Increased Electron Flow Velocity in Presence of a Magnetic Field

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The amount of current flow through a ribbon electrical conductor is determined by Ohm's law, beyond which no improvement is known except cases of superconductors operating at below critical temperatures. The author proposes a potential method for improving electrical conductivity at room temperature by increasing the electron flow velocity in presence of a self-generated or an externally supplied magnetic field by using potential, but hitherto unused, contribution of certain terms in the equations of the force acting on moving electrons, through a change in the physical configuration of ribbon conductors into a suitable modified shape.

A set of steady state equations describing the electron velocities on a ribbon conductor appears in Kittel [1]. Let the $x-$axis be along the current direction on a ribbon conductor, and let the $z-$axis be pointed along the direction of the magnetic field. This makes the $(-x)-$axis the direction of the electron flow, and the $(-y)-$axis the direction of electron movement due to Hall effect. Given the electric field intensity, (E_x, E_y, E_z) the electron velocity, (v_x, v_y, v_z) in components are given by

$$v_x = -\frac{e\tau}{m}E_x - \omega_c \tau v_y \qquad (1a)$$

$$v_y = -\frac{e\tau}{m}E_y + \omega_c \tau v_x \qquad (1b)$$

$$v_z = -\frac{e\tau}{m}E_y \qquad (1c)$$

where $\omega_c = eB/mc$ is the cyclotron frequency for the electron with the mass m and the negative charge $-e$, for a magnetic field of strength B and the speed of light c, and τ is the mean collision time. The transverse

v_y in (1b) is negative for Hall current, made more negative by a higher magnitude of v_x, but becomes zero for an ordinary ribbon conductor due to the balancing

$$E_y = -\frac{e\tau}{m}\frac{B}{c}E_x \tag{2}$$

required of blocking Hall effect [2]. If the v_y can be made somehow positive in presence of B, the magnitude of the v_x is increased by the last term of (1a) proportional to the strength B and the v_y. This was the starting point of the present inquiry.

Consider a modification of the ribbon conductor into a double deck configuration with a single level kept smooth forming the basic continuous ribbon and the other level with parallel and diagonal cutouts to form parallel conductor bridges, separated from the ribbon surface, which are designed to drain accumulating electrons due to Hall current from the edge of electron accumulation and transport them to the opposite electron depleting edge. These parallel bridges, spanning from one edge of the ribbon to the other edge and insulated from the ribbon surface, are called herein *Hall current (drain and return) bridges*, or simply *bridges*. The pitch angle of the bridges is optimally chosen based on experimental results. (In case of Alternating Current (AC) applications, a triple deck configuration may be devised by adding another deck level on the opposite side of the ribbon. The pitch angle of the third deck level bridges is chosen as the opposite pitch angle of the second deck level bridges.)

Having electrons traveling both on the ribbon surface as well as on the bridges, it is now necessary to use the weighted average of the electron velocities of those on the ribbon and of those on the bridges. Let ρ and β denote the relative frequencies of finding electrons on the ribbon and on the bridges respectively. Note that the v_y-component of those electrons on the ribbon is attributed to the Hall current. Having the bridges built, the Hall current is promoted on the ribbon due to the presence of $\omega_c\tau v_x$ term in (1b). A value of $\omega_c\tau$ for a plausible case appears later. Let this velocity component be denoted $-v_H$ with $v_H > O$. In steady state, the Hall current velocity component $-v_H$ must be compensated for by the same magnitude of transport velocity component v_H along the opposite positive $y-$axis by the electrons flowing back on the bridges to make the transverse electron flows in both directions possible and the velocity components balanced. I.e., the drained and returning electrons on the bridges are expected to maintain the same velocity component of the magnitude v_H in the positive $y-$axis direction, and the longitudinal velocity component of $v_H \sec\theta$ along the bridges where θ is the bridge pitch angle, $0 < \theta < \pi/2$. Note that no transverse Hall current can exist for those electrons on the bridges and that a balance similar to (2) must be maintained with a tilt by the bridge pitch angle θ. These conditions produce a new added component for the v_x of the magnitude $-v_H \tan\theta$ of those electrons on the bridges. Another possible additional velocity component of the v_y of those electrons on the bridges is the carry-over from the longitudinal v_x on the ribbon, because the electrons do not decelerate suddenly in aggregate velocity when they move onto the bridges. This component is expected to be fairly close to or somewhat less than the value $-v_x \cos\theta$. Since the $-v_H$ of the Hall current is balanced by the return flow through the bridges, the $-\beta v_x \cos\theta$ yields an upper bound of the possible positive weighted value for the v_y. In the case of the weighted v_x, a renormalization is required to adjust for the number of electrons on the ribbon at the last stage of computation to compare to usual copper ribbon conductor, i.e., by dividing the weighted sum by ρ. First the electrons on the ribbon have a velocity component v_x with relative frequency ρ. Those on the bridges have the additional velocity components of at most $(v_x \sin\theta - v_H \tan\theta)$ with relative frequency of β. The last term of (1a) yields at most, $\beta\omega_c\tau v_x \cos\theta$. The renormalization then yields a modified velocity, v'_x, expected to satisfy

$$v_x + \frac{\beta}{\rho}(-v_H \tan\theta) \leq v'_x < v_x + \frac{\beta}{\rho}(v_x \sin\theta - v_H \tan\theta + \omega_c\tau v_x \cos\theta) \quad (3)$$

along the ribbon part of the modified conductor with a magnitude greater than $v_x = -(e\tau/m)E_x$ of a simple ribbon conductor with the same width and thickness.

In case of an electromagnetic device of a self generating magnetic field, the strength B is increased by a higher magnitude of the v'_x. If the weighted v_y is positive, or even set equal to zero, the magnitude of the v'_x becomes greater than that of v_x for $\theta > 0$, and thus in turn the value of B is increased. This is a fortuitous cyclic logic, which increases the B indefinitely so long as the weighted v_y is kept nonnegative. This may provide an inexpensive alternative means for generating a strong magnetic field without resorting to the use of superconductor magnets which require expensive cryogenic cooling and associated devices. The potential room temperature operational capability is highly suitable for plasma containment vessels of thermonuclear reactors and for magnetic vehicle levitation and propulsion.

The following baseline values were given to the author [3]. Magnetic fields generated by copper conductor electromagnets are in the range of 10^4 Oe without using pulsed mode. The cyclotron frequency ω_c in a field of 10^4 Oe is approximately 2×10^{11}/sec. Taking τ as 2×10^{-14}sec, $\omega_c\tau$ is about 3.5×10^{-3}. Start with an initial value of $v_y = 0$. Eq (1b) shows that the v_y is changed to $\omega_c\tau v_x$. Since the v_x is negative, there is an observable transverse current due to Hall effect along the $(-y)-$axis with the velocity $-v_H$. This $-v_H$ is inserted into Eq.(3) to yield v'_x. This increment may be negligible. However, note that the increased magnitude of the v'_x is again fed back into Eq(1b) to yield yet a larger magnitude of the $-v_H$. This cyclic logic is unbounded and infinite. It can be expected to yield substantial increases in the absolute values of the v'_xs in incremental steps. It is impossible to quantify how much of end result increase one should expect without actual experimental proof.

No experiment has been conducted as yet. US and foreign patents were granted and available for the above conceptual work.

References

[1] Kittel, C., *Introduction to Solid State Physics*, 5th edit., p. 173, John Wiley, New York, 1976.
[2] Kittel, C., loc. cit., p. 174.
[3] Private communication from Dr. Richard Alben of GE Research Laboratory, Schenectady, New York, 2/26/95.

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