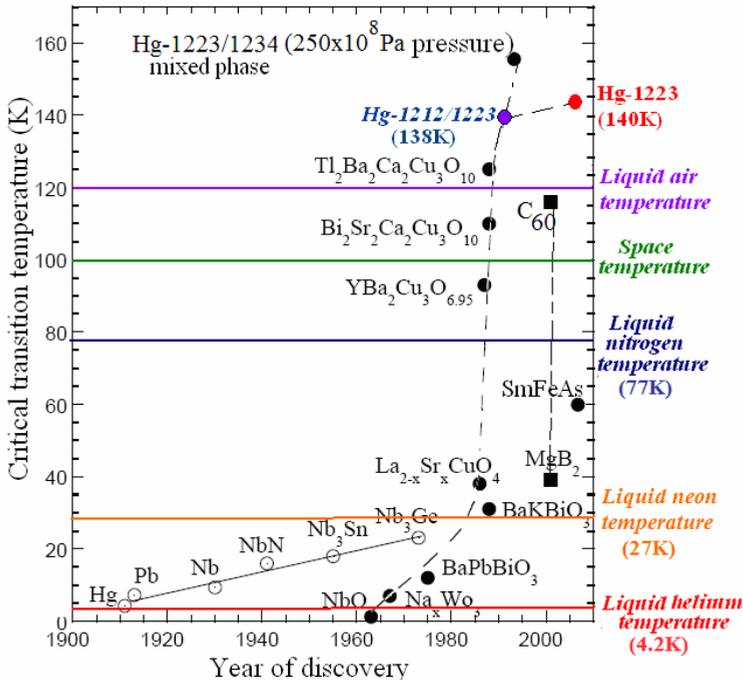


Fig. 1. Illustration of the years of discovery of some superconducting materials and their critical transition temperatures.

In general, layered superconductors such as Bi-Sr-Ca-Cu-O, are considered as an alternating layers of a superconducting and an insulating materials namely intrinsic Josephson junction arrays (Helm et al., 1997; Ketterson & Song, 1999). As is known that Josephson junction comprises two superconductors separated by a thin insulating layer and the Josephson current crosses the insulating barrier by the quantum mechanical tunnelling process (Josephson, 1962). The schematic representation of the superconducting-insulating-superconducting layered structure is illustrated in Fig. 2.

In the Lawrence-Doniach model, it is assumed that infinitesimally thin superconducting layers are coupled via superconducting order parameter tunnelling through the insulating layers in layered superconductors (Lawrence & Doniach, 1971). Recent work on the optimally oxygen doped mercury cuprate superconductors has shown that the Hg-1223 superconducting system is also considered as an array of nearly ideal, intrinsic Josephson junctions which is placed in a weak external field along the c -axis (Özdemir et al., 2006).

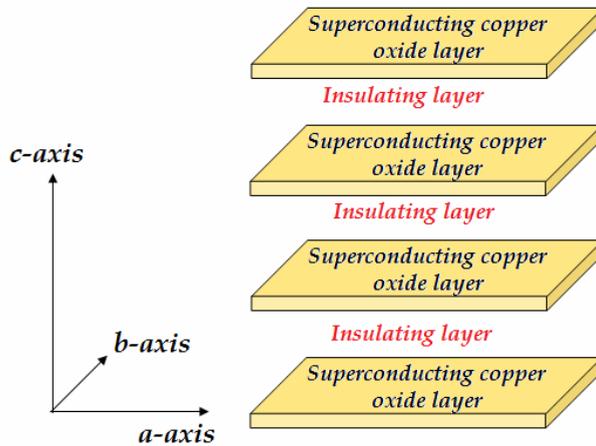


Fig. 2. The schematic representation of the intrinsic Josephson structure in the layered high temperature superconductors.

Moreover, the Hg-1223 superconducting system verifies the Interlayer theory, which expresses the superconductivity in the copper oxide layered superconductors in terms of the occurrence of the crossover from two-dimensional to three-dimensional coherent electron pair transport. The realization of the three dimensional coherent electron pair transport can be achieved by the Josephson-like or Lawrence-Doniach-like superconducting coupling between the superconducting copper oxide layers (Anderson, 1997; Anderson, 1998). In other words, if the Josephson coupling energy equals to superconducting condensation energy, the superconducting system exhibits the perfect coupling along the c -axis (Anderson, 1998). With respect to this point of view, we have analyzed the mercury cuprate system by comparing the formation energy of superconductivity with the Josephson coupling energy and the equality of these energies has been achieved at around the liquid helium temperature for the system (Özdemir et al., 2006; Güven Özdemir et al., 2009).

Since the mercury cuprates justify the Interlayer theory at the vicinity of the liquid helium temperature, the mercury cuprate Hg-1223 superconducting system acts as an electromagnetic wave cavity (microwave and infrared) with the frequency range between 10^{12} and 10^{13} Hz depending on the temperature (Özdemir et al., 2006; Güven Özdemir et al., 2007). Moreover, the optimally oxygen doped $\text{HgBa}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+x}$ (Hg-1223) superconductor exhibits three-dimensional Bose-Einstein Condensation (BEC) via Josephson coupling at the Josephson plasma resonance frequency at the vicinity of the liquid helium temperature (4.2K-7K) (Güven Özdemir et al., 2007; Güven Özdemir et al., 2009). In this context, mercury based superconductors have a great interest for both technological and theoretical investigations due to the occurrence of intrinsic Josephson junction effects and the three dimensional BEC. In this context, the mercury cuprate superconductors have a great potential for the advanced and high sensitive technological applications due to their high superconducting critical parameters, the occurrence of the intrinsic Josephson junction effects and, the three dimensional BEC. Due to that reasons, the importance of the determination of the concealed physical properties of the mercury cuprates becomes crucial. To avow the fact, the effective mass of the quasi-particles, which describes the dynamics of the condensed system, has been investigated in details in the following sections.

3. Derivation of the effective mass equation of quasi particles via order parameter in the $\text{HgBa}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+x}$ mercury cuprate superconductors

In our previous works, the effective mass equation of quasi-particles in the mercury cuprate superconductors has already been established by invoking an advanced analogy between the supercurrent density J_s , which depends on the Josephson penetration depth, λ_j , and the third derivative of the phase of the quantum wave function of the superconducting relativistic system (Aslan et al., 2007; Aslan Çataltepe et al., 2010). In this section, the logic of the derivation process of the effective mass equation has been expressed in details.

Since the mercury cuprate system exhibits three dimensional BEC, the system is represented by the unique symmetric wave function, ψ , and all quasi-particles occupy the same quantum state. In this context, the superconducting state is represented by the superconducting order parameter¹, ψ , which is defined by the phase differences, φ between the superconducting copper oxide layers of the system.

$$\psi = |\psi| \exp(i\varphi) \quad (1)$$

In this context, in order to derive the effective mass equation, our starting point is the universally invariant parameter of φ by means of Ferrel & Prange equation (Ferrell & Prange, 1963). As is known, the Ferrel & Prange equation (Eq. 2) predicts how the screening magnetic field penetrates into parallel to the Josephson junction

$$\frac{d^2\varphi}{dx^2} = \frac{1}{\lambda_j^2} \sin\varphi \quad (2)$$

where λ_j is the Josephson penetration depth (Ferrell & Prange, 1963, Schmidt, 1997). *The Josephson penetration depth represents the penetration of the magnetic field induced by the supercurrent flowing in the superconductor*². The Josephson penetration depth is defined as

$$\lambda_j = \sqrt{\frac{c\phi_0}{8\pi^2 J_c d}} \quad (3)$$

where, c is the speed of light, J_c is the magnetic critical current density, ϕ_0 is the magnetic flux quantum, and d is the average distance between the copper oxide layers. The solution of the Ferrel & Prange equation gives the phase difference distribution over the junction. If the external magnetic field is very weak, both the current through the Josephson junction and the phase difference become small. In these conditions, the Ferrel & Prange equation has an exponential solution as given in Eq. (4) (Schmidt, 1997; Fossheim & Sudbo, 2004)

$$\varphi(x) = \varphi_0 \exp\left(-\frac{x}{\lambda_j}\right) \quad (4)$$

¹The superconducting order parameter, ψ is the hallmark of the phenomenological Ginzburg & Landau theory that describes the superconductivity by means of free energy function.

²The italic and bold representation intends to prevent the confusion from the concept of London penetration depth.

where φ_0 is phase value at $x=0$. Eq. (4) represents the invariant quantity of the phase of the quantum system, φ , as a function of distance, x for low magnetic fields (lower than H_{c1}) (Fig. 3(b)-1).

According to Schmidt, the first and second derivatives with respect to distance correspond to the magnetic field, $H(x)$ at any point of the Josephson junction and the supercurrent density, J_s , respectively (Schmidt, 1997). The related $H(x)=f(x)$ and $J_s=f(x)$ graphics for low magnetic fields are illustrated in Fig. 3(b)-2 and 3, respectively. Since the supercurrent density, J_s , is related to the velocity of the quasi-particles, we have made an analogy between the velocity versus wave vector schema and the super current density versus distance schema in Fig. 3. As is known in condensed matter physics, the effective mass of the quasi-particles is derived from the first derivative of the velocity with respect to wave vector. Like this process, the effective mass of the quasi-particles in the mercury cuprate superconductors can be determined by the first derivative of the J_s with respect to distance x . From this point of view, in order to achieve the effective mass of the quasi-particles, the first derivative of the supercurrent with respect to distance has been taken. The first

derivative of the supercurrent density, $\frac{dJ_s}{dx}$, is proportional to third derivative of the phase, $\frac{d^3\varphi(x)}{dx^3}$.

$$\frac{dJ_s}{dx} = \frac{c\phi_0}{8\pi^2 d} \frac{d^3\varphi(x)}{dx^3} = \frac{c\phi_0}{8\pi^2 d} \left(-\frac{1}{\lambda_j}\right)^3 \varphi_0 \exp\left(-\frac{x}{\lambda_j}\right) \tag{5}$$

Consequently, we have calculated the inverse values of m^* via the first derivative of the supercurrent density of the system.

$$\frac{1}{\varphi_0 m^*} = \frac{c\phi_0}{8\pi^2 d} \left(-\frac{1}{\lambda_j}\right)^3 \exp\left(-\frac{x}{\lambda_j}\right) \tag{6}$$

We have called Eq. (6) as “Ongüas Equation” that gives the relationship between the m^* and the phase of the superconducting state (Aslan et al., 2007; Aslan Çataltepe et al., 2010). This effective mass equation also confirms the suggestion, proposed by P.W. Anderson, that the effective mass is expected to scale like the reverse of the supercurrent density (Anderson, 1997). The derivation of the effective mass equation are summarized in Fig. 3.

Let us examine the signification of the effective mass determined by the Ongüas Equation. As is known, the effective mass of the quasi-particles is classified as the in-plane (m_{ab}^*) and out off-plane (m_c^*) effective masses in the anisotropic layered superconductors, like mercury cuprates (Tinkham, 1996). On the other hand, as the mercury cuprate superconducting system is represented by a single bosonic quantum state due to the occurrence of the spatial i.e. three dimensional Bose-Einstein condensation, there is no need to consider the in-plane (m_{ab}^*) and out off-plane (m_c^*) effective masses, one by one. In this context, the effective mass of the quasi-particles, m^* , calculated by the Eq. (6), is interpreted as the “*net effective mass of the quasi-particles*” for the superconductor which exhibits the spatial resonance. Hence, the quasi-particles, described by the net effective mass, cannot be attributed to the Bogoliubov quasi-particles in the Bardeen-Cooper-Schrieffer (BCS) state. We have proposed that the generation of the mentioned net effective mass of the quasi-particles is directly

related to the Higgs mechanism in the superconductors, which will be discussed in Section 5. (Higgs, 1964 (a), (b)).

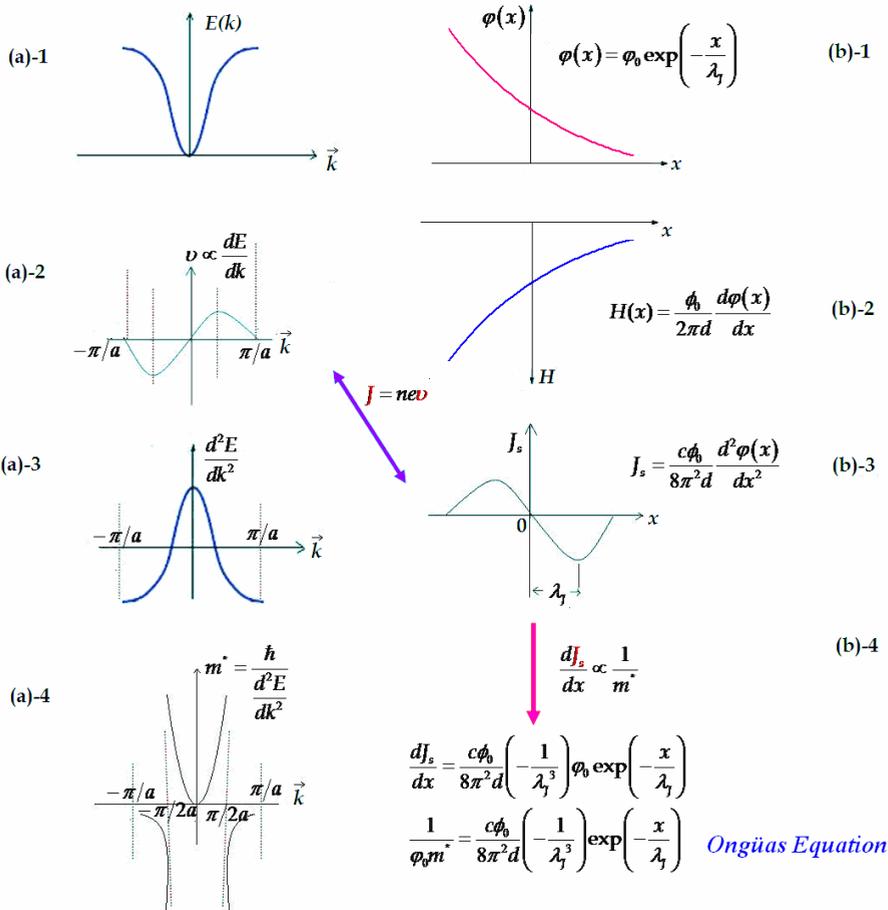


Fig. 3. The derivation procedure of the effective mass equation of the quasi-particles in the condensed matter physics and the mercury cuprates are given in (a)-1,2,3,4 and (b)-1,2,3,4, respectively. (b)-1 The phase versus length graphic for the low magnetic fields in the Josephson junction. (b)-2 The distance dependence of the magnetic field in the Josephson junction. (b)-3 The super current in the Josephson junction versus distance graph. (b)-4 The effective mass equation of the quasi-particles has been derived from the relation of the supercurrent density versus distance.

4. The net effective mass of the quasi particles in the optimally and over oxygen doped mercury cuprate superconductors

In our previous works, the effect of the rate of the oxygen doping on the mercury cuprates has been investigated in the context of both the superconducting critical parameters, such as

the Meissner critical transition temperature, lower and upper critical magnetic fields, critical current density and the electrodynamic parameters by means of Josephson coupling energy, Josephson penetration depth, anisotropy factor etc. In this section, the effect of the oxygen doping on the effective mass of the quasi-particles has been examined on both the optimally and over oxygen doped mercury cuprates from the same batch. The net effective mass values have been calculated via the magnetization versus magnetic field experimental data obtained by the SQUID magnetometer, Model MPMS-5S. During the SQUID measurements, the magnetic field of 1 Gauss was applied parallel to the *c*-axis of the superconductors and the critical currents flowed in the *ab*-plane of the sample. The magnetic hysteresis curves for the optimally and over oxygen doped Hg-1223 superconductors at various temperatures are given in Fig. 4 and Fig. 5, respectively.

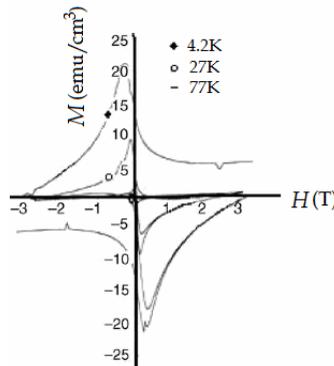


Fig. 4. The magnetization versus applied magnetic field curves of the optimally oxygen doped mercury cuprates at 4.2, 27 and 77K (Özdemir et al., 2006).

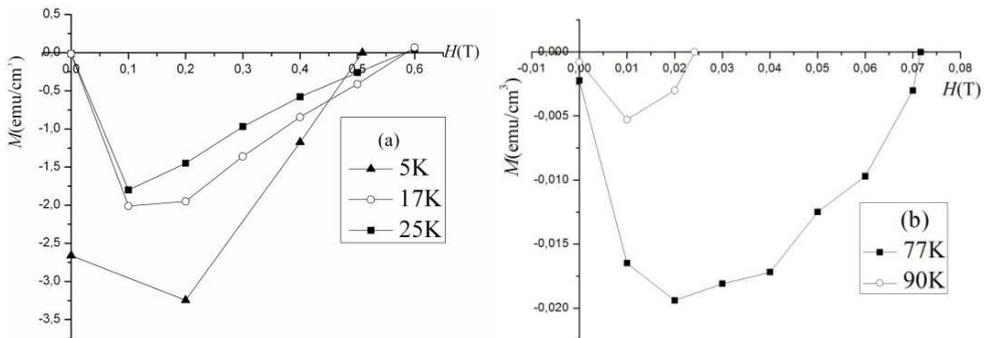


Fig. 5. The magnetization versus applied magnetic field of the over oxygen doped mercury cuprates at 5, 17, 25, 77 and, 90K are seen in Figure 5(a) and (b), respectively. (Aslan Çataltepe, 2010).

According to the Bean critical state model, the critical current densities of the Hg-1223 superconductors have been calculated at the lower critical magnetic field of, H_{c1} (Bean, 1962; Bean, 1964). In this context, the system does not have any vortex. The magnetization difference between the increasing and decreasing field branches, ΔM , has been extracted

from magnetization versus magnetic field curves and the average grain size of the sample has been taken as $1.5\mu\text{m}$ (Onbaşlı, 1998). The Josephson penetration depth values, which have a crucial role in determining the net effective mass, have been calculated by Eq. (3). In Eq. (3), the average distance between the superconducting layers, d , has been obtained by XRD data that reveals to $7.887 \times 10^{-10} \text{ m}$ (Özdemir et al., 2006).

The critical current densities (J_c) have been calculated at the lower critical magnetic field and the corresponding Josephson penetration depths are given in Table 1 for the optimally and over oxygen doped Hg-1223 superconductors (Özdemir et al., 2006; Güven Özdemir, 2007).

Material	Temperature (K)	J_c (A/m ²) at H_{c1}	λ_J (μm)
Optimally oxygen doped Hg-1223 superconductor	4.2	1.00×10^{12}	0.575
	27	1.62×10^{11}	1.430
	77	1.00×10^{10}	5.75
Over oxygen doped Hg-1223 superconductor	5	1.58×10^{11}	1.449
	17	6.88×10^{10}	2.195
	25	5.71×10^{10}	2.410
	77	5.07×10^8	25.581
	90	3.44×10^8	31.055

Table 1. The critical current density and Josephson penetration depth values for the optimally and over oxygen doped mercury cuprates.

Variations of the Josephson penetration depth with temperature for the optimally and over oxygen doped Hg-1223 superconductors have been obtained by the Origin Lab 8.0® program (Fig. 6-(a) and (b)).

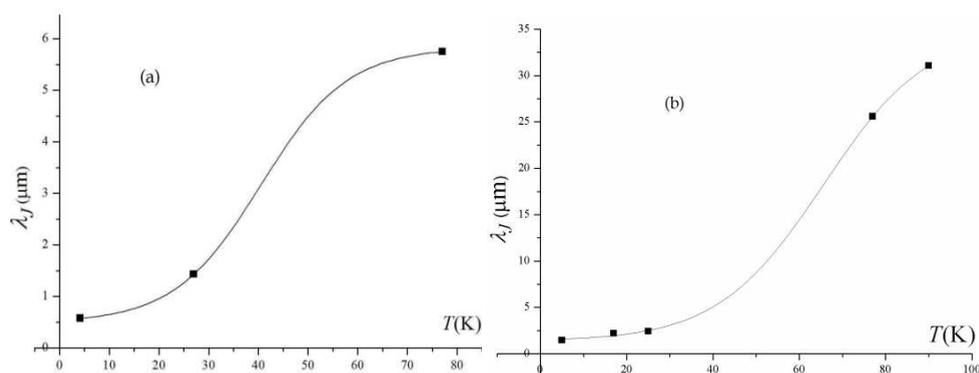


Fig. 6. The temperature dependence of the Josephson penetration for (a) the optimally (b) the over oxygen doped Hg-1223 superconductors.

The temperature dependences of the Josephson penetration depth for the optimally and over doped samples both satisfy the Boltzmann equations which are given in Eqs. (7-a) and (7-b), respectively.

$$\lambda_j(\mu m) = 5.82915 + \frac{(0.49346 - 5.82915)}{1 + \exp\left(\frac{T - 40.46878}{8.70652}\right)} \text{ for the optimally doped Hg-1223} \quad (7a)$$

$$\lambda_j(\mu m) = 35.08815 + \frac{(1.33383 - 35.08815)}{1 + \exp\left(\frac{T - 65.54345}{12.24175}\right)} \text{ for the over doped Hg-1223} \quad (7b)$$

In addition to experimental data, some λ_j values for various temperatures have been calculated by using Eqs. (7-a) and (7-b).

The net effective mass values for the optimally and over oxygen doped superconductors have been calculated by Eq. (6). The phase value at $x=0$ has been taken as a constant parameter in all calculations. In order to investigate the temperature dependence of the net effective mass, the distance parameter, x in Eq. (6) has been chosen as $0.3 \mu m$ which is smaller than the lowest λ_j values for both the optimally and over oxygen doped samples.

The net effective mass values for the optimally and over oxygen doped Hg-1223 superconductors are given in Table 2.

The optimally oxygen doped Hg-1223		The over oxygen doped Hg-1223	
T(K)	m^* (kg)	T(K)	m^* (kg)
4.2	-3.20×10^{-20}	5	-3.76×10^{-19}
10	-4.35×10^{-20}	10	-5.79×10^{-19}
17	-8.24×10^{-20}	17	-1.21×10^{-18}
20	-1.20×10^{-19}	20	-1.20×10^{-18}
25	-2.57×10^{-19}	25	-1.59×10^{-18}
27	-3.76×10^{-19}	27	-2.26×10^{-18}
30	-6.14×10^{-19}	30	-3.26×10^{-18}
40	-3.26×10^{-18}	40	-1.38×10^{-17}
50	-9.72×10^{-18}	50	-6.92×10^{-17}
60	-1.596×10^{-17}	60	-3.09×10^{-16}
70	-1.91×10^{-17}	70	-9.76×10^{-16}
77	-2.00×10^{-17}	77	-1.70×10^{-15}
90	-2.07×10^{-17}	90	-3.03×10^{-15}
100	-2.08×10^{-17}	100	-3.70×10^{-15}

Table 2. The net effective mass values for the optimally and over oxygen doped mercury cuprates.

According to the data in Table 2, the temperature dependences of the net effective mass of the quasi-particles for the optimally and over oxygen doped mercury cuprates from the same batch both satisfy Boltzmann fitting (Fig. 7 and Fig. 8).

5. The relativistic interpretation of the net effective mass

In this section, we have developed a relativistic interpretation of the net effective mass of the quasi-particles in the mercury cuprate superconductors. Let us review the origin of mass in the context of Higgs mechanism to construct a relativistic bridge between condensed matter and high energy physics.

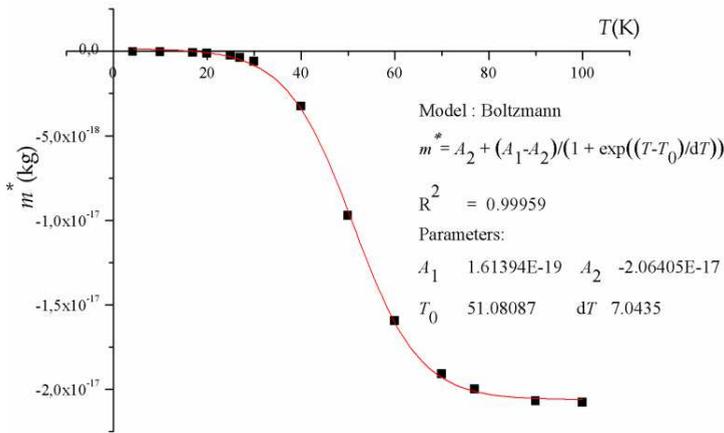


Fig. 7. The m^* versus temperature for the optimally O₂ doped Hg-1223 superconductor.

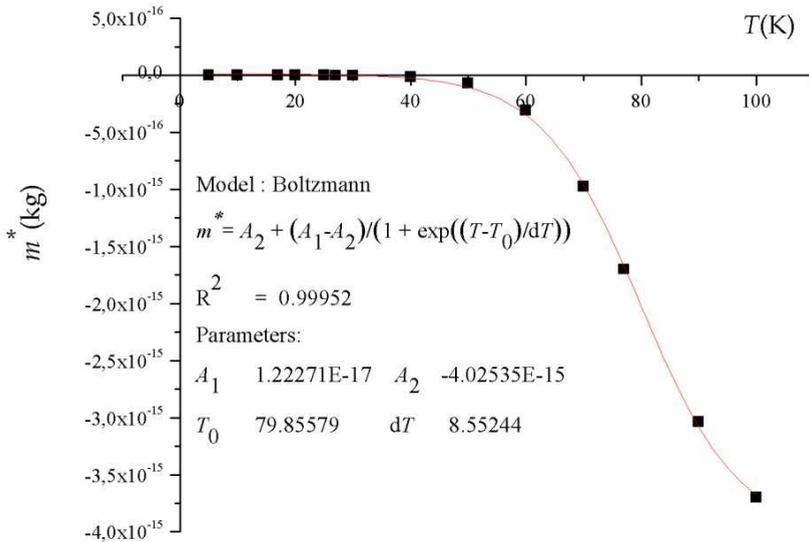


Fig. 8. The m^* versus temperature for the over O₂ doped Hg-1223 superconductor.

As is known, the superconducting phase transition generally offers an instructive model for the electroweak symmetry breaking. The weak force bosons of W^\pm and Z^0 become massive when the electroweak symmetry is broken. This phenomenon is known as the Higgs mechanism which can be considered as the relativistic generalization of the Ginzburg-Landau theory of superconductivity (Ginzburg & Landau, 1950; Higgs (a),(b), 1964; Englert & Brout, 1964; Guralnik et al., 1964; Higgs, 1966; Kibble, 1967; Quigg, 2007). **Y. Nambu, who was awarded a Nobel Prize in physics in 2008** for his valuable works on spontaneous symmetry breakings in the particle physics, had also **stated that "the plasma and Meissner effect" had already established the general mechanism of the mass generation for the**

gauge field. So that he suggested a superconductor model for the elementary particle physics on the concept of mass generation in 1960's (Nambu, Y. & Jona-Lasinio, 1961 (a); Nambu, Y. & Jona-Lasinio, 1961 (b); G.; Nambu, 2008). In this context, superconductors can be accepted as the most convenient and reliable candidate frame of reference to extend the comprehension to understand the emerging procedure of mass.

The suggestion already made by Quigg that the superconductors can be utilized as the perfect prototype for the electroweak symmetry breaking (Quigg, 2008) has been realized by the mercury cuprate superconductor via Paramagnetic Meissner effect (PME) (Onbaşlı et al., 2009). As is known, contrast to the Meissner effect, superconductors acquire a net paramagnetic moment when cooled in a small magnetic field in the PME (Braunisch et al., 1992; Braunisch et al., 1993; Schliepe et al., 1993; Khomskii et al., 1994; Riedling et al., 1994; Thompson et al., 1995; Onbaşlı et al., 1996; Magnusson et al., 1998; Patanjali et al., 1998; Nielsen et al., 2000). The PME leads to develop spontaneous currents in the opposite direction with the diamagnetic Meissner current in superconductors that results in the breaking of time reversal symmetry. In other words, at the T_{PME} temperature the orbital current changes its direction. In this context, the T_{PME} point is considered as the second quantum chaotic point of the system. (Onbaşlı et al., 2009). The first chaotic point of the system is the critical transition temperature, T_c , at which the one dimensional global gauge symmetry is broken. Furthermore, it has been determined that the process of inverting the direction of the time flow in the PME also affects the z component of angular momentum, magnetic quantum number, and magnetic moment as has been pointed out in the previous chapter. Moreover, the fact that the spin-orbit coupling process occurs at the T_{PME} temperature reveals to the relativistic effects in the mercury cuprate superconducting system, as well. According to our quantum mechanical investigations on PME, it has been determined that T_{PME} temperature, at which the angular momentum is zero, can be considered as the emerging of Higgs bosons in the superconducting state (Onbaşlı et al., 2009).

In addition to electroweak symmetry breaking phenomenon, there is another remarkable relativistic effect in the mercury cuprate system. It had been already determined that the plasma frequency of the mercury cuprate system shifts from microwave to infrared region at the vicinity of 55.5 K (Özdemir et al., 2006; Güven Özdemir et al., 2007).

Both the occurrence of the electroweak symmetry breaking and the frequency shifting phenomenon in the mercury cuprate system lead us to discuss the net effective mass in terms of relativistic manner. The momentum of the quasi-particles in the superconducting system is to be neglected, since the $p = m * \frac{d\theta}{dt}$ momentum term of the general relativity vanishes due to the fact that there is practically no acceleration term in the sense of temperature rate of change of velocity of the system (Feynmann, 1963). In this context, the corresponding relativistic energies for the net effective mass of the quasi-particles have been calculated by the relativistic energy-mass equation $E = m^*c^2$ where c is the velocity of the light. The related relativistic energy values vary from 10^7 GeV/ c^2 to 10^{13} GeV/ c^2 which coincide with the unexplored energy gap of the particle physics' hierarchic GeV/ c^2 energy scale (Fig. 9) (Aslan Çataltepe et al., 2010).

6. The negative effective mass in the mercury cuprates

In this section, the concept of negative effective mass will be discussed in the context of both condensed matter physics and the concept of anti-gravity.

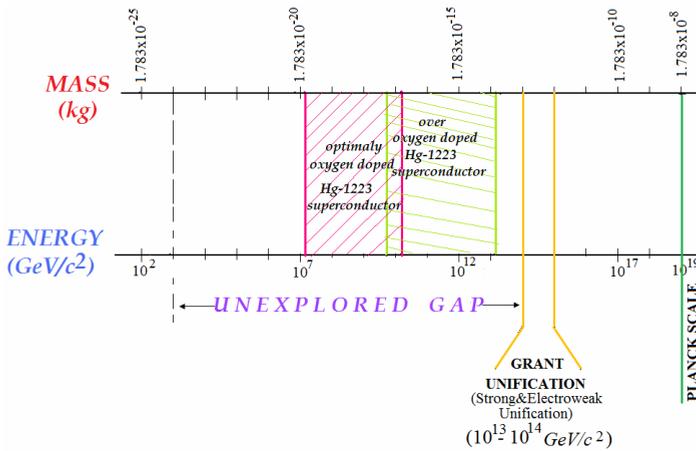


Fig. 9. The representative illustration of the net effective mass values for the optimally and over oxygen doped mercury cuprates in the hierarchic GeV/c^2 energy scale of high energy physics.

- In condensed matter physics, the negative sign of the effective mass indicates that the charge carriers are holes. As is known, the Hall measurements show that the Hg-based high temperature superconductors are hole-type i.e. the charge carries are holes (Adachi et al., 1997; Smart & Moore, 2005). Moreover, it has been already observed that the Hg-1223 mercury cuprate superconductor displays hole-type of conductivity (Onbaşlı et al., 1996). In this context, the negative sign of the net effective mass verify the hole-type of conductivity in the mercury cuprates.
- The Meissner effect, which is the occurrence of the flux expulsion below T_c and the resulting diamagnetic response to the applied magnetic field, causes a magnetic levitation. In addition to magnetic levitation process, superconductors display the magnetic suspension effect as shown in Fig. 10.

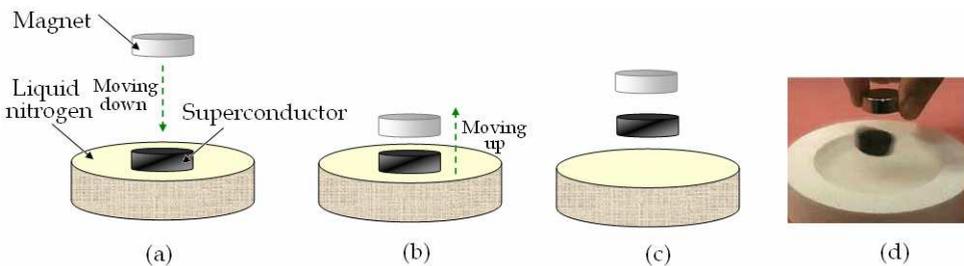


Fig. 10. The schematic representation and the photography of the magnetic suspension effect of the superconductors. (a)- The magnet moves down to the superconductor which is cooled in the liquid nitrogen (b),(c)- When the magnet is lifted up, the superconductor holds its magnetic lines and follows the magnet (www.images.com/articles/superconductors/superconduction-suspension-effect.html) (d)- The photography of the magnetic suspension effect of the superconductor. (Web site of the Superconductivity Laboratory of the University of Oslo, <http://www.fys.uio.no/super/levitation/>)

In the magnetic suspension effect, the superconductor is suspended by magnetic fields. Magnetic pressure is used to counteract the effects of the gravitational and any other accelerations. From this point of view, it is possible to deduce that the negative net effective mass values can be interpreted as the formation of an anti-gravitational force which has the reverse sign to the gravitational field of the Earth.

7. Quantum gravity in the mercury cuprate superconductors

This section is devoted to investigate the quantum gravitational effects in the mercury cuprate superconductors. In order to get knowledge about the quantum gravitational effect in the system, the net force acting on the system has to be determined. The net force is calculated by

$$F = m^* \frac{d\mathcal{G}}{dt} + \frac{dm^*}{dt} \mathcal{G} \quad (8)$$

for the relativistic systems. In Eq. (8), \mathcal{G} represents the velocity of the quasi-particles. Since there is no entropy propagation in the superconducting system, the only variable is the temperature. In this context, the derivatives with respect to time can be considered as the derivatives with respect to temperature in Eq. (8). According to the relativity, "there is practically no acceleration term in the sense of a change velocity under application of a constant force" (Feynmann, 1963). From this point of view, if the acceleration term ($\frac{d\mathcal{G}}{dt}$) goes to zero, the second term in Eq. (8) will describe the net force of the system. Hence, the net force of the system is proportional to the term of $\frac{dm^*}{dT}$.

Consequently, the temperature rate of change of the net effective mass of the quasi-particles for the optimally and over oxygen doped Hg-1223 superconductors are given in Figure 11-(a) and Figure 12-(a), respectively.

According to Figure 11-(a) and Figure 12-(a), the temperatures of 55.5K and 82K, which correspond to the maximum value of the $\frac{dm^*}{dT}$, have been considered as the super critical temperature, T_{SC} for the optimally and over doped samples, respectively.

Moreover, since the plasma frequency shifts from microwave to infrared region at the T_{SC} for the optimally oxygen doped mercury cuprate superconductors (Fig. 11-(b)), the net effective mass of the quasi-particles at T_{SC} corresponds to the quantum gravity peak. However, it is a remarkable point that the plasma frequency shifting phenomenon hasn't been detected for the over doped Hg-1223 superconductor (Fig. 12-(b)).

As is known that the electromagnetic wave shifts to infrared region under gravitational field in a relativistic system (Pound & Rebka, 1959; Pound & Rebka, 1960). Moreover, since the temperature variable can be considered as the time variable of the system in the derivation process as mentioned above, the quantum gravitational effect manifests itself by the variation of temperature in this frame of reference. This phenomenon is consistent with the El Naschie's quantum gravity (Cantorian gravity). According to El Naschie's quantum gravity, the speed at which time flows could be slowed down by a gravitational field. In the other words, by changing the speed of the passing time (temperature), one can create a gravitational effect. Hence, the fluctuation in time creates a fluctuation in gravity and vice versa (El Naschie et al., 1995; El Naschie, 2005 (a); El Naschie, 2005 (b); Agop & Cracuin, 2006).

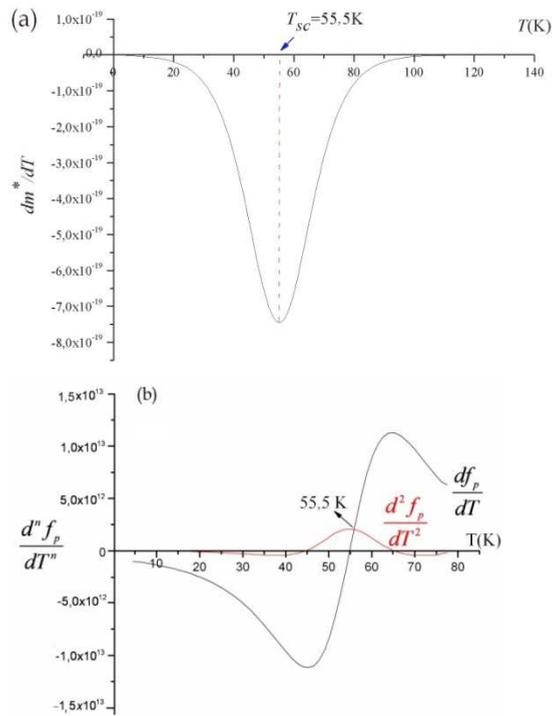


Fig. 11. (a)- The first derivative of the net effective mass with respect to temperature (time). (b)- The plasma frequency shifts from microwave to infrared at the T_{SC} . (Özdemir et al., 2006).

In this point of view, the phenomenon is attributed to the intrinsic gravitational field of the superconducting system that appears at a particular temperature of 55.5 K for the optimally oxygen doped sample (Fig. 11-(a)). Hence it is clear that, the occurrence of the quantum gravitational effect is strongly depending on the initial conditions especially the oxygen content of the system. In this point of view, we have named the net effective mass of the quasi-particles at T_{SC} for the optimally oxygen doped superconducting system mentioned as the "*super critical effective mass*".

8. Force unification in the mercury cuprate superconductors

In this section, the conceptual correspondence of the third symmetry breaking point, T_{QG} to the quantum gravity in high temperature cuprate superconductors will be discussed. As is known that the symmetry breakings give some reliable information about the present forces in a system. In this context, the appearance of the quantum gravitational effects in the mercury cuprate superconductors as a condensed matter media, for sure will give a new insight to the comprehension of the grand unification of the fundamental forces i.e. strong and nuclear forces, electromagnetic force and gravity. Up till now, the grand unification force process has been explained by the Big Bang of the Universe and the four fundamental forces are assumed to be unified up to 10^{-43} s after the Big Bang (Fig. 13).

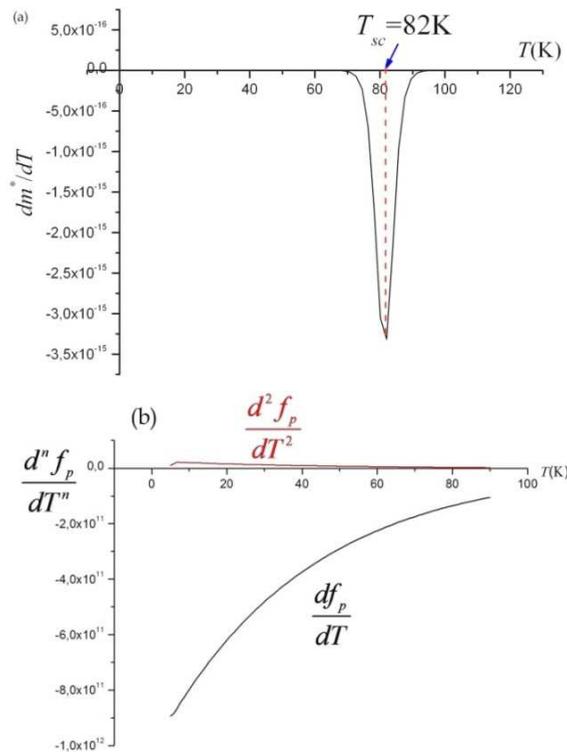


Fig. 12. (a)-The first derivative of the net effective mass with respect to temperature (time). (b)-The plasma frequency does not shift from microwave to infrared at the T_{sc} .

On the other hand, by dealing with the magnetic susceptibility data, it can be easily realized that a kind of mini-Big Bang is driven in the mercury cuprate high temperature superconductors by the variation of the temperature. The related temperature variation causes some symmetry breakings in the system as is summarized in Fig. 14.

As is known that the Meissner critical transition temperature, T_c corresponds to the second order phase transition in the superconductors. At this temperature, the one-dimensional global gauge symmetry is broken and due to that reason the critical Meissner temperature represents the first quantum chaotic transition point. Since the system exhibits the three dimensional BEC via Josephson coupling process with non-zero coupling coefficient, all entities can be represented by a unique, symmetric wave function, ψ with the phase, φ . Hence, the system can be attributed to a giant molecule which inevitably contains the fundamental strong forces at T_c . Moreover, since the mercury cuprate system behaves as an electromagnetic wave cavity, the T_c also marks the presence of the electromagnetic force in the superconducting media.

If the temperature is cooled down to T_{PME} , the time reversal symmetry and the electroweak symmetry are both broken. So that the T_{PME} point indicates the second quantum chaotic transition point. Moreover, towards the lower temperatures, we have observed a peak value on the temperature rate of change of the net effective mass of the quasi-particles at the

T_{QG} temperature, which has been attributed to **the third quantum chaotic transition point**. Obviously, the system undergoes a quantum transition that can be observed via the **fourth derivative of the phase of the order parameter of the superconductor**.

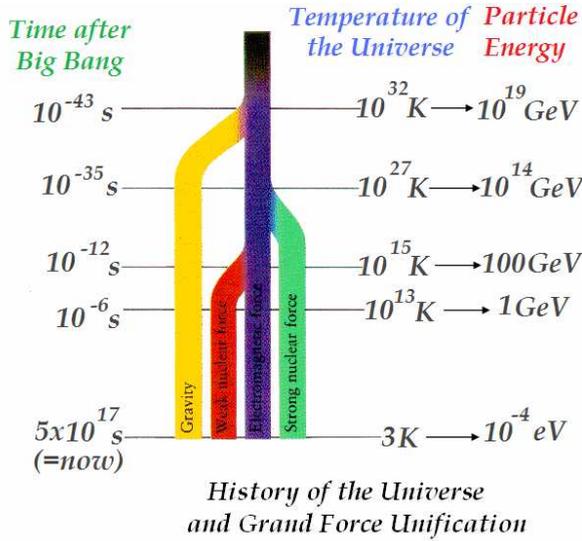


Fig. 13. The schematic representation of the history of the Universe and Grand force unification (<http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/eraplanck.htm>).

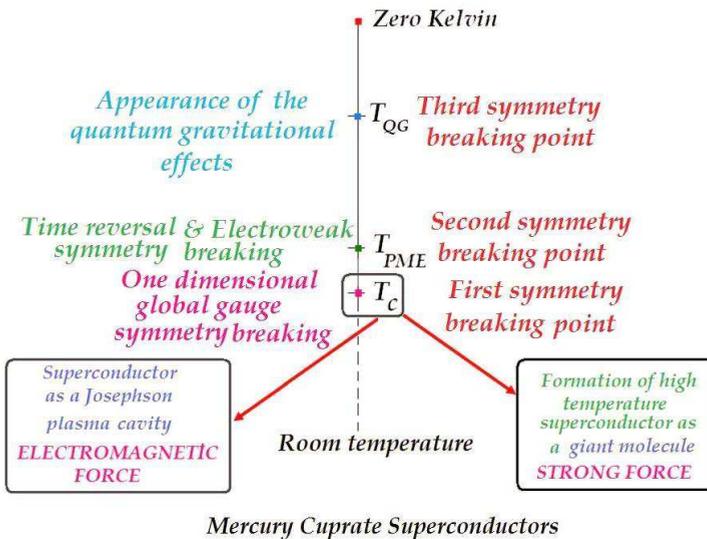


Fig. 14. The schematic representation of the symmetry breakings and the force unification in the optimally oxygen doped mercury cuprate superconductors.

According to Fig. 14, we have concluded that the high temperature superconducting system is a reliable frame of reference for the condensed matter physicists as well as the high energy physicists to get know about the controllable existence of the field particles, such as gluons, photons, weak force particles (W^\pm and Z^0 bosons) and gravitons.

9. Conclusions

In this chapter, the concept of the phase, φ of the order parameter, which is the unique invariant parameter in the universe, has been utilized to derive the net effective mass equation "Ongüas Equation" of the quasi-particles. The net effective mass of the quasi-particles has been reinterpreted in the relativistic manner. The corresponding relativistic energy values for the net effective mass coincide with some part of the unexplored energy gap of high energy physics, which lies between $10^3 \text{ GeV}/c^2$ - $10^{13} \text{ GeV}/c^2$. Hence, the unexplored energy gap of the GeV/c^2 hierarchic scale of high energy physics finds an opportunity to be investigated by the superconducting frame of reference for the first time. In this context, we hope that, this method enlightens the secret reality behind the origin and the formation of mass.

Moreover, in this work, the influence of the quantum gravity has been made clear without any doubt in the superconducting condensed matter media. Furthermore, we believe that the discussion of the symmetry breakings in the context of force unification procedure may also give a positive feedback about the dilemma about the force unification efforts that has been going on for many decades.

Ultimately, we hope that this work will unveil the mystery about the universal realities in nature such as the origin of having a mass, force unification process which have been accepted as some of the unsolved problems in physics in 21st century.

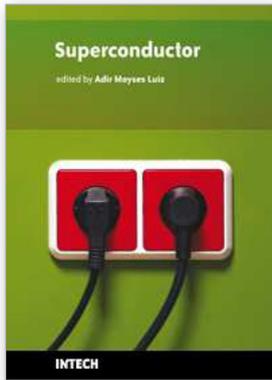
10. References

- Adachi, S.; Tokiwa-Yamamoto, A.; Fukuoka, A.; Usami, R.; Tatsuki, T.; Morikawaki, Y. & Tanabe, K. (1997). Hg-base homologous series of superconductors, Hg-12(n-1)n (Hg-Tl)-22(n-1)n. *Studies of High Temperature Superconductors (Advances In Research & Applications) Hg-Based High T_c Superconductors Part I Volume 23* Anant Narlikar (Ed.) Nova Science Publishers, INC., 163-191, ISBN: 1-56072-472-2, New York.
- Agop, M. & Craciun, P. (2006). El Naschie's Cantorian gravity and Einstein's quantum gravity. *Chaos, Solitons & Fractals* Vol. 30 No.1 (October 2006) 30-40 ISSN:0960-0779.
- Anderson, P.W. (1997). *The Theory of Superconductivity in the High- T_c Cuprates*, Princeton University Press, ISBN: 0-691-04365-5, Princeton, New Jersey.
- Anderson, P.W. (1998). C-Axis electrodynamics as evidence for the interlayer theory of high temperature superconductivity. *Science*, Vol. 279, No. 5354, (20 February 1998) 1196-1198, ISSN:0036-8075 (Print version).
- Aslan, Ö.; Güven Özdemir, Z. & Onbaşı, Ü. (2007). Correlation between the anisotropy and the effective mass of the quasi-particles in oxide superconductors, In: *The VI.th International Conference of The Balkan Physical Union, 22-26 August 2006 American Institute of Physics Conf. Proc. 899*, S.A. Çetin & İ. Hikmet (Eds.), 271-272, Springer-Verlag, ISBN:978-07354-0405-2, New York.

- Aslan Çataltepe Ö.; Güven Özdemir, Z.; Arık, M. & Onbaşı Ü. (2010). Strong-electroweak unification and quantum gravity achieved in chaotic regime. submitted to *Chaos Solitons & Fractals* ISSN:0960-0779 (online)
- Bean, C.P. (1962). Magnetization of hard superconductors. *Physical Review Letters*, Vol. 8, No. 6, 250-253, ISSN:1079-7114 (Online version).
- Bean, C.P. (1964). Magnetization of high field superconductors. *Review of Modern Physics*, Vol. 36, No. 1, 31-39, ISSN:1539-0756 (Online version).
- Braunisch, W.; Knauf, N.; Kataev, V.; Neuhauser, S.; Grütz, A.; Kock, A.; Roden B.; Khomskii, D. & Wohlleben, D. (1992). Paramagnetic Meissner effect in Bi high temperature superconductors. *Physical Review Letters*, Vol. 68, No.12, 1908-1911, ISSN:1079-7114 (Online version).
- Braunisch, W.; Kanuf, N.; Bauer, G.; Kock, A.; Becker, A.; Freitag, B.; Grütz, A.; Kataev, V.; Neuhausen, S.; Roden, B.; Khomskii, D.; Wohlleben, D.; Bock, J. & Preisler, E. (1993). Paramagnetic Meissner effect in high temperature superconductors. *Physical Review B* Vol. 48, No. 6, 4030-4042, ISSN:1550-235X (Online version).
- El Naschie, M.S. (a). (2005). From experimental quantum optics to quantum gravity via a fuzzy Kähler manifold. *Chaos, Solitons & Fractals*, Vol. 25 No. 5, (September 2005) 969-977, ISSN:0960-0779 (Online version).
- El Naschie, M.S. (b). (2005). Non-Euclidean spacetime structure and the two-slit experiment. *Chaos, Solitons & Fractals*, Vol. 26, No. 15, (October 2005) 1-6, ISSN:0960-0779 (Online version).
- El Naschie, M.S.; Rossler, O.E. & Prigogine, I. (1995). *Quantum Mechanics, Diffusion and Chaotic fractals*, Pergamon, ISBN: 0080420273, Oxford.
- Englert, F. & Brout, R. (1964). Broken symmetry and the mass of gauge vector bosons. *Physical Review Letters*, Vol. 13, No. 9 321-323, ISSN:1079-7114 (Online version).
- Ferrell R. & Prange R. (1963). Self field of Josephson tunneling of superconducting electron pairs. *Physical Review Letters*, Vol. 10, No. 11, 479-481, ISSN:1079-7114 (Online version).
- Feynman, R. (1963). *Lectures on Physics vol 1*, Addison Wesley Publishing, ISBN-10: 0201021161/0-201-02116-1 Massachusetts.
- Fossheim, K. & Sudbo, A. (2004) *Superconductivity: Physics and Applications*, John Wiley & Sons, Ltd, ISBN-10: 0-470-84452-3, Great Britain.
- Gao, L.; Huang, J.Z.; Meng, R.L.; Lin, G.; Chen, F.; Beauvais, L.; Sun, Y.Y.; Xue, Y.Y. & Chu, C.W. (1993). Study of superconductivity in the Hg-Ba-Ca-Cu-O system. *Physica C*, Vol. 213, No.3-4, (15 August 1993) 261-265, ISSN:0921-4534.
- Ginzburg, V. L. & Landau, L. D. (1950) *Zh. Eksp. Teor. Fiz.* 20 1064-1082. Translated into English in *Collected Papers of L. D. Landau*, D. Ter Haar (Ed.), Intl Pub Distributor Inc., ISBN-10: 0677205503 (June 1965), 546.
- Guralnik, G. S.; Hagen, C.R. & Kibble, T.W.B. (1964). Global conservation laws and massless particles. *Physical Review Letters*, Vol. 13, No. 20 585-587, ISSN:1079-7114 (Online version).
- Güven Özdemir, Z.; Aslan, Ö. & Onbaşı, Ü. (2009). Terahertz oscillations in mercury cuprate superconductors. *Pramana-Journal of Physics* Vol. 73, No.4 755-763, ISSN: 03044289.
- Güven Özdemir Z.; Onbaşı, Ü. & Aslan, Ö. (2007). Calculation of microwave plasma oscillation in high temperature superconductors. In: *The Seventh International Conference on Vibration Problems ICOVP 2005 Springer Proceedings in Physics*, E. İnan

- & E. Kırış (Eds.), 377-382, Springer, ISBN: 978-1-4020-5400-6, Dordrecht, The Netherlands.
- Helm, Ch.; Preis Ch.; Forsthofer, F.; Keller J.; Schlenga, K.; Kleiner, R. & Müller P. (1997). Coupling between phonons and intrinsic Josephson oscillations in cuprate superconductors. *Physical Review Letters*, Vol.79, No. 4 737-740, ISSN:1079-7114 (Online version).
- Higgs, P. W. (a). (1964). Broken symmetries and the masses of gauge bosons. *Physical Review Letters* Vol. 13 No. 16 508-509, ISSN:1079-7114 (Online version).
- Higgs, P. W. (b). (1964). Broken symmetries, massless particles and gauge fields. *Physics Letters*, Vol. 12, No. 2, (15 September 1964) 132-133, ISSN:0375-9601.
- Higgs, P. W. (1966). Spontaneous symmetry breakdown without massless bosons. *Physical Review*, Vol. 145, No. 4 1156-1163, ISSN:1536-6065 (Online version).
- Ihara, H.; Hirobayashi, M.; Tanino, H.; Tokiwa, K.; Ozawa, H.; Akahana, Y. & Kawamura, H. (1993). The resistivity measurements of $\text{HgBa}_2\text{Ca}_2\text{Cu}_3\text{O}_{8+x}$ and $\text{HgBa}_2\text{Ca}_3\text{Cu}_4\text{O}_{10+x}$ superconductors under high pressure. *Japanese Journal of Applied Physics*, Vol. 32, No: 12A L1732-L1734, ISSN:1347-4065 (Online version).
- Josephson, B.D. (1962). Possible new effects in superconducting tunneling. *Physics Letters*, Vol. 1 No. 7, (1 July 1962) 251-253, ISSN: 0375-9601.
- Ketterson, J. B. & Song S. N. (1999) *Superconductivity*, Cambridge University Press, ISBN:0-521-56295-3, United Kingdom.
- Khomskii, D. I. (1994). Wohleben effect (Paramagnetic Meissner effect) in high-temperature superconductors, *Journal of Low Temp. Physics*, Vol. 95, No. 1-2 205-223, ISSN: 0022-2291.
- Kibble T.W.B. (1967). Symmetry Breaking in Non-Abelian Gauge Theories. *Physical Review* Vol. 155 No.5 1554-1561, ISSN:1536-6065 (Online version).
- Lawrence, W.E. & Doniach S. (1971). Theory of Layer Structure Superconductors. In: *Proceedings of the 12th International Conference on Low Temperature Physics*, E. Kanda (Ed.), 361-362, Academic Press of Japan, Kyoto.
- Magnusson, J. ; Papadopoulou, E.; Svedlindh, P. & Nordblad, P. (1998). Ac susceptibility of a paramagnetic Meissner effect sample, *Physica C*, Vol. 297, No:3-4, (10 March 1998) 317-325, ISSN:0921-9601 .
- Nambu, Y. & Jona-Lasinio, G. (a). (1961). Dynamical model of elementary particles based on an analogy with superconductivity I. *Physical Review* Vol. 122, No. 1 345-358, ISSN: 1536-6065 (Online version).
- Nambu, Y. & Jona-Lasinio, G. (b). (1961). Dynamical model of elementary particles based on an analogy with superconductivity II. *Physical Review* Vol. 124, No. 1 246-254, ISSN: 1536-6065 (Online version).
- Nambu, Y. Nobel Prize Lecture Slides. (2008). http://nobelprize.org/nobel_prizes/physics/laureates/2008/nambu-slides.pdf
- Nielsen, A. P.; Cawthorne, A.B.; Barbara, P.; Wellstood, F.C.; Lobb, C.J.; Newrock, R.S. & Forrester, M.G. (2000). Paramagnetic Meissner effect in multiply-connected superconductors, *Physical Review B*, Vol. 62, No.21 14380-14383, ISSN: 1550-235X (Online version).
- Onbaşı, Ü.; Wang, Y.T.; Naziripour, A.; Tello, R.; Kiehl, W. & Hermann, A.M. (1996). Transport properties of high Tc mercury cuprates. *Physica Status Solidi B* Vol. 194, 371-382, ISSN: 0370-1972.

- Onbaşı, Ü.; Öztürk, S.; & Hasçıçek, Y. (1998). Magnetic measurement of critical currents on mercury cuprates. *Applied Superconductivity Conference California*, September 1998, USA.
- Onbaşı, Ü.; Güven Özdemir, Z. & Aslan, Ö. (2009). Symmetry breakings and topological solitons in mercury based d-wave superconductors. *Chaos, Solitons & Fractals* Vol. 42, No. 4, (30 November 2009) 1980-1989, ISSN:0960-0779 (Online version).
- Özdemir, Z.G.; Aslan Ö. & Onbaşı Ü. (2006). Determination of c-axis electrodynamic parameters of mercury cuprates. *Journal of Physics and Chemistry of Solids*, Vol. 67 No. 1-3 (January-March 2006) 453-456 ISSN:0022-3697.
- Pound, R.V. & Rebka, G.A. (1959). Gravitational red-shift in nuclear resonance. *Physical Review Letters* Vol. 3, No. 9 439-441, ISSN: 1079-7114 (Online version).
- Pound, R.V. & Rebka, G.A. (1960). Apparent Weight of Photons. *Physical Review Letters* Vol. 4, No. 7 337-341, ISSN: 1079-7114 (Online version).
- Patanjali, P. V.; Seshu Bai, V.; Kadam, R.M. & Sastry, M.D.(1998). Anomalous microwave absorption in GdBCO powder: π -junctions and the paramagnetic Meissner effect. *Physica C*, Vol. 296, No. 3-4, (20 February 1998) 188-194, ISSN:0921-4534.
- Putulin, S.N.; Antipov, E.V.; Chmaissem, O. & Marezio, M. (1993). Superconductivity at 94 K in HgBa₂CuO₄+ δ . *Nature* Vol. 362, No. 6417, (18 March 1993) 226-228 ISSN:0028-0836.
- Quigg, C. (2007). Spontaneous symmetry breaking as a basis of particle mass. *Reports On Progress In Physics*, Vol. 70, No. 7, (July 2007) 1019-1053, ISSN: 0034-4885.
- Quigg C. (2008). The coming revolutions in particle physics. *Scientific American* February 2008, 46-53, ISSN:0036-8733.
- Riedling, S.; Brauchle, G.; Lucht, R.; Röhberg, K.; Löhneysen, H.V.; Claus, H.; Erb, A. & Müller-Vogt, G.(1994). Observation of the Wohlleben effect in YBa₂Cu₃O₇- δ single crystals. *Physical Review B*, Vol. 49, No.18 13283-13286, ISSN: 1550-235X (Online version).
- Schilling, A.; Cantoni, M.; Guo, J.D. & Ott, H.R. (1993). Superconductivity above 130 K in the Hg-Ba-Ca-Cu-O system. *Nature* Vol. 363, No. 6424, (6 May 1993) 56-58, ISSN:0028-0836.
- Schliepe, B.; Stindtmann, M.; Nikolic, I. & Baberschke, K. (1993). Positive field-cooled susceptibility in high-T_c superconductors. *Physical Review B*, Vol. 47, No. 13 8331-8334, ISSN: 1550-235X (Online version).
- Schmidt V. V. (1997). *The Physics of Superconductors, Introduction to Fundamentals and Applications*. P. Müller & A.V. Ustinov (Eds.), 81-86, Springer, ISBN-10: 3540612432, Erlangen, Germany.
- Smart, L. E. & Moore, E.A. (2005). *Solid State Chemistry: An Introduction*, Taylor and Francis Group, CRC Press ISBN: 0-7487-7516-1, USA
- Thompson, D.J.; Minhaj, M.S.M.; Wenger, L.E. & Chen, J.T. (1995). Observation of paramagnetic Meissner effect in niobium disks. *Physical Review Letters* Vol. 75, No.3 529-532, ISSN: 1079-7114 (Online version).
- Tinkham M. (2004). *Introduction to Superconductivity*, (Second Edition) Dover Publications, ISBN-10: 0486435032, New York.



Superconductor

Edited by Doctor Adir Moyses Luiz

ISBN 978-953-307-107-7

Hard cover, 344 pages

Publisher Sciyo

Published online 18, August, 2010

Published in print edition August, 2010

This book contains a collection of works intended to study theoretical and experimental aspects of superconductivity. Here you will find interesting reports on low- T_c superconductors (materials with $T_c < 30$ K), as well as a great number of researches on high- T_c superconductors (materials with $T_c > 30$ K). Certainly this book will be useful to encourage further experimental and theoretical researches in superconducting materials.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Ulker Onbasli and Zeynep Guven Ozdemir (2010). Superconductors and Quantum Gravity, Superconductor, Doctor Adir Moyses Luiz (Ed.), ISBN: 978-953-307-107-7, InTech, Available from:
<http://www.intechopen.com/books/superconductor/superconductors-and-quantum-gravity>

INTECH

open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2010 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the [Creative Commons Attribution-NonCommercial-ShareAlike-3.0 License](#), which permits use, distribution and reproduction for non-commercial purposes, provided the original is properly cited and derivative works building on this content are distributed under the same license.