International Journal of Industrial Electronics and Electrical Engineering, ISSN: 2347-6982 Volume-4, Issue-9, Sep.-2016

THE JAHN TELLER METAL: AN INSIGHT OF THE FUTURE MRI (MAGNETIC RESONANT IMAGING)

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Abstract— Invention is adventure. Adventure is an addiction and let that addiction be our utopia. Let the inked words ignite ideas and imagination to run free. An international team of researchers at TOKOHU UNIVERSITY at Japan studying a superconductor made from Bucky balls or C_{60} molecules discovered a new type of metallic state of matter named as, Jahn Teller Metal. It's a combination of insulating, magnetic, metallic and superconducting phases having the potential to achieve superconductivity at a relatively high T_c (high) as in -135 degree Celsius. We now aim to deploy this concept in Magnetic Resonant Imaging(MRI) i.e. the Jahn teller metal is being used as a solenoid in the MRI thus, undermining the usage of liquid Helium by causing Superconductivity to occur at -135 degree Celsius in juxtapose with the former used -269.1 degree Celsius. Here, a major observation of high temperature superconductors, which has the potential of Jahn Teller Metal, is also further taken into consideration. Moreover, this usage of the metal can cause myriad of aid to the dearth of liquid Helium.

Index Terms— Magnetic Resonance Imaging, Helium, Magnetic Field, Jahn Teller Metal, Jahn Teller Effect, Crystal Field Theory, BCS Theory, High Temp. Superconductors.

I. INTRODUCTION

In this contemporary world, Medical Sciences is one of the strongest celluloid upon which the populace relies on for its healthy life. Navigating through this reservoir let's have a rendezvous on MRI(Magnetic Resonant Imaging).Magnetic Resonance Imaging (MRI)[1] is a wonderful tool that lets you see inside the body with amazing clarity It uses the body's natural magnetic properties to produce detailed images from any part of the body. For imaging purposes the hydrogen nucleus (a single proton) is used because of its abundance in water and fat. The best part is that it does this with no harmful radiation.

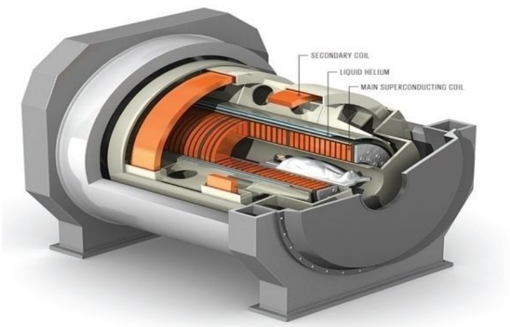


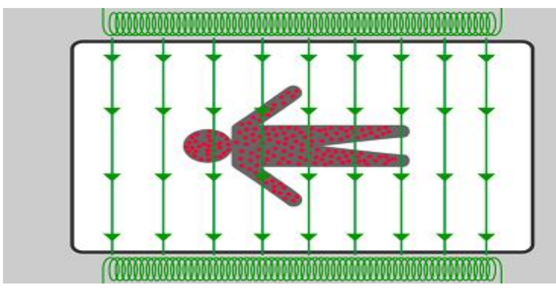
Fig.1 (MRI Machine inside out)

II. WORKING PRINCIPLE

The technique uses a very powerful magnet to align the nuclei of atoms inside the body, and a variable magnetic field that causes the atoms to resonate, a phenomenon called nuclear magnetic resonance[2]. What happens is:

The MRI machine is able to "see" water. It only sees the hydrogen nuclei contained in water molecules . Let us start by giving our MRI machine a strong magnet. The magnetic fields produced by the magnet is continuously present and in our example, goes from the top to the bottom. . According to the weird laws of quantum mechanics[3] the hydrogen nuclei have a property called 'spin' which can be 'oriented' in certain ways.

The strong magnetic field makes the spins of the hydrogen nuclei line up along the magnetic field so some of the hydrogen nuclei line up in the direction of the magnetic field while the other line up opposite to the direction of the magnetic field .You will now notice that there are slightly more low energy nuclei than high energy nuclei. The MRI machine uses 'energy' to 'irritate' the low energy hydrogen nuclei. The MRI machine applies a current to this energy producing coil for a short period. During this period, the coil produces energy in the form of a rapidly changing magnetic field which is called "radio frequency"[4] energy (RF energy) and the coil, radio frequency coil (RF coil). These hydrogen nuclei with low energy absorb the energy sent from the RF coil, which changes the energy state of the low energy hydrogen nuclei an make them high energy nuclei. After a short period, the RF energy is stopped. The high energy hydrogen then go back to their previous, 'low energy' state and they start releasing the energy they absorbed in the form of wave which is further received by the RF coil. This coil converts the energy waves into an electrical current signal. And hence, the MRI machine is able to detect hydrogen nuclei in the body.



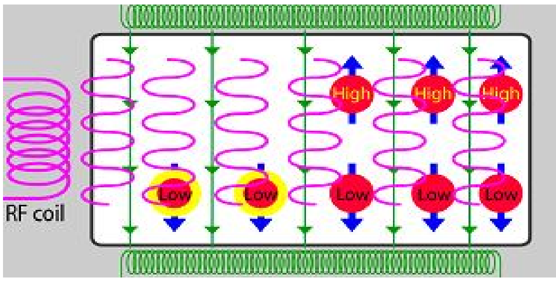


Fig.2 Hydrogen atom getting triggered in human body place in MRI.

Now all this works by generating a very large magnetic field using a super conducting magnet and to temperament a large magnetic field you need a lot of energy which is accomplished using superconductivity. This is done by bathing the wires in a continuous supply of liquid helium[5] at -269.1C.A typical MRI scanner uses 1,700 litres of liquid helium, which needs to be topped up periodically. Ironically, being the second most abundant material in the universe, helium is scarce on Earth as its lightness means it is not gravitationally bound to the atmosphere and is therefore constantly being lost to space. The majority of the world's helium supply is created through natural radioactive decay and cannot be artificially synthesised, meaning the gas is a non-renewable resource.

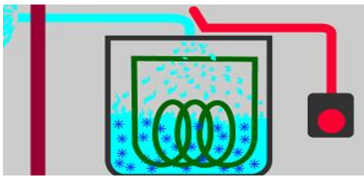


Fig.3. Liq.Helium used to cool solenoid.

III. PRESS THE SPACEBAR.

Improved superconducting wire is key to making such a powerful machine. Ideas build the world and so does the inventions. Time is never static and there is a creative dancing going on. Let us lay an insight on a new metal **"THE JAHN TELLER METAL"[6,7]** which allows superconductivity to occur at -135 degree Celsius, thus escalating the temperature of -269.1 degree Celsius of superconducting alloys which is generally used in solenoids of MRI and hence narrowing the usage of liquid Helium to a considerate extent. This entirely new state of matter allows superconductivity to occur at low temperature which when put through an array of tests, displayed an unusual combination of properties—insulator, metal, superconductor, magnet.

IV. PROPOSED WORK

Here comes the newest state of matter, "the Jahn teller metal" that appears to be insulator, magnetic, metal and superconductor - including the otherwise unknown properties all rolled into one.[8]The surprising thing about this metal is that it involves an intermediate state never seen before. And it is this intermediate state that we are interested, as it seems that just applying pressure can turn the material from an insulator into a conductor. The research provides important clues about how the interplay between the electronic structure of the molecules and their spacing within the lattice can strengthen interactions between electrons that cause superconductivity.

What happens in Jahn Teller Metal is that as pressure is applied, and as what was previously an insulator – due to the electrically-distorting Jahn teller effect – becomes a metal, the effect persists for a while. The molecules hang on to their old shapes. So, there is an overlap of sorts, where the material still looks an awful lot like an insulator, but the electrons also manage to hop around as freely as if the material were a conductor. Jahn-Teller effect describes how at low pressures, the geometric arrangement of molecules and ions in an electronic state can become distorted; this new state of matter allows scientists to transform an insulator - into a conductor.

4.1 Making of Jahn Teller Metal

Alkali-Fulleride superconductors were discovered in the early 90s and they consist of C60 molecules forming a body-centered-cubic or face-centered cubic lattice with 3 Alkali atoms (Cs, Rb, K). The superconducting transition temperature can be tuned by hydrostatic pressure or by chemical pressure, i.e. substituting one Alkali atom with another one which has a different ionic radius.[9]

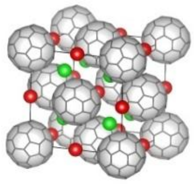


Fig.4. Crystal Structure of A3C60 where A=Cs, Rb, K, face centered cubic version.

Introduction of *rubidium* to carbon-60 molecules arranged as *fullerenes*, apply pressure forcing its molecule closer together by brute force tweaking the distance between the molecules by adding or subtracting some sort of barriers between them. When put through an array of tests, this structure displayed a combination of insulating, metallic, superconducting, and magnetic phases, including a brand new one, which the researchers have named 'Jahn-Teller metals'. And it's this transition phase between insulator and conductor that, until now, scientists have never seen before, and hints at the possibility of transforming insulating materials into super-valuable superconducting materials. And this buckyball crystalline structure appears to be able to do it at a relatively high t_c.

4.2 Understanding the Jahn Teller Effect

In the electronically degenerate state, the orbitals are said to be asymmetrically occupied and get more energy. Therefore the system tries to get rid of this extra energy by lowering the overall symmetry of the molecule i.e., undergoing distortion, which is otherwise known as **Jahn Teller distortion**.

The Jahn-Teller effect/distortion is best explained by considering a different system: a d-electron metal ion in an octahedral bonding environment. The starting point is crystal field theory.We know that all five *d*-orbitals of, say, copper atom, have the same energy.

However, when this atom is put into a crystal with other atoms, the energy of some of these orbitals will be lowered relative to others because of electrostatic repulsion from electrons in other orbitals. In the image below, this is illustrated for a d-electron ion surrounded by 8 oxygens (octahedral environment), among the in-plane d-orbitals, the ones whose lobes point along the crystallographic directions (the so-called eg orbitals) suffer a Coulomb-repulsion energy penalty as compared to the ones which point along the diagonals (the $t_{2\ g}$ orbitals) because of increased overlap with oxygen p_x and p_y orbitals. Other bonding configurations (e.g. tetrahedral) will put an energy penalty on different orbitals. This crystal-field-induced energy splitting has implications for how electrons are placed into the d-orbitals (with crystal-field effects, the lower energy orbitals are populated first, whereas without crystal field effects, one just uses Hund's rules) which has implications for magnetism and metallicity.

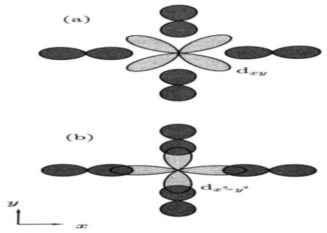


Fig.5. The crystal field originates from an electrostatic interaction (a) The d_{xy} orbital is lowered in energy with respect to (b) the $d_{x^2-y^2}$ orbital is in octahedral environment.

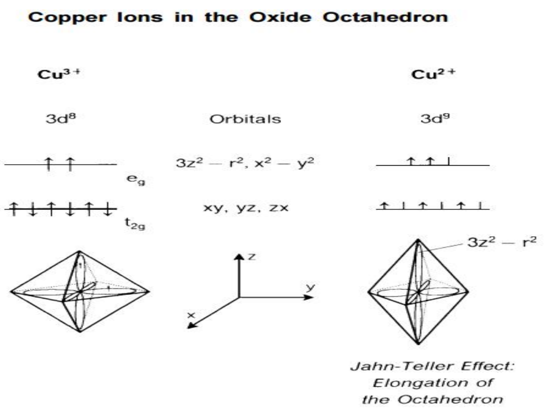


Fig.6. Schematic representation of electron orbitals for octahedrally coordinated copper ions in oxides. For Cu^{3+} with $3d^8$ configuration, the orbitals transforming as base functions of the cubic e_g group are half-filled, thus a singlet ground state is formed. In the presence of Cu^{2+} with $3d^9$ configuration, the ground state is degenerate, and a spontaneous distortion of the octahedron occurs to remove this degeneracy known as the Jahn-Teller effect.

Originally, electrons can sit in one of three degenerate molecular orbitals, but compression (or stretching) of the entire buckeyball can lift the degeneracy, change the spin state, and change the orbital overlap with adjacent molecules (i.e. the metallicity).

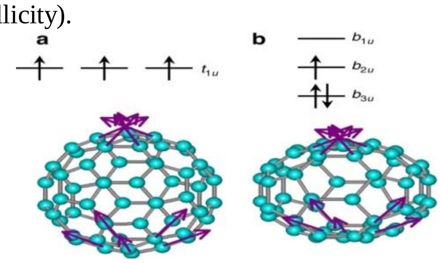


Fig.7. Distortion at molecular level occurring due to Jahn Teller Effect. Jahn-Teller effect in the parent insulating state of the molecular superconductor Cs_3C60.

One of the most exciting things about Jahn Teller Metal is that on the one hand, they behave like conventional superconductors, superconductors explained by BCS theory ,for instance, buckeyball phonon modes appear to play a role in superconductivity, but on the other hand, the fact that their superconducting properties are tuneable by pressure implicates electron-electron interactions as seen above , which lend them similarity to unconventional superconductors, such as high-T_c cuprates.`

This is all pretty important because this transition from insulator to metal is also a transition from insulator to *potential superconductor. The resulting metal* just needs low enough temperatures and all of a sudden its electrons start pairing up and skipping around, with the result being a sudden drop to exactly zero electrical resistance.It's this pairing up of electons, which are together known as Cooper pairs, that's crucial for superconductivity. And in this way superconductivity is observed. When distortion of the buckeyballs favors an insulating electronic structure, Mott-jahn teller insulator occurs.

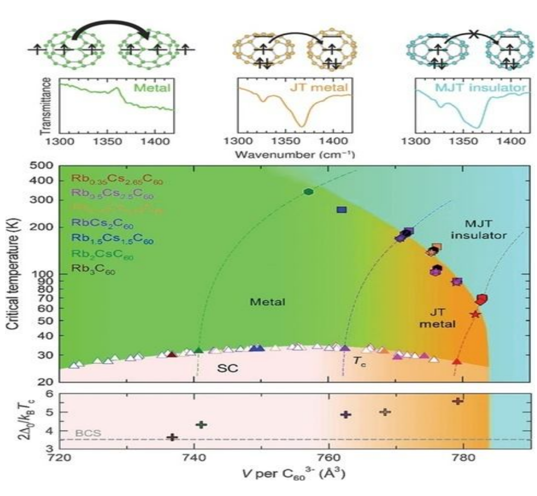


Fig.8. Phase diagram of FCC A3C60, where the axis is the unit-cell volume, tuned by either chemical or hydrostatic pressure. The diagrams at the top illustrate Jahn-Teller distortion and the resulting molecular-orbital energy splitting, but they do not explain why conduction is permitted in the middle sketch but not in the right sketch.

A well documented example includes complexes of the type $M_2PbCu(NO_2)_6$. For M=Cs, below 285K the molecule shows tetragonal symmetry, for M=K this occurs at below 273K, for M=Rb at less than 276K and for M=Tl at temperatures less than 245K. Above these temperatures the molecules appear octahedral due to the dynamic Jahn-Teller effect.

$CuBr_2$	4 Br at 240pm 2 Br at 318pm
$CuCl_2$	4 Cl at 230pm 2 Cl at 295pm
$CuCl_2.2H_2O$	2 O at 193pm 2 Cl at 228pm 2 Cl at 295pm
$CsCuCl_3$	4 Cl at 230pm 2 Cl at 265pm
CuF_2	4 F at 193pm 2 F at 227pm
$CuSO_4.4NH_3.H_2O$	4 N at 205pm 1 O at 259pm 1 O at 337pm
K_2CuF_4	4 F at 191pm 2 F at 237pm
$KCuAlF_6$	2 F at 188pm 4 F at 220pm

Fig.9. Some examples of Jahn-Teller distorted complexes.

This proves the potential of Jahn Teller Metals as high temperature superconductors which can be used as solenoids in the MRI.

CONCLUSION

In this dynamic era, imaging of human internal organs with exact and non-invasive methods is very important for medical diagnosis, treatment and follow-up. An MRI scan is one of the most sophisticated diagnostic tools available to help a referring clinician understand the cause of your particular health issue. It's a medical investigation that uses an exceptionally strong magnet and radio frequency waves to generate image of your body. But due to the issue of acute prices to be paid for its continuous reinforcement like liquid helium to continue with the strong magnetic waves, we urgently need to do away with this drag. As we all know that, what is now proved was once only imagined, we aim to mitigate this issue by the introduction of the new state of matter, "THE JAHN TELLER METAL" which provides an eccentric edge by acting as a solenoid in the MRI. This metal is going to provide the superconductivity at -135.4 degree Celsius as compared to -269.1 degree Celsius , thus deprecating the usage of liquid Helium to a greater extent.

This spectacle has gathered the steam and as without the audience there is no theatre, we need that the populace should get acquainted with these new findings to bring the medical sciences to the buzz of the future MRI. Bend the rules and let's go invent tomorrow.

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