# Dynamics of defects near melting of classical 2D electrons

Autor(en): Deville, G.

Objekttyp: Article

Zeitschrift: Helvetica Physica Acta

Band (Jahr): 65 (1992)

Heft 2-3

PDF erstellt am: 03.05.2024

Persistenter Link: https://doi.org/10.5169/seals-116487

## Nutzungsbedingungen

Die ETH-Bibliothek ist Anbieterin der digitalisierten Zeitschriften. Sie besitzt keine Urheberrechte an den Inhalten der Zeitschriften. Die Rechte liegen in der Regel bei den Herausgebern. Die auf der Plattform e-periodica veröffentlichten Dokumente stehen für nicht-kommerzielle Zwecke in Lehre und Forschung sowie für die private Nutzung frei zur Verfügung. Einzelne Dateien oder Ausdrucke aus diesem Angebot können zusammen mit diesen Nutzungsbedingungen und den korrekten Herkunftsbezeichnungen weitergegeben werden.

Das Veröffentlichen von Bildern in Print- und Online-Publikationen ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. Die systematische Speicherung von Teilen des elektronischen Angebots auf anderen Servern bedarf ebenfalls des schriftlichen Einverständnisses der Rechteinhaber.

## Haftungsausschluss

Alle Angaben erfolgen ohne Gewähr für Vollständigkeit oder Richtigkeit. Es wird keine Haftung übernommen für Schäden durch die Verwendung von Informationen aus diesem Online-Angebot oder durch das Fehlen von Informationen. Dies gilt auch für Inhalte Dritter, die über dieses Angebot zugänglich sind.

Ein Dienst der *ETH-Bibliothek* ETH Zürich, Rämistrasse 101, 8092 Zürich, Schweiz, www.library.ethz.ch

# http://www.e-periodica.ch

## DYNAMICS OF DEFECTS NEAR MELTING OF CLASSICAL 2D ELECTRONS

#### **G.Deville**

# Service de Physique de l'Etat Condensé CEA Saclay B.P. 2, 91191 Gif-sur-Yvette cedex, France

Abstract. A slow dynamical response of a classical 2D electron system is observed in the vicinity of the liquid-solid transition. The R.F. absorption data, analysed in the framework of the dislocation mediated melting model, yield a precise determination of the defect core energies.

## Introduction.

The theory of melting in 2 dimensions driven by the unbinding of dislocation pairs in the crystal (Kosterlitz Thouless (KT) model<sup>[1]</sup>), is remarkably supported by the experiments performed with electrons trapped at the gas-liquid interface of helium<sup>[2,3,4,5]</sup>. All these studies emphasize the crucial part assigned to the defects in the transition mechanism, but very little is known about the dynamics of these defects. The long time response on crossing the liquid-solid transition gives some information on the dislocations.

#### Experiments.

We detect collective modes of the 2D electron system with a wide band RF spectrometer. A guard ring electrode produces a modulation  $\delta n$  of the electron density n, in the KHz range and a phase sensitive detector (PSD) selects the transmitted RF power at the modulation frequency  $\omega_{mod}$ .

The experiment is based upon the modification of the collective modes on crossing the liquidsolid transition. Of particular interest is the local mode appearing in the solid phase, where an electron vibrates in the potential well of the deformed helium surface, at frequency  $\omega_0$ . The longitudinal frequency for a wavevector k is then modified from  $(\frac{2\pi ne^2}{m}k)^{1/2}$  in the liquid phase to  $(\frac{2\pi ne^2}{m}k + \omega_0^2)^{1/2}$  in the solid phase. This discontinuous change of the longitudinal frequency is obtained in the limit of steady equilibrium. If the temperature is kept constant at the non perturbed melting value  $T_m$ , the modulation makes the system cross the transition with frequency  $\omega_{mod}$ , which is seen as a frequency modulation in the longitudinal response. The output signals displayed on Figures (1a) and (1b) show that the electron modes do not follow a sudden crossing of the freezing transition. The phase lag  $\theta$  between excitation and detection at  $\omega_{mod}$  results in an out of phase signal  $S_2$  in a narrow temperature interval around  $T_m$ . Analysing the  $S_2$  amplitude, we obtain the relation  $tg\theta = \omega_{mod} \times \tau(n)$ , where the time  $\tau$ , lying in the 10  $\mu$ sec range, obeys the equation:  $\tau(n) \propto n^{-1}$  as displayed in Figure (2).

## A model for dislocation equilibrium.

According to the KT theory, the binding of free dislocations into pairs is the central phenomena at freezing. Thus the equilibrium is determined by the dislocations, involving particle motion in the crystal. The lengh scale for this process is the mean distance between two dislocations (density  $n_d$ ):  $L = (a^2/n_d)^{1/2}$  and we assume that the dislocation system reaches equilibrium when a particle covers this distance L. Following Fisher, Halperin and Morf (FHM)<sup>[6]</sup>, the particle motion is diffusive, dominated by interstitial defects of density  $\rho_i$ , with a diffusion constant  $D \simeq a^2 \omega_D \rho_i$ . The dislocation equilibrium time is then:

$$au_{\rm calc} \simeq (L)^2 / D \simeq \frac{1}{n_d} \times \frac{1}{\rho_i} \times \frac{1}{\omega_D}$$
 (1)



Fig. 1 a) Detected signal as a function of the swept radiofrequency  $(n = 7.8 \ 10^8 \ \mathrm{cm}^{-2}, T_m = 630 \ \mathrm{mK})$ . The arrows at 21 and 48 MHz show the first acoustic electron surface modes in the solid phase. b) Detected electron signal  $(n = 7.8 \ 10^8 \ \mathrm{cm}^{-2})$  at fixed RF frequency (100 MHz), when the temperature is swept near  $T_m$ . The analysis of  $S_2/S_1$  gives  $\tau_{exp}$ .



Fig.2 Log-Log plot of the electron time equilibrium  $\tau_{exp}$  as a function of the electron density showing the  $n^{-1}$  variation. The determination of  $\tau_{exp}$  is less accurate for low density because the local mode frequency decreases as  $n^{3/2}$ .

Thus,  $\tau_{calc}$  depends on *n* through the Debye frequency  $\omega_D \propto n^{3/4}$ . FHM calculated the defect densities in term of the core energies  $E_c$  and  $E_i$  for dislocations and interstitials, which are proportional to the Coulomb energy  $V_c = e^2 \sqrt{\pi n}$ . Inserting their values in Eq.(1) gives  $\tau_{calc} = 3 \mu \sec$  for  $n = 6 \ 10^8 cm^{-2}$ , to be compared with  $\tau_{exp} = 10 \mu \sec$ . It is worth noting that this difference can be removed through a small increase of  $E_c$  or  $E_i$ , of about 7%, which is within the uncertainties estimated by FHM.

Conversely, if we assume that the model is correct, this experiment appears to be a precise determination of the defect densities. Inserting  $\tau_{exp}$  in Eq.(1), we get the sum  $E_c + E_i = 13.5 \ 10^{-2}V_c + \beta \log n$ . The small logarithmic term which makes  $\tau_{calc}$  to have the  $n^{-1}$  dependence of  $\tau_{exp}$ , could indicate edge effects in the core energies.

## Acknowledgements

T. Williams is gratefully acknowledged for much help and counsel.

#### References

- [1] J.M. Kosterlitz and D.J. Thouless, J. Phys. C6, 1181 (1973).
- [2] C.C Grimes and G. Adams, Phys. Rev. Lett. 42, 795 (1979).
- [3] G. Deville et al, Phys. Rev. Lett. 53, 588 (1984).
- [4] D.C. Glattli et al, Phys. Rev. Lett. 60, 420 (1988).
- [5] M.A Stan and A.J. Dahm, Phys. Rev. B40, 8995 (1989).
- [6] D.S. Fisher, B.I. Halperin and R. Morf, Phys. Rev. B20, 4692, (1979).