

**ECE 495N**

# **Fundamentals of Nanoelectronics**

**Fall 2008**

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**Lecture: 23  
Title: Density of States II  
Date: October 24, 2008**

**Video Lectures posted at:  
<https://www.nanohub.org/resources/5346/>**

**Class notes taken by: Panagopoulos Georgios  
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# Density of States II

## Lecture 23

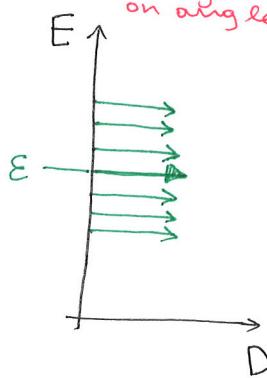
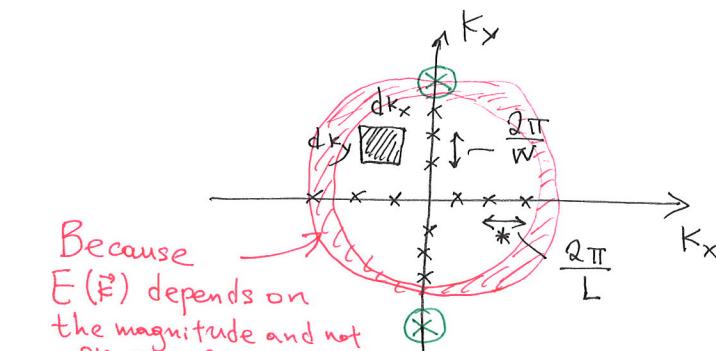
Oct. 24, 2008

$$E(\vec{k}) = \epsilon \pm |\hbar_0| \simeq \epsilon \pm at\sqrt{k_x^2 + k_y^2}, \quad \beta_y \equiv k_y - \frac{2\pi}{3b}$$

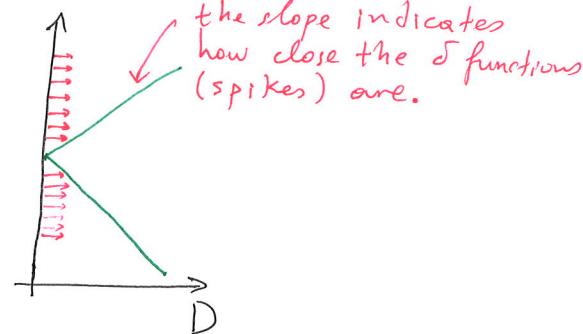
$$D(E) = \sum_{\vec{k}} \delta(E - E(\vec{k}))$$

This formula convert the  $E(E)$  relationship to a DOS relationship which is useful for calculate currents

\* assuming periodic boundary conditions (P.B.C.)



?



$$\begin{aligned} D(E) &= \iint \frac{dk_x dk_y}{2\pi \cdot 2\pi} \delta(E - E(\vec{k})) \\ &= \iint \frac{dk_x dk_y}{L \cdot W} \delta(E(\vec{k}) - E) = \frac{L \cdot W}{4\pi^2} \int d\theta \int dk \delta(E(\vec{k}) - E) \\ &\stackrel{\text{area of the sheet}}{=} \frac{LW}{4\pi^2} 2\pi \int \frac{dE}{at} \cdot \frac{\epsilon}{at} \delta(E - E) = \frac{S}{2\pi} \frac{E}{at^2} \end{aligned}$$

$\epsilon(\vec{k}) = at|\vec{k}|$   
 $dE(k) = at dk$

$$\Rightarrow D(E) = \frac{S}{2\pi} \frac{|E|}{at^2}$$

If we have a graphene sheet which is long in the  $x$  direction but we keep ~~the~~ small in the  $y$  direction the the summation for DOS is written as:

$$\epsilon(\vec{k}) = \alpha t \sqrt{k_x^2 + k_y^2}$$

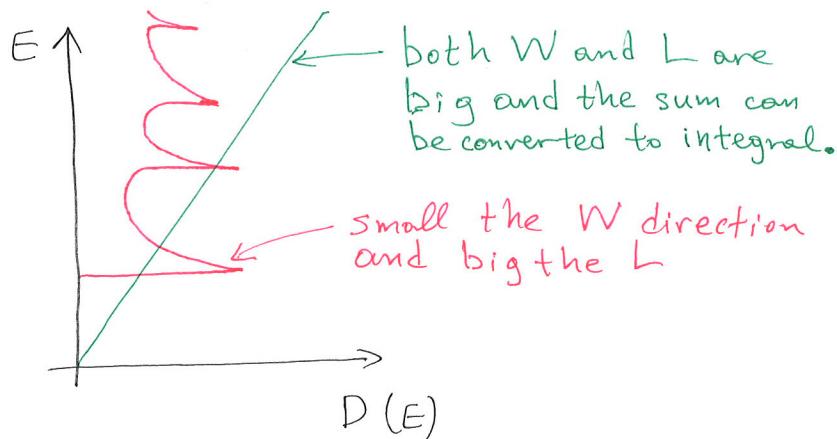
$$D(E) = \sum_{\vec{k}} \delta(\epsilon(\vec{k}) - E) = \sum_{k_y} \int \frac{dk_x}{2\pi L} \delta(\epsilon(\vec{k}) - E)$$

$$\begin{aligned} * \epsilon &= \alpha^2 t^2 (k_x^2 + k_y^2) \\ \Rightarrow 2E dE &= 2\alpha^2 t^2 k_x dk_x \\ \Rightarrow dk_x &= \frac{E dE}{\alpha^2 t^2 k_x} \\ \Rightarrow k_x &= \sqrt{\frac{E^2 - \alpha^2 t^2 k_y^2}{\alpha^2 t^2}} \Rightarrow \\ \Rightarrow dk_x &= \frac{E dE \alpha t}{\alpha^4 t^2 \sqrt{E^2 - \alpha^2 t^2 k_y^2}} \end{aligned}$$

$$* = \frac{L}{2\pi} \sum_{k_y} \int dE \frac{E}{\alpha t \sqrt{E^2 - \alpha^2 t^2 k_y^2}} \delta(E - E)$$

$$D(E) = \frac{L}{2\pi \alpha t} \sum_{k_y} \frac{E}{\sqrt{E^2 - \alpha^2 t^2 k_y^2}}$$

Since in  $y$  direction the states are discrete so  $k_y = \frac{2\pi}{W} * v$ ,  $v$  is an integer.



$$\int_{-\infty}^{+\infty} \frac{dk_x}{2\pi W}$$

P. B. C

vs.

$$\int_0^{+\infty} \frac{dk_x}{\pi W}$$

B. B. C



Depending on where we are doing the summation ( $W$  or  $L$ ) the DOS are different and we see that experimentally.