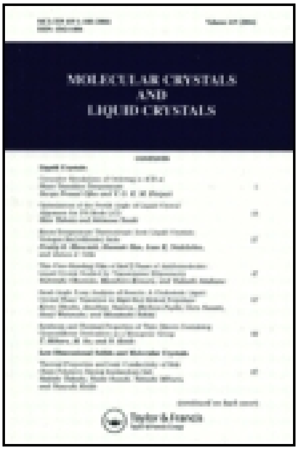

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

Magnetoconductivity Of 2D Conductors

A. Isihara [a] & Y. Nakane [a]
[a] Department of Physics, State University of New York at Buffalo, Buffalo, New York, 14260, USA
Version of record first published: 20 Apr 2011.

To cite this article: A. Isihara & Y. Nakane (1985): Magnetoconductivity Of 2D Conductors, Molecular Crystals and Liquid Crystals, 121:1-4, 169-172

To link to this article: http://dx.doi.org/10.1080/00268948508074856

Mol. Cryst. Liq. Cryst. 1985, Vol. 121, pp. 169-172
0026-8941/85/1214-0169/$10.00/0

MAGNETOCONDUCTIVITY OF 2D CONDUCTORS

A. ISIHARA and Y. NAKANE
Department of Physics, State University of New York at Buffalo, Buffalo, New York, 14260, USA

Abstract In consideration of the correlations between Landau levels for low electron densities, we evaluated the magnetoconductivity of 2D conductors as a function of frequency for a set of filling factor ν. Our results show negative shifting of the resonance position when ν is increased from 1.5 to 3.0, in agreement with a recent experiment of Wilson, Allen and Tsui.

INTRODUCTION

Two-dimensional electron systems show interesting and anomalous properties in a strong magnetic field which is applied perpendicularly. We evaluated recently[1] the dielectric function[2] and analyzed cyclotron resonance in 2D conductors.

In using the dielectric function, we avoided divergences in cyclotron resonance by introducing a small imaginary part into the function. This step, although phenomenological, is consistent with the broadening of the Landau levels due to impurity scattering.

It is the purpose of the present work to investigate the conductivity and cyclotron resonance of 2D systems taking into consideration the couplings of low-lying Landau levels which are elliptically broadened. We adopt the Green's function of Ando and Uemura[3] and investigate the range of $1<\nu<3$. Here, ν is the filling factor defined by $\nu = \frac{n}{eH/ch} = \frac{\varepsilon_o}{\mu_B H}$, where n is the electron density and ε_o is the ideal Fermi energy. The above range of ν is interesting because as ν increases from 1, the electrons are excited to low-lying Landau levels and yet the number of these levels is small.

MAGNETOCONDUCTIVITY

The conductivity is expressed in terms of the memory function $M(\omega)$ as follows:

$$\sigma_+(\omega) = \frac{ine^2/m}{\omega-\omega_c+M(\omega)} \tag{1}$$

where ω_c is the cyclotron frequency, and $M(\omega)$ is given to lowest order in impurity scattering as follows:

$$M(\omega) = \frac{n_i}{2Nm\omega} \sum_q q^2|v(q)|^2 \frac{1}{u(q)} \left\{ \frac{1}{\varepsilon(q,\omega)} - \frac{1}{\varepsilon(q,0)} \right\} \tag{2}$$

N is the total number of electrons, $v(q)$ is the impurity potential, $u(q)$ is the Coulomb potential, and the dielectric function $\varepsilon(q,\omega)$ is

$$\varepsilon(q,\omega) = 1 + u(q)\chi(q,\omega), \quad \chi(q,\omega) = \sum_{ij} C_{ij}(q)\Pi_{ij}(\omega) \tag{3}$$

Here, for $t = \frac{(\ell q)^2}{2}$ and $\ell^2 = \frac{\hbar}{m\omega_c}$, $C_{i,i+s} = \frac{eH}{ch}\frac{i!}{(i+s)!} t^s e^{-t}[L_i^s(t)]^2$.

The real and imaginary parts of $\Pi_{ij}(\omega)$ are given by

$$-\mathrm{Re}\Pi_{ij}(\omega) = \frac{1}{\pi}\int_{-\infty}^{\infty} f(z)[\mathrm{Re}G_i(z+\omega)\mathrm{Im}G_j(z)+\mathrm{Re}G_j(z-\omega)G_i(z)]dz \tag{4}$$

$$-\mathrm{Im}\Pi_{ij}(\omega) = \frac{1}{\pi}\int_{-\infty}^{\infty} f(z)[f(z)-f(z+\omega)]\mathrm{Im}G_i(z+\omega)\mathrm{Im}G_j(z)dz \tag{5}$$

$f(z)$ is the Fermi distribution function and $G(z)$ is the Green's function. For a delta-function type short range potential, the broadening parameter Γ in the Green's function is given by

$\Gamma^2 = 4(\frac{eH}{ch})n_i v_o^2$, where n_i is the impurity concentration and $v_o = v(o)/\varepsilon(o,o)$.

RESULTS AND DISCUSSIONS

The present theory is applicable to low temperature 2D electron systems such as chalcogenide compounds MX_2, Si inversion layers and GaAs/GaAlAs. However, the density of the electrons is assumed to be small so that $3>\nu>1.5$. We use the recent cyclotron data on Si inversion layers[4] and choose the theoretical parameters accordingly. The broadening parameter which depends on the strength of the impurity potential is set to be 0.3 ω_c. This value is close to what Isihara and Mukai used.

The resulting magnetoconductivity is plotted against frequency in Figure 1. The ordinate is the real part of the conductivity in arbitrary units, and the abscissa is frequency in cm^{-1}. As can be seen, the curves are asymmetric and are higher as ν increases. The peak positions show shifting. In the range $\nu>2.5$, the shift $\omega-\omega_c$ is of order -3 cm^{-1}, which is negative. The negative shift and magnitude agree well with the experimental data. However, the anomalous shifting for $\nu<1$ cannot be explained by the present theory, requiring improvements on the treatment of electron-electron correlations.

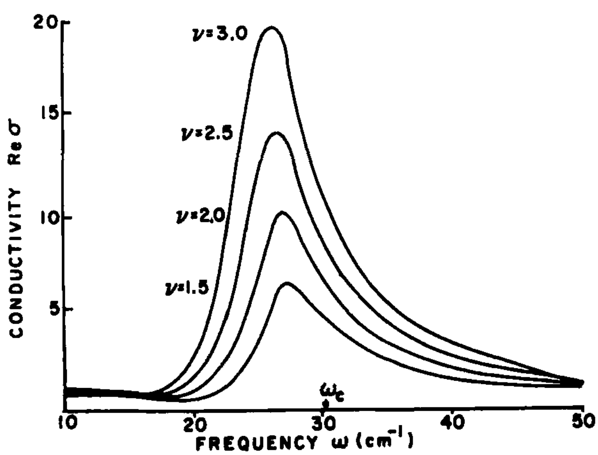

FIGURE 1 Magnetoconductivity of 2D conductors vs. frequency.

ACKNOWLEDGEMENT This work was supported by the Office of Naval Research under Contract N00014-79-C-0451.

REFERENCES

1. A. Isihara, et al, Molec. Cryst. Liq. Crys. 79, 343 (1982).
A. Isihara and M. Mukai, Phys. Rev. B 28, 4842 (1983).
2. A. Isihara, L. Ioriatti and D.Y. Kojima, Z. Phys B 44, 91 (1981).
A. Isihara, et al, Physica 112B, 416 (1982).
3. T. Ando and Y. Uemura, J. Phys. Soc. Jpn. 36, 959 (1974).
4. B.A. Wilson, S.J. Allen, Jr. and D.C. Tsui, Phys. Rev. B 22, 945 (1980).