23

The Mechanism

It isn't that they can't see the solution. It is that they can't see the problem.
G. K. Chesterson

23.1 The crux of the matter

It should at this stage be clear to the reader that in order to find a mechanism which can explain superconduction, the following two incontrovertible experimental facts must be reconciled:
(i) When a superconducting-current flows, the voltage measured across any two contacts to the material through which the current flows becomes identically zero while the charge-carriers move with a constant average speed: Thus, the incontrovertible experimental fact is that there is no electric-field anywhere within or on the surface of a superconductor which accelerate the charge-carriers to, in this way, generate the current that is flowing.
(ii) When a current flows through a normal conductor, even one within which the charge-carriers do not scatter, the charge-carriers are always accelerated by an applied electric-field: As had already been shown in section 7.4.3 above, the incontrovertible experimental fact is then that the voltage across two contacts (to such a normal conductor) can never become zero while a current is flowing through the conductor.

Both statements are experimental facts which are inviolate: Since both must be simultaneously true, one can only reach one logical conclusion: To model superconduction one must find a mechanism which explains why the charge-carriers are not accelerated by an applied electric-field and which explains how they convey a current with a constant drift-speed without being accelerated-and-scattered all the time.

23.2 "Insulduction"

The first why requirement demands that an electric-field, when present, must be cancelled at the position of each and every superconducting charge-carrier so that none of them can be accelerated. What must happen, when an

electric-field is present, is that each one of the charge-carriers must become polarised relative to a charge of opposite sign. In other words the material will respond to an applied electric-field like an insulating dielectric. This, in turn, mandates that when a material becomes superconducting, it must undergo a metal-to-insulator (MI) transition. Although it seems impossible, this impeccable logic forces one to conclude that a superconducting phase must be an insulator constituted by a stationary array of orbitals; each anchored at a site by an opposite charge; so that each orbital has to overcome a binding-energy ΔE_S in order to break free:i.e. it must be a Mott-type insulator.

When a very large electric-field is present within such a material, these orbitals can "tear lose" from their anchor-sites: Dielectric breakdown then occurs. When a smaller electric-field E is applied, each orbital will form a dipole relative to the opposite charge which anchors it. The latter situation is thus the same as the one shown in Fig. 7-9: Obviously, when an orbital polarises in this manner, its binding-energy decreases to become $\Delta E(E)_S < \Delta E_S$.

This impeccably-logical deduction is so important that it is worthwhile repeating it: Each charge-carrier must be a matter-wave (orbital) which is anchored by an opposite charge at a localised position so that it becomes polarised when an electric-field is present within the material: Only in this way can such an electric-field not accelerate these charge-carriers. If the charge-carriers are not anchored, they will always be accelerated by an applied electric-field: Superconduction which mandates the movement of charge-carriers without being accelerated by an electric-field can then not occur.

But if the charge-carriers within a superconducting-phase form an array of anchored orbitals, how does a current manage to flow through the material when external charge-carriers are being injected at a contact? As had already been pointed out in section 9.4 above, an anchored, stationary, localised orbital can move a distance (say R) through an insulator provided that Heisenberg's relationship (see Eq. 9.4) for energy and time allows the orbital to borrow enough energy ΔE in order to break free from its anchor-point and to then move with a speed v through this distance R. In other words it moves by means of a quantum fluctuation!

The required energy is thus given by $\Delta E = \Delta E_S + T_K$, where T_K is the kinetic-energy required for movement with a speed v through the distance R. Since Heisenberg's relationship for energy and time must apply during a quantum fluctuation, such movement can only occur within the time interval Δt allowed by this relationship: i.e. $\Delta E \Delta t = g\hbar$ remains valid (see also sections 1.9.12 and 9.4).

It is thus logical to argue that in order to transport a current through a superconductor, an orbital with mass m has to "borrow" the required energy ΔE to break free and move to the anchor-position of the next adjacent orbital which it then replaces. The orbital being replaced move on in the same man-

ner: When being replaced, it also borrows energy ΔE to move to the next orbital site where it replaces that orbital etc. In each case the borrowed energy is "returned" from where it came after a single orbital has "jumped" to the next position: i.e. the motion of superconducting charge-carriers is occurring (as discussed and defined in sections 9.3 and 9.4) by means of "barrier-jumping". It is postulated here that this is the only possible mechanism which allows charge-movement without requiring a permanent increase in kinetic energy of the charge-carriers. The latter would require the charge-carriers to be accelerated so that a voltage must be measured.

Assuming that the time-interval Δt is solely determined by the time it takes the orbital to move with a speed v from one anchor-site to the next anchor-site one can write that:

$$\Delta t = R / v \tag{23.1}$$

Simple, secondary school, algebra can be used to derive a formula for the speed v with which an orbital moves from one site to the next site a distance R away; subject to Heisenberg's relationship for energy and time given by: $\Delta E \Delta t = g\hbar$. The expression for the speed v is such an important formula that it will be given here and explained:

$$v = \left(\frac{g\hbar}{mR}\right)\left[1 - \sqrt{1 - \frac{2m\Delta E_S R^2}{(g\hbar)^2}}\right] \tag{23.2}$$

Owing to the presence of the square root, this is a very cunning formula: It is amazing how compatible mathematics is when modelling physics correctly. We will call the second term under the square root the superconducting-governor Λ: i.e.

$$\Lambda = \frac{2m\Delta E_S R^2}{(g\hbar)^2} \tag{23.3}$$

When this term is larger than unity, which will be the case when, for a certain value of ΔE_S, R is too large, the square root is taken over a negative number: i.e. the number is an imaginary number and the speed v is thus a complex number. Such a speed cannot manifest within our three-dimensional space: Therefore, for such large values of R the orbitals cannot jump.

When R reduces to a critical value R_C, so that the second term under the square root becomes unity, the square root becomes zero, and the speed v becomes a real number v_C which is obviously given by Eq. 23.2, as:

$$v_C = \frac{g\hbar}{mR_C} \tag{23.4}$$

Since the last term under the square root is equal to unity, one can also derive a relationship between R_C and the binding-energy ΔE_S: i.e.

$$R_C = \frac{g\hbar}{\sqrt{2m\Delta E_S}} \tag{23.5}$$

Furthermore, Eqs. 23.2 and 23.4 combine to give:

$$v_C = \sqrt{\frac{2\Delta E_S}{m}} \tag{23.6}$$

And thus:

$$\Delta t_C = \frac{R_C}{v_C} = \frac{g\hbar}{2\Delta E_S} \tag{23.7}$$

Where Δt_C is the jump-time when superconduction initiates at the critical temperature. Thus, the larger the binding-energy ΔE_S, the smaller R_C must be for superconduction to initiate.

It is mind-boggling that these simple equations provide the complete, fundamental mechanism which makes superconduction possible in all the superconductors which have been discovered to date. As will be seen in this book, the presence of the factor g explains why it has been incorrectly concluded from magnetic measurements on flux quantization that the charge-carriers in superconducting metals must be paired electrons (see section 25.7 below).

When the orbital-density increases without any change in the value of the ionisation-energy ΔE_S (which, for example, happens when lowering the temperature of the superconducting phase), the distances R become smaller than R_C: One expects that this will allow the orbitals to jump faster; but this is not the case: Contrary to intuition, the speed with which the orbitals jump, decreases when the distance R decreases.

The normalised speed v/v_C as a function of the normalised distance R/R_C is shown in Fig. 23-1. Although the diagram seems complicated, it conveys a simple message: At the critical temperature T_c one has that $R = R_C$ and below the critical temperature one has that $R < R_C$: What the value of R/R_C will be at absolute zero temperature depends on the electronic-properties of the material which, in turn, determine the minimum distance R_0 at absolute zero temperature; if there are still such localised orbitals at this temperature.

One can similarly derive the normalised time-interval $\Delta t/\Delta t_C$ required for an orbital to jump from its own anchor-site to the next anchor-site situated a

normalised distance R/R_C further on. This relationship is also shown in Fig. 23-1: In this case this time-interval increases when R/R_C decreases. Thus, even though the distance becomes shorter, the limitation placed on the barrier-jumps by Heisenberg's relationship for energy and time causes the jump-time to increase and approach a normalised value of 2 at absolute zero temperature.

It is important to emphasise here that the curves in Fig. 23-1 have been derived by assuming that the binding-energy ΔE_S remains constant while R decreases: As will be seen below, this also means that ΔE_S does not decrease when the temperature decreases. In situations where the applicable binding-energy changes when R changes, the relationship between the speed and the distance R between the orbitals will obviously be different from that shown in Fig. 23-1: However, all the data that had been published for superconductors to date seem to be commensurate with ΔE_S not changing with temperature.

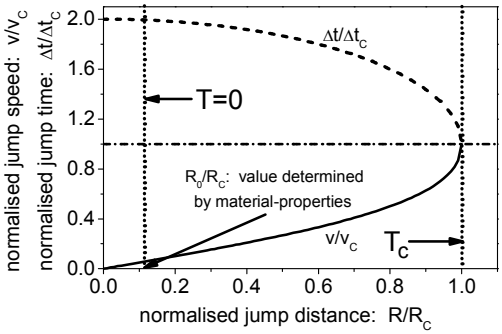

Figure 23-1: *The normalised jump speed v/v_C and jump time $\Delta t/\Delta t_C$ for an orbital (from one anchor-point to the next) as a function of the normalised jump-distance R/R_C between adjacent anchor-points: It is assumed that the ionisation-energy ΔE_S remains constant.*

At low temperatures for which R is far smaller than R_C, the jump-speed in Eq. 23.2 can be approximated by:

$$v = \frac{R\Delta E_S}{g\hbar} \qquad (23.8)$$

How does an orbital replace the next orbital? A possibility is that they interact by means of "transient entanglement". The proposed mechanism could be as follows: For a short time interval $\Delta t_r = \Delta t_e$ the two waves "merge". The energy of the merged wave is, however, too large to remain at the anchor-

site for longer than a very short time interval. At the end of such an interval, two orbitals disentangle: One remaining at the anchor-site, and the other proceeding further to the next anchor-site; etc.

It is therefore possible that the value of Δt could be longer than the actual time-interval Δt_v to move from one anchor point to the next one: It might have to include a time interval Δt_e during which it breaks free, and a concomitant time Δt_r to replace the next orbital. Thus, if the time to move with a speed v from one anchor-site to the next anchor-site is $\Delta t_v < \Delta t$, then the total time given by $\Delta t = \Delta t_e + \Delta t_r + \Delta t_v$ is determined by Heisenberg's relationship for energy and time. Since v_C is now determined by a smaller time interval Δt_v, it could be different from the values derived above.

One expects, however, that in most cases the time intervals Δt_e and Δt_r will be much shorter than Δt_v; so that they can be neglected. Furthermore, one expects that the time to break free (given by Δt_e) and the time to replace the next orbital (given by Δt_r) must be the same: It seems logical that when an arriving orbital requires the time-interval Δt_r to replace the next orbital, that this should be equal to the time Δt_e for the next orbital to break free.

To summarise: For a binding-energy ΔE_S there is a critical distance R_C, so that when the distances R between adjacent orbitals are larger than this distance, barrier-jumping from one anchor-site to the next cannot occur. When, however, $R \leq R_C$ an orbital can borrow energy ΔE to break free and to move with a speed v to the position of the next orbital where it then replaces this orbital; at which point it "returns" all the borrowed energy: The orbital it replaces then borrows energy and moves to the next site; etc. Charge is thus transferred by the orbitals running a relay race: And this happens without permanently acquiring kinetic energy by acceleration, which, if it were generated, requires the presence of a non-zero electric-field. As already pointed out, if such a field does exist and energy is generated by acceleration of the charge-carriers, superconduction will not occur.

23.3 Perpetual motion

As discussed, in section 7.2.5, an engine which can obtain energy from a source, then uses this energy to do work, and then returns the same amount of energy to the source, will be a perpetual-motion machine (see Fig. 7-2). In the case of superconduction, an orbital obtains energy, when it is allowed by Heisenberg's relationship for energy and time to do so, then uses this energy to do work (break free and move to an adjacent position) and then returns this energy to where it came from. Thus when orbitals convey a super-current, each barrier-jump occurs by means of a perpetual motion cycle.

The latter is a hell-of-a-risky statement to make; since claiming "perpetual motion" has become synonymous with being a crackpot. This is probably the reason why one will only find statements in the scientific literature like the following: "S*uperconduction is the nearest that we can get to perpetual mo-*

tion". It should, however, be crystal clear that the only way in which an electric current can keep on flowing around a ring without requiring continuous acceleration, must be by means of perpetual motion!

What is the source of this energy which is continually being borrowed and returned? As already discussed in section 7.5.9, the kinetic-energy of a stationary, harmonic electron-wave does not reside within our three-dimensional space, but within a fourth- and a fifth dimension (related to Argand-space). Thus, it is compelling to conclude that the energy required for an orbital to move, must appear within our three-dimensional space from external dimensions which we cannot observe within our three-dimensional space; and is then returned to these external dimensions.

When observing such a process, one will conclude that the energy appears "out of nothing" (i.e. it is "vacuum-energy"): However, this energy is not the same, nonsensical "vacuum-energy" which is modelled by quantum field theory. The amount of "vacuum-energy" driving superconduction relates directly to the amount of mass-energy within our three-dimensional space: It is not "infinite" and does most certainly not require "renormalisation".

About ten years ago cosmological observations found that our universe is not just expanding, but that this expansion-rate is increasing. This behaviour has been ascribed to the presence of "dark-energy"; which requires that a cosmological constant should be added to Einstein's equations that model the general theory of relativity. It seems compelling to conclude that it is this dark energy which enables superconduction to occur. Can we tap into it in other ways? If we could, it would be the ultimate solution to obtain clean energy for our planet's future.

23.4 Low-temperature metals

23.4.1 Anchored orbitals in a metal

Can an insulating phase, consisting of anchored orbitals, form within a metal? As had already been pointed out in section 8.13.1 above, Eugene Wigner predicted in 1938 that exactly such an array of orbitals should form at low temperatures within "non-ideal"-metals. As had also been pointed out, the heat-capacity of the e-matter within such a metal must increase sharply when such a metal-insulator transition occurs: i.e. at the point when the Fermi-level moves into an energy-gap. This is exactly what is observed when a metal is cooled through its superconducting critical-temperature T_c (see Fig. 15-1).

In addition to the Fermi-level moving into the gap, the density of Wigner-orbitals must already be high enough so that the distances R are less than the critical distance R_C at which superconduction becomes possible. Since two conditions must manifest for superconduction to be possible, it seems reasonable to ask which one manifests first when cooling a superconducting metal. Could the Fermi-level move into the gap while the orbitals cannot yet move by barrier-jumping? It seems that this occurs in the case of disordered,

metallic superconducting thin films (see section 23.7 below); and also in the case of the higher temperature ceramic superconductors (see section 23.5 below); causing a so-called pseudogap in the latter case.

23.4.2 Transferring a single charge

Consider the following hypothetical case illustrated schematically by the electron-energy diagram in Fig. 23-2:

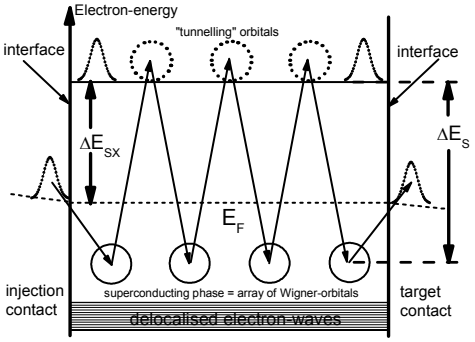

Figure 23.2: *Schematic electron-energy diagram illustrating how the charge of a single injected wave-packet is transferred through a superconducting phase consisting of an array of Wigner-orbitals. Since the energy for movement from one orbital site to another is supplied by the Heisenberg's relationship for energy and time, the total energy of the superconducting phase remains at the same lowest equilibrium energy. Since there is no electric-field within the superconductor, the Fermi-level has the same energy at the injection- and target-contacts. Within the contacts there is an electric-field and therefore the Fermi-level changes with position: i.e. has a slope.*

The Fermi-level is present within the energy gap, as it must be for superconduction to be possible, and the density of Wigner-orbitals is high enough to allow barrier-jumping: A single wave-packet is injected from a metal-contact into such an insulator: It reaches and replaces a stationary orbital near the injection-contact by "morphing" to become a trapped orbital at that site: Using the same impeccable interface-physics, mentioned in sections 9, 12 and 13., it is easy to prove that the latter replacement is energetically possible.

There are now two possibilities:
(i) The amount of kinetic-energy with which the injected charge-carrier reaches the site of the first orbital, is transferred to the second orbital during the brief encounter at this anchor-site. The latter orbital then borrows the additional energy required to move on and replace the next orbital; which in turn borrows additional energy and moves on to the next site, etc. The injected

energy is thus “piggy-backed” from the injection-contact to the target-contact. This seems unlikely.

(ii) The alternative scenario is that this amount of additional energy with which the charge-carrier is injected, dissipates when the injected charge-carrier replaces the first orbital. It should be noted that such dissipation of energy within the superconductor adjacent to the injection-contact cannot be ascribed to “resistance” within the superconductor: This is so since the kinetic energy has been generated outside the superconductor: Thus, even though this kinetic energy is dissipated after entering the superconductor, the concomitant resistance has to be added to the electronic elements outside the superconductor. By sequential, synchronous replacements of orbitals, an orbital will eventually be replaced at the target-contact. The last orbital can now borrow energy to move into the contact: It then returns the borrowed energy: This would mean that there is a layer within the contact which acts as an induced superconductor. Such an effect has been found experimentally and is called the proximity effect.

The injected wave-packet causes a relay race so that an orbital finally enters the target-contact; within which it morphs into a wave-packet. The latter wave-packet then becomes part of the non-superconducting target-contact and is thus accelerated further into the contact. From starting off as a wave-packet within the injection-contact, an injected charge reappears as a wave-packet within the target-contact: i.e. it is as if a wave-packet simply “disappeared” within the injection-contact, while later “reappearing” within the target-contact.

A single charge can thus be transferred in this manner from the injecttion-contact to the target-contact without any acceleration of the charge-carriers within the superconductor: No voltage-difference can thus be measured across any two contacts (between the injection and target-contacts) to the superconducting material when a current is flowing since there is no energy-difference between the charge-carriers at the injection-contact and the charge-carriers at the ejection-contact.

If the charge-carriers within the superconductor could have been accelerated by an applied electric-field, as they will be if they are, for example, Cooper pairs which are not anchored entities, kinetic energy must be generated by acceleration: i.e. potential energy must be transmuted. A voltage must then be measured across two contacts to the material: Superconduction can then not occur; even if it were possible that there could be no scattering at all of the charge-carriers between the injection- and the target-contacts; and even if there could be no scattering outside the superconductor. The mere absence of scattering is not a sufficient requirement for superconduction to occur.

23.4.3 Drift speed of charge-carriers

It should also be noted that for the mechanism based on barrier-jumping, which is being proposed here, there is an average drift-speed v which is created by the interrupted movement of the charge-carriers from one anchor-point to the next one. In this case, this interrupted movement is not caused by acceleration-scattering events (see section 14); but by (energy-borrowing)-(charge-transfer)-events; as allowed by Heisenberg's relationship for energy and time. It is for this reason that the charge-carriers still move with a constant drift-velocity even though they are not being accelerated-and-scattered. This non energy-dissipative, interrupted, steady-state movement would not have been possible if the charge-carriers could have been accelerated by an applied electric-field.

23.4.4 Coherent movement of charge-carriers

What is even more significant to note is that not all the charge-carriers within a superconductor move "with long-range coherence" to transfer a current; as is being assumed in the BCS-theory. To transfer a current by superconduction, the phase must only transfer those charges which are being injected at the injection-contact: Obviously no more than this is required.

A single charge-carrier has already been considered above. If the injection of a single charge-carrier has to cause all the Cooper pairs to move with long-range coherence, how does its solitary appearance at the injection-contact (within the superconductor) induce the Cooper pairs (as a collective entity) to move simultaneously? Obviously, such an assumption leads to nonsensical physics!

There is, however, coherence in movement when more than one charge carrier is injected per unit time (see section 27.6).

23.4.5 Maintaining a ground-state

Consider the superconducting-phase before any charge-carriers are being injected: As already postulated above, it consists of an array of anchored orbitals. Furthermore, each one of these orbitals cannot relax to a lower energy. Thus, the macro Schrödinger wave defining the superconducting-phase is at the lowest energy it can be at, subject to the boundary conditions under which it exists: It is in a so-called macro quantum-mechanical "ground-state" as one would expect that it must be in order to act as a superconducting phase; or else it will have energy which can dissipate. We will call this wave sc-matter.

Now apply an electric-field across the superconductor without injecting charge-carriers. The orbitals become polarised: This causes their energies to increase: This means that their ionisation energies ΔE_S (see Fig, 23-2) decrease to become equal to $\Delta E(E)_S < \Delta E_S$.

The material is now in a higher energy state: However, as soon as charges are injected so that a superconducting-current flows from the injecting-contact to the target-contact, this current short-circuits these contacts: This is so since the charge-carriers leaving the injection-contact arrives at the target-contact still having the same energy. There is thus not a difference in potential energy required between the two contacts. This in turn, means that there cannot be an electric-field within the material. The binding-energies of the orbitals return to being ΔE_S when a supercurrent is flowing.

Initially I have made the mistake to argue that the charge-carriers can be polarised even when a current is flowing. Fortunately, it was pointed out to me in no uncertain terms in a discussion forum on the internet that I have been utterly stupid to reason in this manner, since if there is no electric-field during current flow, there is also not an electric-field to polarise the charge-carriers. This criticism is correct and I apologise for having reasoned otherwise. My only defense is that we are all human beings that can make mistakes: Even Einstein divided by zero in one of his manuscripts. It is just a pity that the persons who corrected me made far more mistakes on this same discus-sion forum, but refuse point blank to admit that they could be wrong.

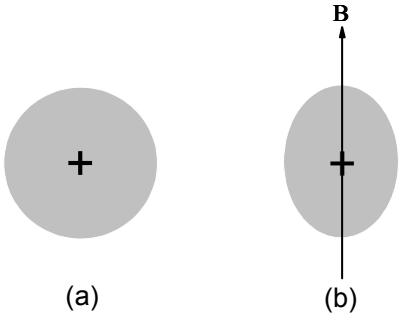

Figure 23-3: *Schematic illustration of Wigner-orbitals within a non-ideal metal forming a distributed electron-charge around an induced positive charge: (a) Spherically symmetric orbital in the absence of a magnetic-field; (b) Ovoid orbital with higher energy when switching on a magnetic-field.*

The application of a magnetic-field has a more permanent effect. When solving the Schrödinger equation for an electronic harmonic-oscillator in the presence of a magnetic-field, it is found that the orbitals distort from being spherical to become ovoid around the field-direction (see Fig. 23-3(b)). This increases the energy of each orbital, and thus decreases the ionisation-energy from ΔE_S to become $\Delta E(B)_S$. This decrease in binding-energy, also decreases the activation-energy to become $\Delta E(E)_{SX}$. This lowering in energies, however, remains in this case when a superconducting-current is flowing. By

increasing the magnetic field, the activation-energy will eventually become zero: At this point the Fermi-level moves out of the gap and an insulator-to-metal transition occurs. Superconduction will disappear. It is, of course, a well-known property of superconductors that a strong-enough magnetic-field quenches superconduction.

What is important to emphasise is that, when injecting-charge-carriers, a current flows in order to maintain a lowest-energy equilibrium state. This can be seen as follows: During current flow the density of the anchored orbitals and their total energy stays the same since the extra moving orbitals are not anchored and are moving by borrowing energy. They are (so to say) being "juggled to stay in the air" in order not to become part and parcel of the sc-matter. Oh how cunning is the Lord!

From a "black-box" perspective, one can reason that one has a single macro-wave constituting the ground-state sc-phase so that when a charge-carrier is injected (which would require the wave's energy to increase) a similar charge must be ejected at the target-contact within a time Δt_M as allowed (for the whole macro-wave) by Heisenberg's relationship for energy and time. The charge-carriers "within" the macro-wave might be different for different macro-waves: In the case of the low-temperature metals the evidence is compelling that they are Wigner-type orbitals.

23.4.7 Binding- and activation-energies

At temperatures higher than absolute zero the activation-energy ΔE_{SX} is smaller than the ionisation-energy ΔE_S (see Fig. 23-2). Since, for the low-temperature elemental metals, the initiation of superconduction requires that the Fermi-level moves into the gap, ΔE_{SX} starts off being zero at the critical temperature, and increases towards ΔE_S when the temperature of the superconducting phase approaches absolute zero. One can measure the activation-energy ΔE_{SX} by, for example, doing "tunnelling" (barrier-jumping) experiments across interfaces between different superconductors (see section 28 be-low) or by other methods.

According to the BCS-model, the energy ΔE_{SX} is interpreted as the binding-energy (usually written as 2Δ) of a Cooper-pair. As had already been mentioned above (see section 15.4), such an interpretation can never explain the sudden increase in heat-capacity of the e-matter at the critical temperature T_c. In the case of the Wigner-orbitals the reason for this increase is crystal-clear; since, at the critical temperature T_c, the Fermi-level moves into the energy-gap and therefore a metal-insulator transition occurs: This mandates that such a jump in heat-capacity must occur.

Measurements of energy-gaps within superconducting lead (Pb), using inelastic nuclear scattering, are shown as a function of temperature in Fig. 23-4. These results were recently published in *Science* (volume 330, page 1509; 2008), and created quite a stir. The authors reported two gaps; which

are shown by the square and triangular data points: The square data points were "identified" as the "binding-energy" 2Δ of the Cooper pairs while the appearance of the triangular data points could not be explained. The theoretical curve for the binding-energy, as calculated from BCS-model, is shown in Fig. 23-4(a).

The stir was caused by the fact that the triangular data-points and square-data points converge when absolute zero temperature is approached. They become the same gap.

Science asked an expert on superconduction Dr. D. J. Scalapino, for a perspective comment on this unexpected result; and part of his comments is the following: "*The data imply that either there is new physics not contained in the accepted theory of superconductivity or there is some aspect of this theory that we have not yet recognized. Either way, it is remarkable to learn something new about elemental superconductors, which we thought were understood more than 40 years ago.*"

The actual fact is, however, that the accepted BCS-theory of superconduction is just plain wrong; and it is for this reason that it cannot explain these results! In Fig. 23-4(b) the best theoretical fit to the square data-points is shown when assuming Wigner-orbitals and barrier-jumping; and allocating this energy-gap to the activation-energy ΔE_{SX} (see Fig. 23-2 as a reminder): It is crystal clear that the latter model is able to fit the square experimental data-points far better than the BCS-model does in Fig. 23-4(a).

Furthermore, from the Wigner-orbital model, one expects that localised (triangular) energy gaps should already be present at temperatures larger than the critical temperature, since it is a measure of the ionisation-energy ΔE_S of Wigner-orbitals which already start to form at localised positions before the Fermi-level moves into this gap (see Fig. 8-10 as a reminder). Only when the Fermi-level moves into the gap does the activation-energy gap ΔE_{SX} appear and it then increases with decreasing temperature from zero to become equal to the ionisation-energy ΔE_S at absolute zero; exactly as found experimentally.

Since *Science* found this data exceptional, and since this magazine is the mouthpiece of the American Association for the Advancement of Science (AAAS), they would surely be very excited that I can propose a solution which fits and explains the data far better than the accepted BCS model does. Is this not what physics is all about; especially if it is your purpose to <u>really</u> advance science? I thus submitted a short manuscript which was rejected by the senior editor Dr. Ian Osborne so fast that I wonder whether the manuscript passed over his desk exceeding the speed of light (see also section 37).

I also decided to send a copy to Dr. Doug Scalapino which exacted the following message from him: "*The BCS theory of superconductivity has been clearly established and Pb is essentially the poster child for the electron-*

phonon mechanism. Thus I believe that what Keimer et al have found will be explained within a frame work that explains essentially all that is seen in Pb. This is the BCS theory as expressed in the Eliashberg formalism." Translated it means that: "*We will find an epicycle, or suitable fudge-factor, so that we do not have to reject the BCS-model!*"

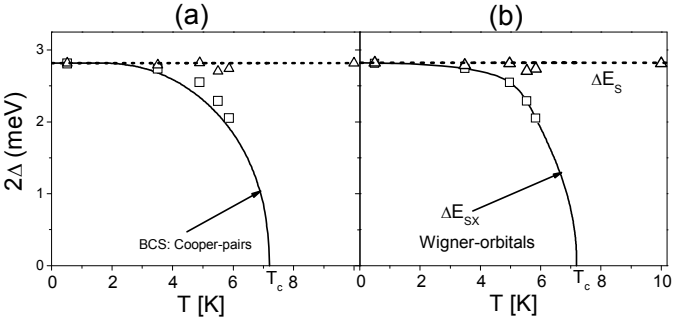

Figure 23.4: *Energy gaps measured by means of inelastic neutron scattering at different temperatures when lead is cooled through its superconducting critical temperature T_c. [From:* P. Aynajian, T. Keller, L. Boeri, S. M. Shapiro, K. Habicht, B. Keimer, *Science* **330**, 1509 (2008)]. *The two gaps shown by the square and triangular data-points respectively, approach the same value when the temperature approaches absolute zero. (a) Here the square points are interpreted as the binding-energy of Cooper pairs. The solid curve is the best theoretical fit when using the BCS-model. (b) Here the square points are interpreted as the activation-energy for an array of Wigner-orbitals. The solid curve is the best theoretical fit using the model described in this section of this book.*

Wow!! Is this the same guy who wrote: "*Either way, it is remarkable to learn something new about elemental superconductors, which we thought were understood more than 40 years ago."?* In other words: "*Yes the answer lies somewhere in the dark, but I believe we will find it by searching under the street lamp. Thus don't confuse me with any alternative explanations!"* And we thought that physicists have learned from Galileo!

23.4.8. Wave packets and zero volt

Since, within the temperature range $T_c > T > 0$, one has that: $\Delta E_{SX} < \Delta E_S$, there are still thermally-activated electronic wave-packets with energies which are at least ΔE_S higher than the energies of the Wigner-orbitals (as schematically shown also in Fig. 23-2): These wave-packets cannot cancel an applied electric-field at their positions while a current is flowing: So why do they not accelerate?

As already pointed out above, the simple fact is that as soon as super-conduction initiates, there are two parallel channels available for injected charge-carriers: One which do not require a voltage across the contacts, and another which do require a voltage across the contacts: From an electronic point of view one can immediately see that the path, not requiring a voltage, short-circuits the path requiring a voltage; so that no voltage is possible across both parallel paths. Thus, for this reason, the wave-packets cannot be acele-rated when a superconducting-current flows.

23.4.9 Isotope effect

The frequency of "an electron" vibrating through an induced positive charge within a material is strongly dependent on the isotope mass of the atoms within the material. The proof will not be done here: It is simple first year physics.

As had already been mentioned in section 15.4, the reason why it is believed that Cooper pairs are formed by the exchange of virtual phonons is exactly the presence of this isotope effect within the low-temperature metal-superconductors. But by using this experimental observation to postulate Cooper pairs, the fact was ignored that the isotope-effect does not occur within all the low-temperature metal-superconductors. To overcome this difficulty, fudge-factors had to be introduced to explain this inconvenient truth away.

In terms of Wigner-orbitals this behaviour is straightforward: When the induced positive charge is such that the electron does not vibrate directly through it, the isotope effect becomes smaller and even negligible. Whether the electron vibrates directly through an induced positive charge or just within the field of a positive charge, is determined by the symmetry involved at the site of vibration. As will be seen in section 23.5, this is also the reason why the isotope-effect is different and mostly negligible for the high-temperature ceramic-superconductors.

23.5 Entangled superconducting phase

23.5.1 Macro-entanglement of electrons

In the case of the superconducting phase which forms between an n-type diamond's surface and an anode, stationary anchored Wigner-orbitals cannot form within a vacuum and remain there when switching off the current. There is only one way in which this phase can stay stable when no current is flowing: It has to be a single, holistic ground-state wave which is not formed by simple superposition of single-electron waves: If single-electron, or bi-electron waves were present, the latter waves or orbitals would push each other out of the gap when there is no current flowing.

As already alluded to above, this sc-matter wave must be an entity which has formed from "electrons" in such a manner that the single-electron waves totally lose their individual identities: i.e. the sc-matter is in this case a

macro-wave which has formed by the “entanglement” of many single-electron waves. When injecting an extra electron wave-packet into such a wave, this “electron” also entangles and thus “disappears” at the injection-contact: In this process it increases the energy of the ground-state wave. To remain in the ground-state, the wave has to (within a time Δt) eject an electron at the target-contact.

23.5.2 Teleportation?

The fascinating aspect is that “within” this holistic wave there are not separate orbitals which can convey a current. An injected electron must thus “materialise” at the target-contact without a current flowing from the injection-contact to the target-contact. This is called “non-local transfer of charge”; which, although having been discussed in the scientific literature, has never been demonstrated experimentally before I did my experiment. Another way to interpret this process is to say that the charge has been teleported from the injection-contact to the target-contact.

23.5.3 Faster than the speed of light?

Even more fascinating is the fact that such a superconducting phase must under suitable conditions transmit an electric signal from an injection-contact to a target-contact at a speed faster than the speed of light. When the energy ΔE of the signal being injected exceeds a certain limit, the allowed time interval Δt becomes small enough so that the total injected charge must be ejected at the target-contact within a time which is much shorter than the time required for a “particle” with mass to move from the injection-contact to the target-contact; even at the speed of light.

This is, of course, further proof that entanglement allows communication between different parts of an entangled wave at a speed that is faster than the speed of light. It is also further proof that the Copenhagen-interpretation must be wrong since two separate waves (or “particles”) cannot achieve this feat; just as Einstein, Podolsky and Rosen had correctly pointed out: The principle of complementarity is obviously wrong!

23.6 The ceramic superconductors

23.6.1 Why ceramics?

What should be obvious by now is that superconduction via charge-carriers occurs under conditions when Heisenberg’s relationship for energy and time allows it to occur: i.e. only when orbitals constituting a “multi-particle” Schrödinger wave within a material can borrow energy to accommodate an increase in energy for a time interval Δt, while transferring the charge. In a metal this only becomes possible after the metal has gone through a metal-insulator (MI) transition: Most probably the one which had been modelled by Wigner in 1938. It thus seems compelling that one should rather seek for superconduction within insulators than within metals.

From this perspective it is not really surprising that Bednorz and Müller discovered superconduction with higher critical temperatures within the copper-oxide ceramics: These materials are normally insulators! They always have localised orbitals which become polarised when applying an electric-field. But why do all insulators then not superconduct?

The reason is that for superconduction to occur, the orbitals must have a high enough density which allows barrier-jumping to occur: i.e. an orbital must be able to borrow an amount of energy which is larger than the binding-energy ΔE_S of the orbitals. If the density of the orbitals is too low for the value of ΔE_S, superconduction is not possible.

To increase the density of orbitals, ΔE_S must increase; but this increase must be low-enough to accommodate the limitation placed on the process by Heisenberg's relationship for energy and time. Only when these two conditions are simultaneously satisfied at a temperature T is superconduction possible through an insulating material at this temperature. In most insulators the binding-energy ΔE_S is too high to allow superconduction for the available densities of their orbitals.

23.6.2 Importance of layers

The copper-oxide ceramics are able to form orbital arrays which simultaneously have a high-enough density and a low-enough ionisation-energy ΔE_S so that superconduction is able to manifest at higher temperatures than within the metal-superconductors. The reason for this is that these materials all have a layered crystallographic structure consisting of planes of atoms with gaps between these planes. This does not imply that all layered structures can form a superconducting phase; but only that it can be an advantage when it comes to the formation of a superconducting phase in these materials. It might even be mandatory.

So how does a layered structure help? Suitable orbitals can form between these crystallographic layers. Thus, if there are suitable donors within the crystallographic layers which can eject electrons into the gaps between the layers, and if these electrons can lose energy during this process, these ejected electrons will form an array of anchored orbitals within these gaps between the crystallographic layers.

It is a well-established fact that these materials must be doped before they can superconduct: However, in the standard literature it is believed that these dopants must be acceptors. The reason for this is that above the critical temperature T_c hole-conduction is measured within the crystallographic layers. The fact is, however, that hole-conduction is measured precisely because there are donors which eject electrons into the gaps between the crystallographic layers: i.e. the electrons they donate do not end up at a higher energy within a conduction-band but at a lower-energy ΔE_S between the crystallographic planes where they form an insulating array of orbitals. This initial

phase when lowering the temperature has been observed in the ceramic superconductors and has been ascribed to a so-called pseudogap.

The mathematical modelling will not be done in detail here: Suffice to say that in such a situation, those donor-electrons which are still within the crystallographic planes (and not within the gaps between the layers) can move to neutralise ionised donors; and when the ratio of non-ionised donors to ionised, positively-charged donors is high, it will seem as if it is positive-charges which are moving: A Hall-effect measurement will thus record the motion of holes within the layers; just as is observed.

A schematic illustration of such an orbital-array between crystallographic planes is shown in Fig. 23-5. In this figure, the orbitals have been chosen to be singly-charged and situated on only one crystallographic interface to the gap. Obviously, other arrangements are possible: For example, singly-charged orbitals situated on both interfaces to the gap which jointly form a single array of orbitals; doubly-charged orbitals connected like covalent bonds between the two interfaces; etc. I have deliberately chosen singly-charged orbitals because, as will be seen in this book, it is not necessary for them to be doubly-charged in order to convey a supercurrent. In fact the evidence is compelling that in all the superconducting materials discovered to date the charge-carriers are singly-charged.

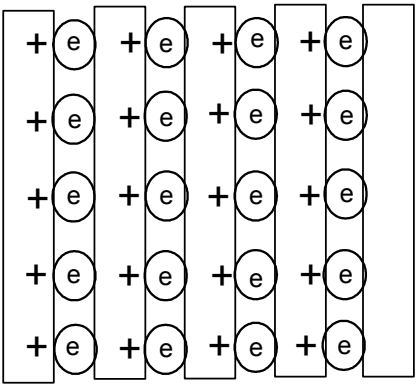

Figure 23-5: *Schematic illustration of arrays of donor-generated "electron-orbitals" between crystallographic layers within a typical superconducting copper-oxide ceramic.*

Since there is an energy-offset ΔE_S between the donor-centres (within the crystallographic layers) and the lower-energy orbitals (between the layers), the density of orbitals will increase with decreasing temperature, just like the density of Wigner-orbitals does within a metal. Superconduction thus (al-

so in this case) initiates when such an orbital-array reaches a critical density at which the orbitals can transport charge by means of Heisenberg's relationship for energy and time.

The reason why these materials can superconduct at temperatures higher than the low-temperature metals is that the orbital-density is determined by the density of donors; and this density is very much higher than the density of induced positive-charges can be within a metal. Thus, the orbital-density becomes high enough within the ceramics for superconduction to initiate at higher temperatures.

As already discussed in section 9.1, parallel to the crystallographic planes such orbitals are (like Wigner-orbitals) Gaussian zero-point waves. But in this case, the "electron" forming the lateral-orbital does not "vibrate" through an induced positive charge, but within the field of a positive donor-charge which is situated within the crystallographic-layer. One thus expects a different isotope effect than what is measured within the elemental metals (see section 23.3): This has been, and still is consistently observed experimentally for these materials. This is one of the aspects which the "experts" in charge of the superconductor physics-sect just could not yet figure out. And as long as they cling to the concept of pair-formation, they will never be able to understand it.

23.6.3 YBCO

A ceramic superconductor which has been studied intensively is yttrium-barium-copper-oxide (which has become known as YBCO). When the crystallographic-structure of YBCO is "chemically correct", the number of oxygen atoms per unit cell is equal to 7. The layered crystallographic-structure of this material is formed by copper-oxide (CuO_2) planes which are separated by yttrium (Y) atoms. Below these planes there are barium-oxide (BaO) planes and then planes within which oxygen atoms are aligned along chains. In YBCO, as in many of the other related ceramic superconducting materials, oxygen is usually stoichiometrically deficient: This impressive word means that (in this case) the number of oxygen atoms per unit cell is less than 7.

It is found experimentally that superconduction occurs when the number y of oxygen atoms lies within the following limits $6.4<y\leq 7$. It has been experimentally concluded that when y reaches the value 6, there are none or very few oxygen atoms forming oxygen chains. Superconduction relates to the presence of the latter atoms. This is demonstrated by the experimental data points in Fig. 23-6. The critical temperature increases as the oxygen content y increases above the value 6.4. There is, however, a plateau with the critical temperature at $\approx$60 K for values of y between 6.6 and 6.8. The BCS-model cannot explain any of this behaviour at all.

This data provides compelling evidence that the oxygen atoms within the chains must be forming donor-centres which supply electrons so that the

required arrays of electron orbitals form between the crystallographic planes. Using the model proposed here, the dotted curve in Fig. 23-6 is an average fit through all the data points. In turn, the solid curve has been fitted through all the data points with the highest critical temperatures. For both curves one finds that the oxygen-density y_0 at which oxygen-atoms start to fill the donor chain positions is not equal to 6. For the solid curve it is $y_0 \approx 5.36$: This indicates that not all the non-chain oxygen sites have been filled when the chains start to form.

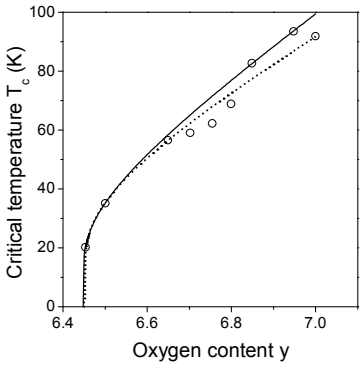

Figure 23-6: *Theoretical curves fitted to YBCO data. The dashed curve is the best average fit, while the solid curve has been fitted through the highest critical temperatures. (Data from: K. Segawa and Y. Ando, Phys. Rev. Lett.* ***86*** *4907 (2001))*

Therefore one can explain the 60 K plateau as follows: When increasing the oxygen atoms, they at first keep on adding mostly to the chain-sites while those atoms not in chain-positions stay approximately constant at $y_0 \approx 5.36$. The plateau initiates when some, if not all the oxygen atoms being added, start to fill non-chain positions, until they are all filled. After this point is reached, all the additional oxygen has to fill chain-positions again and the data points increase to fall on the solid curve.

The decrease in T_c, when y is equal to 7, is explained by a decrease in ΔE_S when the orbital-density increases beyond a certain value. That this must be so can be easily proved by solving Schrödinger's equation for an array of orbitals: Above this density the increase in Coulomb-repulsion (between the orbitals) causes this decrease. In fact within some of the ceramic superconductors this interaction becomes so strong that superconduction stops before the maximum possible density of dopants has been achieved.

The accepted models for superconduction cannot explain Fig. 23-6, while my model can. Do you think I could succeed to get this information pub-

lished over the last six years? Not on your ninny! “How can the BCS-model be wrong? It has withstood the “test of time for more than 50 years!”

23.6.4 Applying pressure

Recently data have been published within *Science* (Y. Takabayashi *et al.* vol. 333, page 1585: 2009; see also commentary on page 1570 of the same edition) showing that by applying pressure to a suitable insulating material, superconduction can be induced with a critical temperature which increases with pressure. The critical temperature eventually goes through a maximum and then decreases to again approach zero. It was pointed out that this behaviour is similar to the increase in critical temperature when increasing the dopant-density within some of the ceramic superconductors.

Obviously this behaviour cannot be explained by BCS-theory: In terms of my model, however, this is exactly what one would expect to happen. When increasing the dopant density one increases the orbital-density so that the distances R between them become less. When applying pressure, one pushes the orbitals towards each other to in this way decrease R. The effect must thus be the same!

Do you think I should submit another manuscript to *Science* in order to help them out of their misery? I would like to, but I am sure that Dr. Ian Osborne will again wipe this heresy from his desk.

23.7 Superconduction through p-type diamond

23.7.1 High dopant density

As had already been mentioned in section 21, superconduction at low temperatures has been discovered in 2004 within heavily boron-doped, p-type diamond (E. A. Ekimov *et al. Nature,* vol. 439, page 543: 2004). By heavily-doped, it means that the density of acceptor-sites is so high that a Mott-transition has occurred with the formation of a hole impurity-band.

23.7.2 Hole-energy diagram

As had been pointed out in section 8.11 above, when working with holes and acceptor states, the electron-energy diagram must be inverted to obtain a hole-energy-diagram. Such a diagram which depicts the required conditions that allow superconduction to occur within a highly-doped p-type diamond is shown in Fig. 23-7.

It should be remembered that the electron valence-band is now the “hole-conduction-band”, and that the impurity-band consists of delocalised hole-states. Furthermore, since the acceptors do not form a perfect crystalline structure, there is a mobility-edge; above which there are localised hole-states owing to an Anderson metal-insulator transition.

The similarity of this energy diagram to the one in Fig. 23-2 is obvious; except that the localised “Wigner-orbitals” are now positively charged. One thus expects that when these localised states (above the mobility-edge)

reach a suitable density, superconduction by means of the barrier-jumping mechanism should become possible. This is exactly the reason why superconduction occurs through such a highly-doped semiconductor.

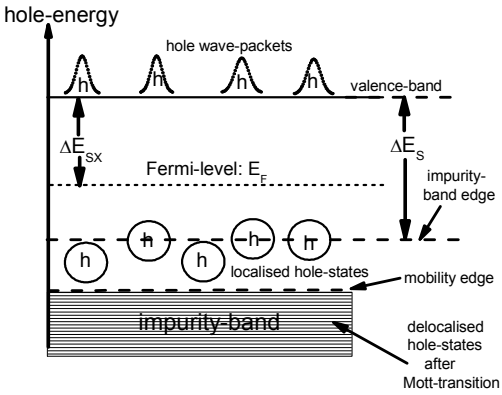

***Figure 23-7: H**ole-energy diagram for a highly-doped, superconducting, p-type diamond.*

23.7.3 Disordered localised states

At a specific temperature and dopant density, superconduction becomes possible when the nearest-neighbour distances between orbitals with a suitable ionisation-energy ΔE_S are all smaller than the applicable critical distance R_C as determined by Heisenberg's relationship for energy and time; even when these orbitals are surrounded by other orbitals with different ionisation energies.

It is important to note that a single link in such a network, for which the distance that an orbital must move by barrier-jumping from its position to an adjacent position is larger than R_C, will make charge-transfer by means of barrier-jumping impossible. In terms of scientific parlance it is said that a "percolation threshold" must be reached before such a network can transport charge from one contact to the next. At this threshold the longest distances between adjacent orbitals are equal to, or less than R_C: A "connective pathway" (from the injection-contact to the target-contact) is thus established.

23.7.4 Increasing the dopant density

It is clear that the higher the boron-dopant density becomes, the higher the density of the localised hole-states above the mobility-edge becomes. At a suitable temperature, a point will be reached at which the density is high enough for superconduction to initiate. This, in turn, means that the higher the boron-density becomes, the higher the critical temperature will become at which superconduction initiates. This is exactly what has been observed.

Typical data-points for the critical temperature T_c as a function of boron-dopant density [reported by T. Klein *et al. Phys. Rev. B* vol. 75, page 165323: (2007)] are shown in Fig. 23-8. The BCS-model cannot explain this behaviour; and never will be able to do so. The solid curve has been calcu-lated using barrier-jumping. The fit is perfect!

An interesting question to ask at this point is whether these hole-localised-states are really the same as the orbitals which had been predicted by Wigner: Can one model them as holes which are "vibrating" through an induced negative charge? It is highly probable that this is the case since there are indications that the critical temperature does depend on the isotopic mass of the boron atoms.

Did I get this result published? Nowhere! It was consistently rejected everywhere: Especially viciously by the "diamond physics-sect" (see discussion in section 37).

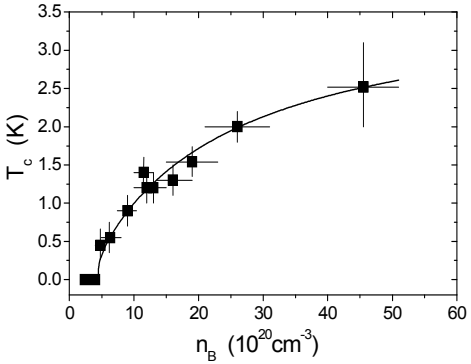

Figure 23-8: *The critical temperature as a function of boron-acceptor density within a heavily-doped diamond (T. Klein et al. Phys. Rev. B* ***75****, 165323-1-4, 2007). The BCS model cannot explain this relationship. The solid curve has been fitted using the barrier-jumping mechanism.*

23.8 Superconduction through disordered thin films

23.8.1 Original intent

Superconduction within disordered thin films has been an ongoing study for nearly 70 years. The literature within this field is vast and can thus not be covered here in detail. A few important aspects will be summarised:

As already discussed in section 8.13, crystallographic disorder causes Anderson-localisation of extended (delocalised) valence-electron waves to form an insulating-phase: i.e. a phase which, above absolute zero, conducts

by some form of hopping conduction and which is expected to be an insulator at absolute zero temperature. Since superconduction has been consistently modelled as a manifestation of long-range phase-coherence between Cooper-pairs, it has been argued that a high-level of electronic-localisation must place a limitation on the size of the concomitant superconducting electron-waves: And this must, in turn, destroy the supposed "electron-pairing" as well as any "long-range coherence" between such supposedly "boson-like charge-carriers".

23.8.2 Homogeneous disorder

It has indeed been found experimentally that suitably-disordered, superconducting thin films become insulating when the amount of disorder is above a critical level D_C. It is obviously a problem to define a parameter which can be used to quantify the level of disorder: For example, some films are granular since they consist of small crystallites. The preferred films are those which are so-called "homogeneously-disordered" so that the effect that this disorder should have on superconduction will hopefully be the same at "every point" within the film. Various techniques have been developed to generate such films. These techniques are not directly of interest here and will thus not be discussed.

23.8.3 The separatrix

Just as in the case of a non-disordered material, a film with disorder, which is less than D_C, can, by the application of a magnetic field, be prevented from forming (or staying within) a phase which is able to superconduct. The behaviour of superconducting thin films when increasing the disorder and the behaviour when such a thin film is subjected to an increasing magnetic-field are qualitatively the same. This is illustrated in Fig. 23-9.

Traditionally, superconduction is ascribed to those curves for which the resistance turns downward towards zero when $T=0$ is approached. Above a near-horizontal resistance-curve, which has been termed the separatrix, the resistance curves have been observed to increase in resistance when the temperature decreases.

Since measurements right up to $T=0$ are not possible, the latter experimental results have led to the conclusion that the horizontal separatrix demarcates the critical disorder D_C or critical magnetic-field $\mathbf{B}_C$, (depending on which parameter is being varied) at which the superconducting phase turns into an insulating phase. The latter conclusion could be wrong since it might be possible, and most probably must happen, that the curves above the separatrix, or at least some of them near the separatrix, turn around at lower temperatures and plunge towards zero resistivity when absolute zero is approached.

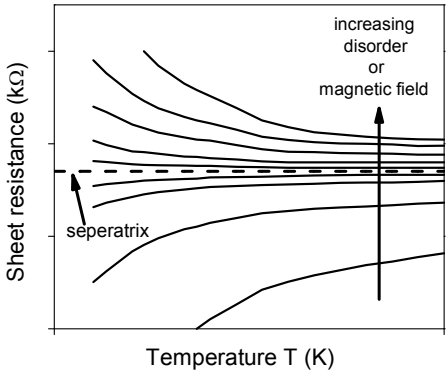

Figure 23-9: *The behaviour with temperature when subjecting a homogeneously-disordered film to an increasing applied magnetic-field. Below the so-called seperatrix the resistance goes to zero when absolute-zero temperature is approached; indicating that the film becomes superconducting. Above the seperatrix the resistance increases when approaching absolute zero temperature, indicating that the film becomes insulating*

23.8.4 Insulating phase above separatrix

It has been found that for conditions above the seperatrix, an insulating-phase is generated which conducts at low, non-zero temperatures by manifesting an activation-barrier: i.e. the change in resistance with temperature follows an Arrhenius-type law as one would expect within a doped semiconductor which is not disordered. This is the part of the resistance curves above the seperatrix which increases rapidly as absolute zero is being approached. What is even more astonishing is that when increasing the temperature the same films eventually conduct by variable-range hopping. According to experimental results on doped semiconductors one would have expected that an activation-energy mechanism should rather have occurred at these higher temperatures, while variable-range hopping should have occurred at lower temperatures (see section 8.13).

In an attempt to explain this activated-behaviour, it has been postulated that “droplets” form within which Cooper-pairs are dominant; and that charge-carriers thus “hop” between the “droplets” by scaling an activation barrier. It is near-impossible, if not totally impossible, to understand why “droplets” would form within homogeneously-disordered thin metal-films. Nonetheless, based on the postulate of “Cooper-droplets”, it has been proposed that such an activation-controlled insulator-phase should be called a “Cooper-pair insulator”.

23.8.5 Electron-energy diagram

When a superconducting thin-film becomes disordered, electronic-states above the superconducting gap (possibly also below) become localised-states so that conduction by them (when the Fermi-level is situated amongst them) will proceed by means of variable-range hopping-conduction. A possible scenario for a superconducting-state below a disorder-seperatrix should thus be as illustrated schematically in Fig. 23-10.

Since the localised-states caused by the disorder are delocalised-states before disorder sets in, it will be assumed that the binding-energy of the (localised) Wigner-orbitals must be measured from the edge of the localised states above the gap. The localisation of electronic-states should thus also affect the magnitude of the ionisation-energy ΔE_S of the Wigner-orbitals: i.e. the latter should decrease with increasing disorder.

We will now consider films near the disorder-seperatrix which have the same thickness, but different amounts of disorder: The difference in disorder between those films just below the seperatrix and those just above should thus be small. The physical factor which is expected to be affected the most under these circumstances should not be their density; but more-importantly their distribution: The higher the disorder the more random the orbital array will be.

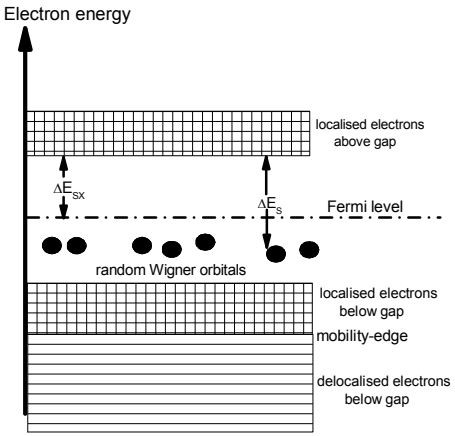

Figure 23-10: *Wigner-orbitals within a disordered metallic-film. Superconduction can occur provided that the distances between adjacent orbitals are less than a critical distance R_C so that a connective pathway can form along which orbital-movement can occur from the injection-contact to the target-contact by means of barrier-jumping: i.e. in scientific vernacular a "percolation threshold" has to be exceeded.*

Superconduction by barrier-jumping of randomly-dispersed orbitals can thus only initiate once the Wigner-orbitals reach a percolation-threshold at

which a connective pathway forms from the injection-contact to the target-contact: i.e. a density at which the distances between adjacent orbitals along such a path are all less than the critical-distance R_C so that barrier-jumping can occur all the way (see section 23.7.3).

The higher the disorder D, the lower the critical temperature T_c will be at which such a connective pathway can be established. Thus, the critical temperature will decrease with increasing disorder: Just as is experimentally observed. When the disorder reaches and exceeds a critical amount D_C, a percolation threshold cannot be reached for any temperature which can be measured experimentally: Superconduction then becomes impossible within this temperature range: Just as is experimentally observed.

The real reason why a so-called "Cooper-pair insulator" manifests at low temperatures is now clear: Although the Fermi-level is situated within the energy-gap, superconduction is not possible since a connective pathway cannot be established. At temperatures $T>0$, electrons are, however, thermally excited from the Wigner-orbitals into the states above the gap. Owing to the disorder, these states are localised states; which should cause variable-range hopping-conduction when the Fermi-level is situated amongst them at higher temperatures: While the Fermi-level is situated within the gap, however, these localised states can still convey a current when their density is higher than a critical amount so that nearest-neighbour hopping (NNH) can occur. This is similar to barrier-jumping through a superconducting phase, except that the energy fluctuations causing the jumps are generated by temperature. When increasing the temperature, the density of localised-states above the gap increases; and this decreases the resistance.

Since NNH-conductivity is proportional to the density of these states, and since this density is determined by the activation-energy required to excite electrons from the Wigner-orbitals to form these localised-states, the decrease in resistance with increasing temperature follows an Arrhenius-relationship. This activated-behaviour is thus **not** caused by the formation of a regular array of "Cooper-droplets" which "magically" form within a homogeneously-disordered thin-film; in which they should not form. A better designation than a "Cooper-pair insulator" might be to call this phase an "NNH-insulator".

When one keeps on increasing the temperature, a point will be reached at which the Fermi-level moves into, and becomes situated amongst the localised-states above the gap. Variable-range hopping conduction will then dominate at these higher temperatures: Just as observed.

23.8.6 Superinsulator

It should be noted that there exists a threshold density of localised states above the gap, below which NNH is impossible. Thus, if at a temperature T, the Wigner-orbitals cannot form a connective pathway from contact-to-

contact and if at the same temperature the density of states above the gap is too low for NNH to manifest, no charge-transport is possible at all: A "super-insulating" phase then manifests.

A study on the latter phase was reported in *Nature* with big fanfare during 2008 (M. V. Vinokur *et al. Nature* **462**, 613-616 (2008)). The authors could not model their results in terms of the BCS-theory but, even so, stubbornly concluded that: "*Although the analytical theory of the droplet state* (of Cooper pairs) *is unknown, we conjecture that the droplet state is an inherent property of the critical region of superconductor-to-insulator transition in the films ……".* Amazing! Although they admit that they do not know what is going on, there **must** be Cooper pairs involved. In terms of Wigner-orbitals the results they obtained can be modelled simply and with ease.

I thus decided to relieve them from their pain and misery and submitted a manuscript to Nature entitled: "*Super-insulating-phases in homogeneously-disordered thin-films: "Cooper-pair droplets" versus "localised harmonic-orbitals*". This manuscript was rejected within three days by a Senior Editor Dr. Karen Southwell. In her letter she argued that: "*Among the considerations that arise at this stage are the length of a manuscript, its likely interest to a general readership of scientists, the pressure on space in the various fields of Nature's interest and the likelihood that a manuscript would seem of great topical interest to those working in the same or related areas of science."*

My manuscript was not longer than the one it was based on. I am further sure that a model which explains results that *Nature* considered so important that they published it, even though the authors could not explain it in terms of conventional theory, must be of interest *to a general readership of scientists* and it must be *of great topical interest to those working in the same or related areas of science*. Of course I appealed. This was the response: "*Our view remains that your manuscript falls short of providing the sort of clear advance in fundamental understanding that would justify its publication in Nature*". No clear advance in fundamental understanding when you have an alternative model that explains what the traditional models cannot! Has the physics-world gone totally crazy?

Yes it has!! We have to be brutally honest about it, and demand that people like Dr. Karen Southwell be relieved from her duties as soon as possible. This also goes for Dr. Ian Osborne of *Science*, and Prof. Sir Michael Berry of the *Proceedings of the Royal Society A*. (see also section 37).