UC Irvine

UC Irvine Previously Published Works

Title

Helicon relaxation of electron spins

Permalink

<https://escholarship.org/uc/item/58x9w15z>

Journal

Physics Letters A, 26

ISSN

0375-9601

Author

Benford, G

Publication Date

1968

Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at <https://creativecommons.org/licenses/by/4.0/>

Peer reviewed

HELICON RELAXATION OF ELECTRON SPINS *

G. BENFORD

Lawrence Radiation Laboratory, University of California, Livermore, California, USA

Received 21 December 1967

It is shown that relaxation of electron spins by thermally excited helicons competes with the phonon process at low temperatures in the lighter metals.

Relaxation of nuclear spins by helicons has been observed when a radio frequency field is applied at the nuclear Larmor frequency [1]. This letter points out that at low temperatures electron spin relaxation in metals may proceed by interaction with the rotating magnetic field of thermally excited helicons. This mechanism produces a relation $T_1 T = \text{const.}$

We use the long-wavelength dispersion relation for helicons

$$\omega_{\mathbf{q}} = c^2 \omega_c q^2 \cos \theta / \omega_p^2 \quad (1)$$

where $\theta = q_z / |\mathbf{q}|$ and $\mathbf{q}$ is the helicon wave vector. The relaxation time due to random magnetic fields in the solid may be written in terms of their spectral density $S(\omega_L)$ at the electron Larmor frequency, ω_L :

$$\frac{1}{T_1} = \gamma^2 [S_{xx}(\omega_L) + S_{yy}(\omega_L)] \quad (2)$$

where γ is the electron gyromagnetic ratio. We have

$$S(\omega_L) = (2V)^{-1} \sum_{\nu} (n_{\nu} + \frac{1}{2}) \hbar \omega_{\nu}^{\frac{1}{2}} [\delta(\omega - \omega_{\nu}) + \delta(\omega + \omega_{\nu})] \quad (3)$$

n_{ν} is the (Bose-Einstein) occupation number for helicons. Eqs. (1), (2) and (3) yield

$$\frac{1}{T_1} = \frac{\gamma^2 k T}{4\pi^2} \left(\frac{\omega_L}{\omega_c^3} \right)^{\frac{1}{2}} \left(\frac{\omega_p}{c} \right)^3 [1 - (\omega_c \tau)^{-\frac{1}{2}}] \quad (4)$$

where τ is the relaxation time ($\omega_c \tau > 1$). We as-

sume $\hbar \omega_L \gg kT$. Present work [2,3] in sodium gives $T_1 \approx 10^{-5}$ sec for samples with low impurity concentration, in the region $T < 10^\circ\text{K}$. Yafet's mechanism [4] (relaxation by electron-phonon scattering accompanied by a spin flip) adequately accounts for this data. [Eq. (4) gives much longer times for sodium.] This process is insensitive to n , so it should give $T_1 \approx 10^{-5}$ in lithium as well. In contrast, note that eq. (4) gives $T_1 \approx n^{\frac{1}{2}}$. In lithium we find $T_1 T = 1.5 \times 10^{-5} \text{ sec}^\circ\text{K}$ for $B = 300$ G. Thus we would expect the helicon and phonon processes to compete in the lightest metals. The electron-phonon scattering mechanism produces a rise in T_1 faster than $1/T$ as T falls below $\sim 30^\circ\text{K}$, so the two processes may be distinguished.

The author would like to thank G. Dunifer and J. Benford for helpful conversations.

References

1. B. Sapoval, Phys. Rev. Letters 17 (1966) 241.
2. F. Vescial, N. S. Vander Ven and R. T. Schumacher, Phys. Rev. 134 (1964) A1286.
3. G. Dunifer and S. Schultz, to be published.
4. Y. Yafet, Solid State Physics 14 (1963) 1.

* Work performed under the auspices of the U.S. Atomic Energy Commission.

* * * * *