MICRO/NANOSCALE ENERGY CONVERSION AND TRASPORT

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The Effects of Scattering on Micro Energy Transport.

ABSTRACT

In this study , we derived an equation following the main procedure by Wilson], and Chapman & Cowling for heat flux. The original idea originally proposed by Cattaneo and subsequently worked on and generalized by Qiu & Tien , Majumdar, Maurer, Anisimov at al, and Joseph & Preziosi. When the transport equation of electrical current derived by using the Boltzmann equation, we arrive at the same equation derived by the above mentioned scientists. If we do not use the electrical current equation the final form of the transport equation for the heat flux has another source term.
The derivation for the transport equation for the heat flux is based on the Boltzmann equation. The manipulation of the scattering term gives different forms of the heat flux transport equation. The most general form of the heat flux equation is an integro-differential equation. In this study, we used the relaxation time assumption and followed the methodology of Wilson, Chapman & Cowling to arrive at the transport equation for the heat flux. We also used the conservations equations of electrons, and lattice developed by Qiu & Tien.
The numerical application shows a good agreement between the full equation for the heat flux together with the lattice and electron energy equations.
The heat flux eq. togetger with the conservation of energy for both electrons and phonon] can be written as follows

$$\tau \frac{\partial Q}{\partial t} + \kappa \frac{\partial T_e}{\partial x} + Q = 0$$

$$C_e(T_e)\frac{\partial T_e}{\partial t} = -\frac{\partial Q}{\partial x} - G(T_e - T_l) + S$$

$$C_l(T_l)\frac{\partial T_l}{\partial t} = G(T_e - T_l)$$

where

$$G = \frac{\pi^4}{18}\frac{(n_e u k_B)}{K_e q}$$

$$S = 0.94\frac{1-R}{t_P\delta}J_S \exp\left[-\frac{x}{\delta} - 2.77(\frac{t}{t_p})^2\right]$$

The boundry and initials conditions are

$T_e(x,-2t_p)=T_0$; $T_l(x,-2t_p)=T_o$

$$\left(\frac{\partial T_e}{\partial t}\right)_{x=0} = 0$$

$$\left(\frac{\partial T_e}{\partial x}\right)_{x=0} = 0 \qquad \left(\frac{\partial T_l}{\partial x}\right)_{x=0} = 0 \qquad \left(\frac{\partial T_e}{\partial x}\right)_{x=L} = 0 \qquad \left(\frac{\partial T_l}{\partial x}\right)_{x=L} = 0$$

After solving heat flux and energy equations with the initial and boundary conditions given above, the following figures are obtained about the variation of T_e versus time (t) and position (x).

In the following figures 1 and 2,depicted values for both electron and phonon temperature variation show a good agreement with the results of Qiu and Tien.

In the Figure 1, the temperature profile is given as a function of both time and spatial dimension. It depicts the temperature variation in gold-chromium two layer film. As it can be seen from the figure-1, the thermalization process in chromium is more rapid than in gold due to the larger electron-lattice coupling factor of chromium.

The following physical properties of gold , chromium and laser heating are taken as follows

t_p :0.1 x10^{-12} , δ=15.3x10^{-9} ,R=0.93,G=2.6x10^{16} ,
κ_{Au}=315,Ce=2.1x10^4,Cl=2.5x10^6,J=500, κ_{Cr}=94

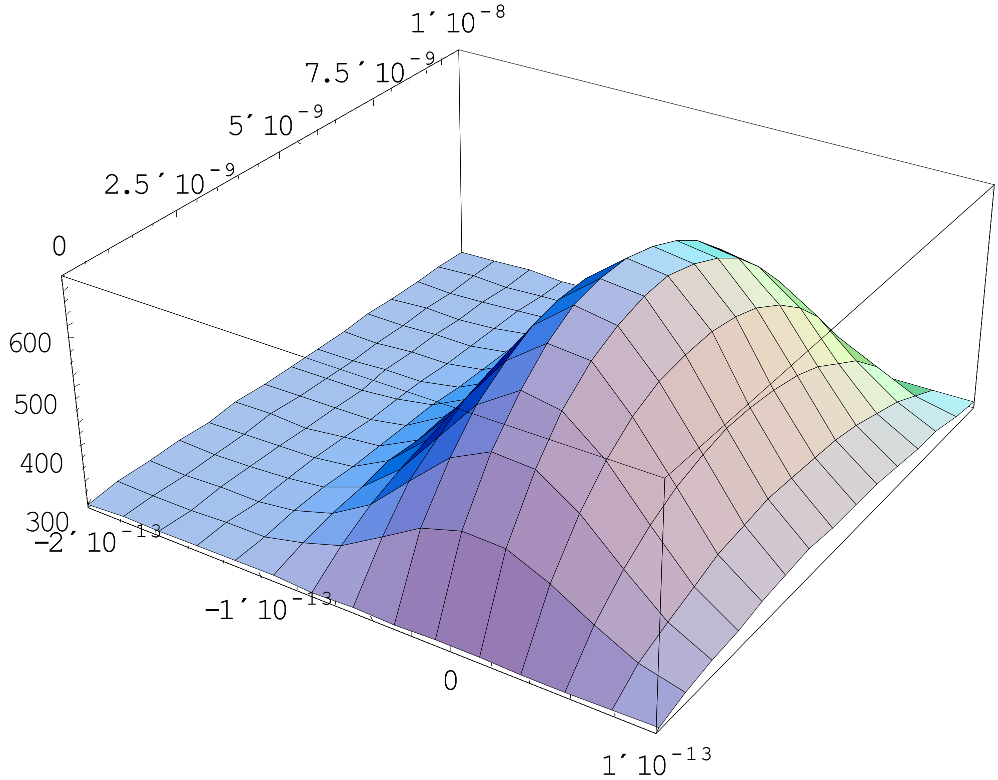

Figure1: The temperature variation versus time and spatial dimension in gold-chromium two layer film.(500 A^0 gold , 500 A^0 chromium)