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Superconductivity in Brain

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Abstract: In this article, the phenomenon of superconductivity in the brain has been examined based on some properties of superconductivity. The possibility of hydrogen-based compounds to be superconducting at ambient temperature and pressure has enabled an analogy to be established between superconductivity and living organisms including high ratio water in other words hydrogen. In this context, the superconductivity phenomenon occurring in microtubules structures in neurons in the brain has been studied and thus the quantum mechanical properties of the brain have been tried to be explained. Due to the behavior of acting like computer memory, the role of repairing deoxyribonucleic acid damage, property of giving the quantum mechanical behavior to the brain, microtubules are very interesting organelles. Hence superconductivity with its extraordinary properties such as the quantum entanglement and bosonic state etc. may be guide for human beings in the respect of long term memory, empathy and consciousness.

Beyindeki Süperiletkenlik

Anahtar Kelimeler
Süperiletkenlik, Kuantum Dolanıklık, Bilinç, Empati, Beyin

Öz: Bu makalede beyindeki süperiletkenlik olgusu, süperiletkenliğin bazı özellikleri temel alınarak incelenmiştir. Hidrojen bazlı bileşiklerin ortam sıcaklığı ve basıncında süperiletken olma olasılığı, süperiletkenlik ile yüksek oranda su yani hidrojen içeren canlı organizmalar arasında bir analoji kurulmasına olanak sağlamıştır. Bu bağlamda, beyindeki nöronlarda bulunan mikrotübül yapılarda meydana gelen süperiletkenlik olgusu incelenmiş ve böylece beynin kuantum mekaniksel özellikleri açıklanmaya çalışılmıştır. Bilgisayar belleği gibi işlev görme davranışı, deoksiribonükleik asit hasarını onarmadaki rolü, beyne kuantum mekaniksel davranış kazandırma özelliği nedeniyle mikrotübüller çok ilginç organellerdir. Dolayısıyla süperiletkenlik kuantum dolaşıklığı ve bozonik durum gibi olağanüstü özellikleriyle uzun süreli hafıza, empati ve bilinç kavramları açısından insanlara yol gösterici olabilir.

1. INTRODUCTION

Superconductivity was discovered by Kamerlingh Onnes in 1911 at Leiden University in mercury at liquid helium temperature for the first time As the temperature decreases to a specific temperature value called as a critical transition temperature, T_c the resistance of the material disappears suddenly and superconductivity occurs in material [1]. Superconducting materials exhibit some interesting properties such as zero resistance below T_c, Meissner effect [2,3], Josephson junction tunneling [4], Bose-Einstein Condensation [5,6], quantum gravity [7,8] quantum entanglement [9], etc. These properties belonging of the superconductivity are of the collective behaviors of the superconducting material. First, general properties of a superconducting material have been summarized in the article and then the phenomenon of superconductivity in living organisms especially in brain is examined from literature in detail. Then the analogy between superconductivity and brain has been made and investigated in the terms of consciousness, memory etc. Also, the study has tried to determine the relationships between some characteristics properties of human brain and quantum mechanics by guiding of superconductivity.

2. THE SOME CRUCIAL PROPERTIES OF SUPERCONDUCTORS

The most known property of the superconductivity is the zero resistivity of material under the critical transition temperature, T_c, as shown in Figure 1. This fundamental property of the superconductivity was discovered for mercury by Kammerlingh Onnes in 1911 for the first time [1].

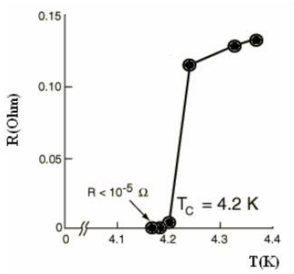

Figure 1. Discovery of superconductivity in mercury with zero electrical resistivity at 4.2K [10].

After the discovery of superconductivity in mercury, many metals, alloys and cuprates have been found to be superconducting at low temperatures. In the following years, studies on superconductors have been continued both in the search of materials with higher critical transition temperatures and in the establishment and development of theories to explain the physical origins of the phenomenon of superconductivity. In this context, the Bardeen-Cooper-Schrieffer (BCS) theory, the first theory of superconductivity, was derived in 1957. The BCS theory states that electron pairs called as Cooper pairs with opposite momentum and spin occur due to the electron-phonon interaction as shown in Figure 2. These quasi particles in superconducting material behave like bosonic particles due to their zero spin and hence occupy the same quantum sate due to the quantum entanglement. Therefore, superconductors can be considered as giant quantum mechanical systems exhibiting Bose-Einstein Condensation (BEC) [11,12].

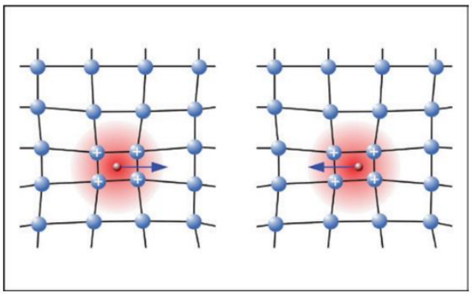

Figure 2. The formation of the Cooper (electron) pairs due to the attractive interaction between two electrons and phonons [13].

BEC in the quasi-2D copper oxide layered superconductors called as cuprates was suggested as the possible mechanism of superconductivity [5,14]. It was determined that with the plasma frequency, BEC in copper oxide layers extends to the whole layers in mercury based CuO_2 layered high temperature superconductors and hence three dimensional BEC were determined for superconducting material for the first time [15]. All electron pairs in the superconducting material have same wave function due to the BEC. Even if you break any electron pair in the superconducting system, the superconductivity in the system is destroyed.

The other main property of all superconductors is the Meissner effect. A superconducting material displays diamagnetic character [2,12,16]. Whereas in normal state, the magnetic field applied to the sample penetrates to the material, it is completely expelled from the sample at superconducting state as seen in Figure 3. The magnetic levitation occurs due to expulsion of magnetic field from the superconducting sample. The magnetic field is completely expelled from the material in an ideal state while it penetrates a small shell of the surface of the superconducting material in reality [13].

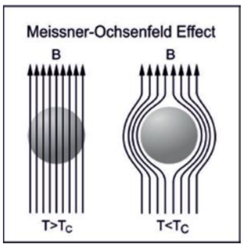

Figure 3. The schematic representation of Meissner effect at upper and below T_c [10].

Superconductors can be categorized as type I and II superconductors. Superconducting materials with type-I called low-T_c superconductivity are generally pure metals. Type-II called high-T_c superconductivity superconductors are alloys and oxides of ceramics. The Meissner effect manifests itself with perfect diamagnetism in the form of complete exclusion of magnetic flux up to a thermodynamically critical magnetic field value, H_c in type I superconductors as seen in Figure 4. In type II superconductors, the applied magnetic field is totally expelled from the type-II superconductor until the first critical field H_{c1} is reached. At magnetic field values above H_{c1}, the magnetic field penetrates the superconductor and vortices, which are the magnetic flux quantum, occur. In these regions where magnetic field penetrates to the sample, it is no longer superconductor. The rest of the material still has superconducting properties. If the magnetic field is increased to the second critical field, H_{c2}, the material is no longer superconducting. H_{c2} is generally upper than H_c of type I superconductors and this explains why type II superconductors are typically used for superconducting magnets [10,13].

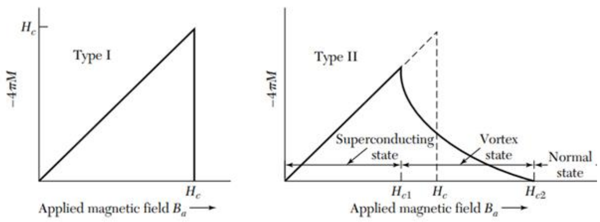

Figure 4. Magnetization versus applied magnetic field curve of type I and type II superconductors [3,10].

In 1962, the young theoretical physicist Brian Josephson observed two different physical phenomena at the Josephson junction (Figure 5), which consists of two superconducting layers separated by a thin insulating layer: d.c. and a.c. the Josephson effect [4].

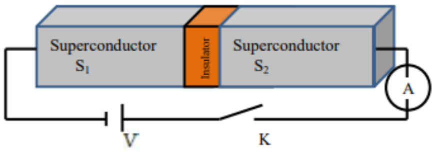

Figure 5. The schematic representation of ac Josephson junction [17].

In the dc Josephson Effect, even if no external voltage is applied to the Josephson junction, supercurrent flows through the junction as a result of electron pairs tunneling the junction, quantum mechanically. Cooper pairs (quasi-particles) in the superconducting regions in the right and left of the junction can be represented by an exponential wave function dependent on the phase difference. When no current flows in superconductors, since all Cooper pairs have the same phase, the system can be described by a single wave function. When superconductors are separated by a thin insulating layer, the wave functions of electron pairs on either side of the junction penetrate the insulator layer, locking them in same phase by quantum mechanical tunneling. In this case, without applying any voltage difference to the junction, a supercurrent proportional to this phase difference flows through the junction due to the phase difference $\Delta\varphi$ between the wave functions of the electron pairs [18].When a d.c. voltage difference is applied to the Josephson junction, an alternating supercurrent flows through the Josephson junction proportional to the voltage applied to the junction. The a.c supercurrent flowing through the Josephson junction can create electromagnetic fields within the junction. Relevant electromagnetic waves were first experimentally observed in 1965 [19].

The other property of the superconductors is quantum gravity phenomenon which has been observed at optimally doped mercury based superconductor for the first time. In mercury-based superconductor, at temperature lower than T_c, the effective mass of the quasi-particles is at maximum value and as an indicator of this event, the plasma frequency shifts from the microwave to the infrared region due to the quantum gravity [7,8].

3. THE SUPERCONDUCTIVITY IN LIVING ORGANISMS

Scientists have been studying that hydrogen-based compounds may be superconductor at ambient temperature and pressure. Some detailed analyses have shown that the highest critical temperatures for superconducting materials are achieved in the molecular and covalent hydrogen–hydrogen interaction materials [20]. Also, the small radius elements alloyed with hydrogen have new bonds instead of pure H-H bonds and these new bonds are more stable than H-H bonds [21]. In this context, materials containing hydrogen, such as living organisms are promising candidates to reach superconductivity at ambient temperature and pressure values.

In recent years, the number of studies on superconductivity and quantum processing of information in living organism have been increasing [22]. Some studies have shown that living organisms being superconducting at room temperature exist in nature. The possibility of higher temperature superconductivity than the room temperature in organic polymers was proposed by W. A. Little in 1964 for the first time [23]. Mikheenko put forward a hypothesis that nature may have discovered the superconductivity in water being one of the most abundant substances in the planet very long time ago and he also stated that the enhanced coherence and quantum processing of information might be enabled by the properties of superconductivity. In this context, water might be the origin of the beginning of the existence of the intelligent life in the planet [22,24,25].

As is known, the ambient pressure like the chemical pressure affects the critical transition temperature of the superconducting system [26-28]. From this point of view, the high pressure is the other crucial parameter as well as water in other word hydrogen for appearing the intelligent life arisen from depth of oceans for the first time. Hydrogen being the lightest ion has very high phonon frequency leading to room temperature superconductivity and it has solid structure under high pressure environment [27]. The studies show that the superconductivity mechanism is related to the number of the hydrogen atoms. During water formation, extra oxygen from water could be release atmosphere and this explains initial high oxygen concentration on the early stages and also evaluation of life on the planet [22].

The studies show that brain water content in humans is approximately 75% for adults and 85% for infants [29]. There are some evidences that water could play essential role for formation of superconductivity and superconductivity could be responsible for coherent behavior of living organisms [24]. The brain and nervous system have the coherent features and could be analyzed by models developed for superconductivity [22]. Superconductivity in brain was suggested in 1972 to explain long-time memory and was explained that if there is room-temperature superconductivity, it should be in a system with high level of organization. Superconductivity in brain was also studied by Halpern and Wolf who explained that the superconductivity could be available in living organism and even consciousness of intelligent organisms [30].

The recent studies propound that if the dimensions of a material decreases, its critical temperature increases. William Little in 1964 developed a remarkable theory deriving very high critical temperature of about 2200 K in linear chains of organic molecules [23,25]. Microtubules being one dimensional structure with linear translational symmetry in living cells, which form the cytoskeleton, are organized as networks and in neurons [31]. It was suggested by scientists that superconductivity developing inside one dimensional microtubules inside neurons of brain could also be responsible for long-term memory [22,24]. Emilly Toomey and her collogues suggested that the superconducting nanowires could be used for the development of an artificial neuron. The artificial neuron has functions with multiple characteristics of biological neurons [32].

Neuromorphic computing systems are inspired by the biological concepts and functions of the human brain [33] and are of studying areas of artificial intelligence and machine learning applications [34]. Superconducting electronics including Josephson junctions and superconducting nanowires have been widely using in neuromorphic computing systems to provide bio-inspired functionality to the device. Neurons in brain exhibit the action potential and in order to make an analogy to action potential, Josephson junctions displaying naturally spiking behavior are used. Two Josephson junctions can imitate the ion channel dynamics observed in firing neurons, and the combination of nanowire resistor can simulate the relaxation oscillations determined in the brain due to the connections of several neurons [35]. Also it has been determined that Josephson junctions in conjunction with single photon detectors fulfill many neural operations occurring in brain and can be utilized to construct synapses for communication requiring a single photon [36].

It is supposed that the brain has a macroscopic quantum wave and quantum processes take in the cytoskeleton. The long-range coherent informational transfer in brain is explained by Bose-Einstein condensation. Nambu-Goldstone bosons, which are quanta of long-range correlation waves of aligned electric dipoles, are generated by the interaction between the water molecules and the local electromagnetic field in neurons [37,38].

Scientists Alain Aspect, John Clauser and Anton Zeilinger who took the Nobel physics award, have investigated entangled quantum states (Figure 6). In the quantum entanglement state, two quantum systems or quantum particles being entities lacking individuality [39] behave like a same system quantum mechanically and share the same quantum state. Due to this reason, the distance between two systems are not important, because they share same quantum state and have same collective attitude. The other crucial property of the entangled particles is that they should be opposite spin with same amplitude. In this point of view, a Cooper pair is considered as a quantum entangled system. Perfect quantum mechanical communication occurs between entangled systems [9]. Also, Anton Zeilinger and his research group have demonstrated that a phenomenon called quantum teleportation between particles is possible regardless of distance [40].

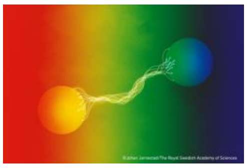

Figure 6. The schematic representation of quantum entanglement [41].

Brain, in which thoughts, intentions, dreams and ideas are created, is responsible for human awareness. The brain waves are produced by metabolic activities. If two individual entities can be considered as two independent human brains, their frequencies and corresponding energy levels in other words state of cognition are quantized. Hence, each state of mind is determined by quantum mechanical wave function. "Thought" has quantum mechanical wave character and one's thought cannot be read by any human made device because of collapsing of quantum wave function. The thought is in solitary wave character and the only possibility of reading of the thought is another brain. This situation is an example of quantum entanglement state between human beings [9]. In other way, when there is harmony between individuals, the flow of information between minds occurs without verbal communication. That is, for communication, individuals may not always need words or verbalizing.

4. DISCUSSION ON SUPERCONDUCTIVITY AND HUMAN BEINGS

Communication is the most important factor leading the formation of culture and civilization. In this context, the brain, in which thoughts, feelings, intentions and hopes are born, has important duties in the transmission of correct information. Hence, the brain and of course neurons have crucial missions and the connection between neurons and empathy is also known.

It has been reported that there is a big correlation between mirror neuron systems and empathy. Many studies have investigated that the mirror neuron system is involved in empathy and emotions. Functions of mirror neurons depend on the anatomy and physiological properties of the brain. As it is known, mirror neurons create a direct link between the sender of a message and the receiver of the massage. Mirror neurons shaped the civilization provide a mechanism for action-understanding, imitation-learning, and the simulation of other people's behavior [42].

An individual who is an empath gives importance to the feelings and thoughts of other people and feels /knows their feelings/thoughts from their behaviors and actions and s/he experiences the same situation as if they were her/his own feelings. The question of "what makes these people with nonverbal communication skills different from other people" becomes important at this point. It is supposed that the mirror neurons of empaths who may exhibit quantum entanglement feature, work more actively and neurons have superconducting microtubule structures, too. In this context, it can be deduced that the neurons of empath people may contain more superconducting microtubules and in this case they may affect the brain waves of the person.

The collapse of the entangled states occurs due to the decoherence. Because of environment-induced decoherence, quantum systems settle into classical states and behave classically [43]. Hence, in which state entanglement occurs, is important. The highest states of being of the eternal program must be the state of entanglement. The reality is obvious only in this state. Tegmark found that decoherence time scale in the brain is in 10^{-20} to 10^{-13} s. Characteristic processes in neuron activity in human brains, which are slower than the decoherence time scale, are in the order of 10^{-3} to 10^{-1} s [44]. The probability of the collapse of a system consisting of entangled particles can be calculated by using the hitting frequency, f which is as a function of total mass of entangled particles. If the frequency of the system is very low, the collapse of the system is nearly impossible. It has been still continuing some arguments which frequency values are very low or not. In this context, philosophical and phenomenological approaches rather than that of scientific are more guiding [45].

According to Ehret and Raymond, animals without systems of attention and long-term memory do not experience awareness of the content of something or consciousness about something to do [46]. Das says that the image of consciousness is stored as binary data in the microtubules structures of the neurons like computer memory [47]. Hence, the genetic structure of the living organisms affects the awareness and consciousness. It has been shown that the microtubule structures of some animals are different [48] and microtubules are also known to play a role in deoxyribonucleic acid (DNA) damage repair [49].

As is known, by using Josephson junction and superconducting nanowires, the artificial neurons are constructed and they display perfect communication between them. Another unusual property of superconductivity is its behavior in the presence of vortices being the non-superconducting regions in superconductor. Although superconducting system has vortices, it tries continuing superconducting properties. Because, by the spatial resonance, entities called vortices formed in a superconducting system are pinned and the superconducting system continues to exist. In this situation, vortices are non-functional entities. In short, in cases where the number of entangled states is greater, the vortices have no effect on the system.

4. DISCUSSION AND CONCLUSION

In this article, the analogy between superconductivity in the brain and superconducting systems has been investigated, especially in the context of the concepts of consciousness and empathy.

The mind's reactions to events shape the system and this can be considered as a part of the evolutionary processes of the systems. As it is known, intelligent systems want to protect their own security and the development of systems is managed and supported by minds. In this context, the superconductivity may conceptually guide us. In this study, superconductivity with its extraordinary properties such as the, quantum entanglement and bosonic state can be an important starting point for the positive change of individuals or systems in terms of long-term memory, empathy and consciousness.

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