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kh. lotfy (✉ khlotfy_1@yahoo.com)

Zagazig University Faculty of Science <https://orcid.org/0000-0001-9383-1361>

A. El-Bary

Arab Academy for Science Technology and Maritime Transport

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Generalized Photo-Thermo-Microstretch Elastic Solid Semiconductor Medium Due to Excitation Process

Kh. Lotfy^{1,2}, A. El-Bary³,

¹*Department of Mathematics, Faculty of Science, P.O. Box 44519, Zagazig University, Zagazig, Egypt.*

²*Department of Mathematics, Faculty of Science, Taibah University, Madinah., Saudi Arabia.*

³*Arab Academy for Science, Technology and Maritime Transport, P.O.Box 1029, Alexandria, Egypt.*

khlotfy_1@yahoo.com, aaelbary@aast.edu

Abstract

A novel model in the theory of photo-thermoelasticity with microstretch properties is studied. The plasma-elastic-thermal plane waves are propagated in a linear isotropic generalized photo-thermo-microstretch elastic semiconductor solid medium. The photothermal excitation occurs in the context of the microinertia of microelement process during two dimensions (2D) deformation. The harmonic wave techniques are used to get the solutions for the basic variables. The analytical solution of the main physical fields; carrier intensity, normal displacement components, temperature, stress load force, microstress and tangential coupled stress can be obtained. Some graphics illustrated when using the plasma, thermal and mechanical load boundary conditions, which they apply at the outer free surface of the elastic medium. Some semiconductor materials as silicon (Si) and Germanium (Ge) are used to make the numerical simulation and some comparisons in different thermal memories are made. The main physical variables with new parameters are discussed theoretically and shown graphically.

Keywords: Photo-thermoelasticity; Thermal conductivity; Semiconductor; Microstretch; Harmonic wave.

Nomenclature

λ, μ	Lame's parameters.
δ_n	The deformation potential difference.
T	Absolute thermodynamic temperature (thermodynamic heat).
T_0	Temperature in its natural state and satisfy $\left \frac{T - T_0}{T_0} \right < 1$.
$\hat{\gamma} = (3\lambda + 2\mu + k)\alpha_{t_1}$	The volume thermal expansion.
α_{t_1}	The linear thermal expansion coefficient
σ_{ij}	The stress tensor components.
ρ	Medium density.
$\alpha_{t_1}, \alpha_{t_2}$	Coefficients of linear thermal expansion.
e	Cubical dilatation.
C_e	Specific heat at constant strain.
k	The thermal conductivity.
D_E	The carrier diffusion coefficient.
τ	The carrier lifetime.
E_g	The energy gap.
e_{ij}	Components of strain tensor.
Π, Ψ	Two scalar functions.
j_0	The microinertia of microelement.
m_{ij}	Couple stress tensor.
$\alpha_0, \lambda_0, \lambda_1$	Microstretch elastic constants.
τ_0, ν_0	Thermal relaxation times.
φ	Rotation vector.
φ^*	The scalar microstretch.

Introduction

The thermoelasticity theory which is the commonest engineering structural material has a great role in steel stress analysis and applied mechanics science. It can describe the mechanical solid behavior of some common elastic materials like coal, concrete and wood. But, it can't describe mechanical behavior for many synthetic materials of polymer and elastomer type like polyethylene. It studies thermal effect and its relation with stresses and strains that occur in elastic bodies. So, another theory can be obtained to achieve that. This theory is called linear micropolar elasticity theory. In this theory, body microstructure influence is significant and this influence gives results of waves can't be exist in elasticity classical theory. Body temperature change is not only caused due to outer and internal heat sources, and also in deformations of itself process during the microinertia of microelement. In most of the previous studies, semiconductor materials can be thought of as an elastic body and therefore thermoelasticity theory can be applied to it. But semiconductor materials have optical properties especially when they are exposed to the sun light or a laser beam. In this case, as a result of the high surface temperature of the semiconductor materials, its resistance decreases, allowing it to be a conductive material. On the other hand, the electrons become in an excited state, which leads to the emergence of what is known as the carrier density or plasma density. Therefore, it must be taken into account the microinertia of microelement (due to the carrier free charge) and the microstretch of the semiconductor material points can contract and stretch independently of their rotations and translations. Microstretch elastic semiconductor theory is different from micropolar elasticity theory in there exist an additional degree of freedom of the medium which called the stretch and an additional kind of coupled stress that can called microstretch vector. Microstretch elastic semiconductors are polymer composite materials. In this case the overlap between the thermo-microstretch theory and photothermal excitation process can be studied.

Misra et al. [1] studied the body microstructure when the thermoelastic interaction in isotropic homogeneous elastic half-space using a generalized linear thermoelasticity theory occurs. The microstructure effects are significant and this influence gives results of waves propagation can't be exist in classical theory of elasticity, this theory is developed by Eringen and Şuhubi [2]. Eringen [3] introduced a new generalized theory of micropolar thermoelasticity theory; this theory is called thermo-microstretch theory for elastic solid bodies. This theory can be chosen as a special case of theory of micromorphic. Singh [4] studied the plane waves during the reflection and refraction processes through a liquid adjacent elastic thermo-microstretch solid. Influence of the theory of two temperatures is used to study the reflection coefficient in micropolar elastic medium when the energy dissipation is introduced [5]. Linear thermo-microstretch elastic solid theory is produced [6]. In this theory, the heat can transfer as thermal waves with a finite thermal speed. The plane wave is obtained during generalized thermo-microstretch theories for an elastic media [7]. Othman et al. [8] illustrated the gravitational influence and hydrostatic initial stress when the generalized magneto-thermo-microstretch theory is used in different thermal memories. Othman and Abbas [9] studied the plane waves with some thermal memories in generalized thermo-microstretch when they used the method of numerical finite element. Many application of thermo-microstretch for porous media are applied when the thermal radiation effect is studied during a casson fluid flow over a stretching sheet [10]. On the other hand, Rashidi et al. [11, 12] investigated the unsteady convective heat and mass transfer in pseudo plastic nano-fluid over a stretching wall, moreover, they used the analysis of heat transfer due to stretching cylinder with partial slip in the context of prescribed heat flux.

The photothermal method is introduced when a sample of intracavity spherical semiconductor material is exposed to a light laser beam [13]. A sensitive

analysis of semiconductor material used the spectroscopy of photoacoustic when a laser beams are fallen on it [14]. Tam et al. [15-17] studied many problems with applications in modern physics using the ultrasensitive laser spectroscopy. The 2D deformation during photothermal transport interactions in elastic semiconductor medium is studied [18]. The electronic deformation mechanism and optically excited are used to discuss the photoacoustic frequency transmission technique on the generalized thermoelastic vibrations [19, 20]. Recently, Lotfy et al. investigated various problems in photo-thermoelasticity theory with many applications in mechanical engineering [21-27]. Abbas et al. [28, 29] studied the dual phase-lags theory of photothermal excitation processes with the interaction of a semiconductor media. Many researchers studied the semiconductor elastic medium when the physical properties of the medium depend on temperature in different external fields [30-33]. Mondal and Sur [34] introduced wave propagation in an orthotropic elastic semiconductor during memory responses. The hyperbolic two-temperature theory is used to modification some models in photo-thermal-elastic interaction [35, 36].

In all the above investigations the influence of thermo-microstretch theory was not taken into consideration in the context of microinertia of microelement is neglected when studied the photo-thermoelasticity theory. But in this work, the thermo-microstretch theory is applied during microinertia of microelement 2D deformation. In this paper, a linear theory for photo-thermal-elastic solids with inner structure whose particles is considered, in addition to the microstretch and plasma-thermal fields. the coupling between the thermo-microstretch theory and photo-thermoelasticity is investigated. In this case, the governing equations are taken in 2D (in the space (x, z)) deformation for semiconductor medium. The microinertia of microelement is taken into consideration. The main physical variables (carrier intensity, displacement components, temperature field

distribution, load force stress, microstress and tangential couple stress distribution) are studied in a generalized photo-thermo-microstretch elastic medium in different thermal relaxation times. The harmonic wave method with some mechanical-thermal and plasma boundary condition is used with some algebraic techniques to get the complete solutions of the basic quantities. The obtained results are discussed and they are made some comparisons graphically.

Mathematical model and main equations

Eringen et al. [2, 37, 38 and 39], construct many models in generalized thermoelasticity. In this problem, a linear isotropic properties of the generalized photo-thermo-microstretch semiconductor medium during photothermal process is studied. The medium is taken in Cartesian coordinates (x, y, z) which having origin at the external elastic surface $y = 0$ when the direction of the z axis pointing vertically into the elastic half-space medium. The thermal waves that occur on the external surface of the solid medium, in this case the photothermal mechanism is obtained and the free carrier charges are generated (plasma wave propagation) [15]. In this case, the overlapping processes are occurred between the waves (plasma-thermal-elastic) during the elastic-photo-thermal-microstretch excitation [16]. The transmission of load across a differential element of the surface of a microstretch semiconductor elastic medium is described by a force vector, a couple stress vector and a microstress vector. The constitutive equations and field equations when the body forces absence in the context of 2D photo-thermo-microstretch theory (x, z) are given as (see geometry of the problem):

Geometry of the problem

The coupled between plasma wave distribution and thermal wave distribution during the photo-excited process of microstretch semiconductor is given by:

$$\frac{\partial N}{\partial t} = D_E \nabla^2 N - \frac{N}{\tau} + \kappa T. \quad (1)$$

The equations of motion for semiconductor material in photo-thermo-microstretch theory can be written as follows [16]:

$$(\lambda + \mu) \nabla (\nabla \cdot \vec{u}) + (k + \mu) \nabla^2 \vec{u} + k (\nabla \times \vec{\phi}) + \lambda_o \nabla \phi^* - \hat{\gamma} (1 + \nu_o \frac{\partial}{\partial t}) \nabla T - \delta_n \nabla N = \rho \ddot{\vec{u}}. \quad (2)$$

$$(\alpha + \beta + \gamma) \nabla (\nabla \cdot \vec{\phi}) - \gamma \nabla \times (\nabla \times \vec{\phi}) + k (\nabla \times \vec{u}) - 2k \vec{\phi} = j \rho \ddot{\vec{\phi}}. \quad (3)$$

$$\alpha_o \nabla^2 \phi^* - \frac{1}{3} \lambda_1 \phi^* - \frac{1}{3} \lambda_o (\nabla \cdot \vec{u}) + \frac{1}{3} \hat{\gamma}_1 (1 + \nu_o \frac{\partial}{\partial t}) T = \frac{3}{2} j \rho \ddot{\phi}^*. \quad (4)$$

Heat conduction equation for semiconductor medium in photo-thermo-microstretch theory can be given as [15]:

$$K \nabla^2 T - \rho C_E (n_1 + \tau_o \frac{\partial}{\partial t}) \dot{T} - \hat{\gamma} T_o (n_1 + n_o \tau_o \frac{\partial}{\partial t}) \dot{e} + \frac{E_g}{\tau K} N = \hat{\gamma}_1 T_o \dot{\phi}^*. \quad (5)$$

The constitutive relations in tensor form with two relaxation times for generalized photo-thermo-microstretch theory can be written as [17]:

$$\sigma_{il} = (\lambda_o \phi^* + \lambda u_{r,r}) \delta_{il} + (k + \mu) u_{li} - k \varepsilon_{ilr} \phi_r - \hat{\gamma} (1 + \nu_o \frac{\partial}{\partial t}) T \delta_{il} - ((3\lambda + 2\mu + k) d_n N) \delta_{il}. \quad (6)$$

Constitutive relations for the generalized thermo-microstretch semiconductor elastic medium are given as:

$$m_{il} = a\varphi_{r,r}\delta_{il} + \beta\varphi_{i,l} + \gamma\varphi_{l,i}, \quad (7)$$

$$\lambda_i = a_o\varphi_i^*. \quad (8)$$

The relation between the strain and the displacement components relation can be written as:

$$e = \frac{\partial u}{\partial x} + \frac{\partial w}{\partial z}. \quad (9)$$

In the above equations, activation coupling the therma represents $\kappa = \frac{\partial n_0}{\partial T}$ parameter in general case and $\hat{\gamma}_1 = (3\lambda + 2\mu + k)\alpha_{t_1}$ and $\hat{\gamma}_2 = (3\lambda + 2\mu + k)\alpha_{t_2}$ are parameter depend on the mechanical source and thermo-microstretch properties, can $\vec{u}$ The displacement vector .the linear thermal expansionscoefficient of ais α_{t_2} be analyzed, rotation vector and the scalar microstretch function in 2D (x, z) which it can be expressed respectively as:

$$\left. \begin{aligned} \vec{u} &= (u, 0, w) ; u = u(x, z, t), w = w(x, z, t), \\ \vec{\varphi} &= (0, \varphi_2, 0) ; \varphi_2 = \varphi_2(x, z, t), \varphi^* = \varphi^*(x, z, t) \end{aligned} \right\}. \quad (10)$$

The governing field equations (2)-(5) can be rewritten in 2D as:

$$\left. \begin{aligned} (\lambda + \mu)(u_{xx} + w_{xz}) + (k + \mu)(u_{xx} + u_{zz}) - k \frac{\partial \varphi_2}{\partial z} + \\ \lambda_o \frac{\partial \varphi^*}{\partial x} - \hat{\gamma}(1 + v_o \frac{\partial}{\partial t}) \frac{\partial T}{\partial x} - \delta_n \frac{\partial N}{\partial x} = \rho u_{tt} \end{aligned} \right\}, \quad (11)$$

$$\left. \begin{aligned} (\lambda + \mu)(u_{xz} + w_{zz}) + (k + \mu)(w_{xx} + w_{zz}) - k \frac{\partial \varphi_2}{\partial x} + \\ \lambda_o \frac{\partial \varphi^*}{\partial z} - \hat{\gamma}(1 + v_o \frac{\partial}{\partial t}) \frac{\partial T}{\partial z} - \delta_n \frac{\partial N}{\partial z} = \rho w_{tt} \end{aligned} \right\}, \quad (12)$$

$$\gamma \left[\frac{\partial^2 \varphi_2}{\partial x^2} + \frac{\partial^2 \varphi_2}{\partial z^2} \right] + k \left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x} \right) - 2k\varphi_2 = j\rho \frac{\partial^2 \varphi_2}{\partial t^2}, \quad (13)$$

$$\alpha_o \left[\frac{\partial^2 \varphi^*}{\partial x^2} + \frac{\partial^2 \varphi^*}{\partial z^2} \right] - \frac{1}{3} \lambda_1 \varphi^* - \frac{1}{3} \lambda_o \left(\frac{\partial u}{\partial x} + \frac{\partial w}{\partial z} \right) + \frac{1}{3} \hat{\gamma}_1 (1 + v_o \frac{\partial}{\partial t}) T = \frac{3}{2} j\rho \frac{\partial^2 \varphi^*}{\partial t^2}. \quad (14)$$

$$K \left[\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial z^2} \right] - \rho C_E (n_1 + \tau_o \frac{\partial}{\partial t}) \frac{\partial T}{\partial t} - \hat{\gamma} T_o (n_1 + n_o \tau_o \frac{\partial}{\partial t}) \frac{\partial e}{\partial t} + \frac{E_s}{\tau K} N = \hat{\gamma}_1 T_o \frac{\partial \varphi^*}{\partial t}. \quad (15)$$

Where the thermal memories and n_o, n_1 (are constants) can be chosen according to the photo-thermo-microstretch theories (classical coupled theory (C-D), Lord and Şhulman (L-S) model and model of Green and Lindsay (G-L)).

To get main fields in dimensionless form, the following non-dimension variables can be used:

$$\left. \begin{aligned} \bar{N} &= \frac{\delta_n}{2\mu + \lambda} N, \quad \bar{x}_i = \frac{\omega^*}{C_2} x_i, \quad \bar{u}_i = \frac{\rho C_2 \omega^*}{T_o \gamma} u_i, \quad \bar{t} = \omega^* t, \quad \bar{\tau}_o = \omega^* \tau_o, \\ \bar{v}_o &= \omega^* v_o, \quad \bar{T} = \frac{T}{T_o}, \quad \bar{\sigma}_{ij} = \frac{\sigma_{ij}}{T_o \gamma}, \quad \bar{m}_{ij} = \frac{\omega^*}{C_2 T_o \gamma} m_{ij}, \quad \bar{\varphi}_2 = \frac{\rho C_2^2}{T_o \gamma} \varphi_2, \\ \bar{\lambda}_3 &= \frac{\omega^*}{C_2 T_o \gamma} \lambda_3, \quad \bar{\varphi}^* = \frac{\rho C_2^2}{T_o \gamma} \varphi^*, \quad \omega^* = \frac{\rho C_E C_2^2}{K}, \quad C_2^2 = \frac{\mu}{\rho}. \end{aligned} \right\}. \quad (16)$$

Using equation (16) for the main governing equations (dropping prim), yields:

$$(\nabla^2 - \varepsilon_3 - \varepsilon_2 \frac{\partial}{\partial t})N + \varepsilon_4 T = 0, \quad (17)$$

$$u_{tt} = \frac{(\lambda + \mu)}{\rho C_2^2} \frac{\partial e}{\partial x} + \frac{(k + \mu)}{\rho C_2^2} \nabla^2 u - \frac{k}{\rho C_2^2} \frac{\partial \varphi_2}{\partial z} + \left. \begin{aligned} &\frac{\lambda_o}{\rho C_2^2} \frac{\partial \varphi^*}{\partial x} - (1 + v_o \frac{\partial}{\partial t}) \frac{\partial T}{\partial x} - \frac{(\lambda + 2\mu)}{\gamma T_o} \frac{\partial N}{\partial x} \end{aligned} \right\}, \quad (18)$$

$$w_{tt} = \frac{(\lambda + \mu)}{\rho C_2^2} \frac{\partial e}{\partial z} + \frac{(k + \mu)}{\rho C_2^2} \nabla^2 w + \frac{k}{\rho C_2^2} \frac{\partial \varphi_2}{\partial x} + \left. \begin{aligned} &\frac{\lambda_o}{\rho C_2^2} \frac{\partial \varphi^*}{\partial z} - (1 + v_o \frac{\partial}{\partial t}) \frac{\partial T}{\partial z} - \frac{(\lambda + 2\mu)}{\gamma T_o} \frac{\partial N}{\partial z} \end{aligned} \right\}, \quad (19)$$

$$\frac{j\rho C_2^2}{\gamma} \frac{\partial^2 \varphi_2}{\partial t^2} = \nabla^2 \varphi_2 + \frac{k C_2^2}{\gamma w^{*2}} \left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x} \right) - \frac{2k C_2^2}{\gamma w^*} \varphi_2, \quad (20)$$

$$\left(\frac{C_3^2}{C_2^2} \nabla^2 - \frac{C_4^2}{w^{*2}} - \frac{\partial^2}{\partial t^2} \right) \varphi^* - \frac{C_5^2}{w^{*2}} e + a_9 (1 + v_o \frac{\partial}{\partial t}) T = 0, \quad (21)$$

$$\left. \begin{aligned} \nabla^2 T - (n_1 + \tau_o \frac{\partial}{\partial t}) \frac{\partial T}{\partial t} - \frac{\hat{\gamma}^2 T_o}{k \rho w^*} (n_1 + n_o \tau_o \frac{\partial}{\partial t}) \frac{\partial e}{\partial t} + \\ \frac{E_s (2\mu + \lambda) C_2^2}{\pi k^2 T_o w^{*2} \delta_n} N = \frac{\hat{\gamma}_1 \hat{\gamma} T_o}{k \rho w^*} \frac{\partial \varphi^*}{\partial t} \end{aligned} \right\}. \quad (22)$$

The potential space-time functions as $\Pi(x, z, t)$ and $\Psi(x, z, t)$, which they can be used to simplify the main equations. These functions can be taken the non-dimensional form as follows:

$$\vec{u} = \text{grad } \Pi + \text{curl } \Psi, \quad u = \frac{\partial \Pi}{\partial x} - \frac{\partial \Psi}{\partial z}, \quad w = \frac{\partial \Pi}{\partial z} + \frac{\partial \Psi}{\partial x}. \quad (23)$$

Where, (Helmholtz's function is vector $\Psi = (0, \psi, 0)$ and function is scalar $\Pi(x, z, t)$ theory in two dimensional (x, z)).

Using equation (35), the main field equations (17-22) in terms of the two potential space-time functions can be written as:

$$(\nabla^2 - a_o \frac{\partial^2}{\partial t^2}) \Pi + a_o (1 + v_o \frac{\partial}{\partial t}) T + a_1 \varphi^* - a_4 N = 0, \quad (24)$$

$$(\nabla^2 - a_2 \frac{\partial^2}{\partial t^2}) \psi - a_3 \varphi_2 = 0, \quad (25)$$

$$(\nabla^2 - 2a_5 - a_6 \frac{\partial^2}{\partial t^2}) \varphi_2 - a_7 \nabla^2 \psi = 0, \quad (26)$$

$$(a_8 \nabla^2 - a_{10} - \frac{\partial^2}{\partial t^2}) \varphi^* - a_{11} \nabla^2 \Pi + a_9 (1 + v_o \frac{\partial}{\partial t}) T = 0, \quad (27)$$

$$[\nabla^2 - (n_1 \frac{\partial}{\partial t} + \tau_o \frac{\partial^2}{\partial t^2})] T - \varepsilon (n_1 \frac{\partial}{\partial t} + n_o \tau_o \frac{\partial^2}{\partial t^2}) \nabla^2 \Pi + \varepsilon_5 N - \varepsilon_1 \frac{\partial \varphi^*}{\partial t} = 0. \quad (28)$$

Where,

$$\left. \begin{aligned}
a_o &= \frac{\rho c_2^2}{2\mu + k + \lambda}, \quad a_1 = \frac{\lambda_o}{2\mu + k + \lambda}, \quad a_2 = \frac{\rho c_2^2}{\mu + k}, \quad a_3 = \frac{k}{\mu + k}, \\
a_4 &= \frac{\rho c_2^2 (2\mu + \lambda)}{\hat{\gamma} T_o (2\mu + k + \lambda)}, \quad a_5 = \frac{k c_2^2}{\gamma w^*}, \quad a_6 = \frac{j \rho c_2^2}{\gamma}, \quad a_7 = \frac{k C_2^2}{\gamma w^{*2}}, \quad a_8 = \frac{C_3^2}{C_2^2}, \\
a_9 &= \frac{2\hat{\gamma}_1 C_2^2}{9\gamma j w^{*2}}, \quad a_{10} = \frac{C_4^2}{w^{*2}}, \quad a_{11} = \frac{C_5^2}{w^{*2}}, \quad \varepsilon = \frac{\hat{\gamma} T_o}{K \rho w^*}, \quad \varepsilon_1 = \frac{\hat{\gamma}_1 \hat{\gamma} T_o}{K \rho w^*}, \\
\varepsilon_2 &= \frac{C_2^2}{D_E w^*}, \quad \varepsilon_3 = \frac{C_2^2}{\tau D_E w^{*2}}, \quad \varepsilon_4 = \frac{\kappa T_o \delta_n C_2^2}{D_E (2\mu + \lambda) w^{*2}}, \quad \varepsilon_5 = \frac{E_g (2\mu + \lambda) C_2^2}{\tau K^2 T_o w^{*2} \delta_n}, \\
C_3^2 &= \frac{2\alpha_o}{3\rho j}, \quad C_4^2 = \frac{2\lambda_1}{9\rho j}, \quad C_5^2 = \frac{2\lambda_o}{9\rho j}, \quad C_6^2 = \frac{2\hat{\gamma}_1}{9\rho j}.
\end{aligned} \right\}. \quad (29)$$

Harmonic wave analysis

The waves propagation in semiconductor and thermoelastic materials has various applications in many fields of modern science and mechanical technology, namely, atomic physics, industrial engineering, thermal power plants, submarine structures, pressure vessel, aerospace, chemical pipes, and metallurgy. Several scientists have attempted to study the propagation of harmonic plane waves in semiconductor and elastic media. The propagation of plane waves in classical thermoelasticity is discussed by Deresiewicz [40], Chadwick and Sneddon [41] and Chadwick [42]. The solution of the considered basic physical variables in 2D deformation can be decomposed in terms of harmonic waves (normal mode technique) as:

$$\left. \begin{aligned}
&[\varphi, \psi, \varphi^*, \varphi_2, \sigma_{il}, T, m_{il}, N](x, z, t) = \\
&[\bar{\varphi}(x), \bar{\psi}(x), \bar{\varphi}^*(x), \bar{\varphi}_2(x), \bar{\sigma}_{il}(x), \bar{T}(x), \bar{m}_{il}(x), \bar{N}(x)] e^{(\omega t + i b z)}
\end{aligned} \right\}. \quad (30)$$

Where, the components $\bar{\varphi}, \bar{\psi}, \bar{\varphi}^*, \bar{\varphi}_2, \bar{\sigma}_{il}, \bar{m}_{il}, \bar{T}, \bar{N}$ are the amplitude of the main field functions (function of the distance x), ω represents a complex frequency and b is the wave number which it is taken in the z -direction. Using the normal mode method (equation (30)) for equations (17) and (24)-(28), yields:

$$(D^2 - \alpha_1)\bar{N} + \varepsilon_4\bar{T} = 0, \quad (31)$$

$$(D^2 - A_1)\bar{\Pi} + A_2\bar{T} + a_1\bar{\varphi}^* - a_4\bar{N} = 0, \quad (32)$$

$$(D^2 - A_3)\bar{\psi} - a_3\bar{\varphi}_2 = 0, \quad (33)$$

$$(D^2 - A_4)\bar{\varphi}_2 - a_7(D^2 - b^2)\bar{\psi} = 0, \quad (34)$$

$$(a_8D^2 - A_5)\bar{\varphi}^* - a_{11}(D^2 - b^2)\bar{\Pi} + a_9(1 + \nu_o\omega)\bar{T} = 0, \quad (35)$$

$$(D^2 - A_6)\bar{T} - A_7(D^2 - b^2)\bar{\Pi} + \varepsilon_5\bar{N} - \varepsilon_1\omega\bar{\varphi}^* = 0. \quad (36)$$

Where,

$$\left. \begin{aligned} \alpha_1 &= b^2 + \varepsilon_3 + \varepsilon_2\omega, \quad A_1 = b^2 + a_o\omega^2, \quad A_2 = a_o(1 + \nu_o\omega), \quad A_3 = b^2 + a_2\omega^2, \quad D = \frac{\partial}{\partial x}, \\ \omega &= \frac{\partial}{\partial t}, \quad A_4 = b^2 + 2a_5 + a_6\omega^2, \quad A_5 = a_8b^2 + a_{10} + \omega^2, \quad A_6 = b^2 + n_1\omega + \tau_o\omega^2, \\ \nabla^2 &= D^2, \quad A_7 = \varepsilon(n_1\omega + n_o\tau_o\omega^2), \quad A_8 = a_9(1 + \nu_o\omega). \end{aligned} \right\}. \quad (37)$$

Eliminating $\bar{\varphi}_2$ and $\bar{\psi}$ between equations (33) and (34), the fourth order ordinary differential equation can be obtained which it satisfied by $\bar{\varphi}_2$ and $\bar{\psi}$ as:

$$[D^4 - AD^2 + B](\bar{\varphi}_2(x), \bar{\psi}(x)) = 0. \quad (38)$$

The other quantities can $\bar{T}$, $\bar{\varphi}^*$, $\bar{N}$ and $\bar{\Pi}$ can be eliminated between equations (31), (32), (35) and (36), the following eighth order ordinary differential equation can be obtain as the following (which they satisfied by) form: $\bar{\Pi}$ and $\bar{T}$, $\bar{\varphi}^*$, $\bar{N}$

$$[D^8 - CD^6 + ED^4 - FD^2 + G]\{\bar{\varphi}^*(x), \bar{\Pi}(x), \bar{T}(x), \bar{N}(x)\} = 0. \quad (39)$$

The solutions of the ordinary differential equations (38) and (39) according to the linearity properties take the form:

$$\bar{\psi}(x) = \sum_{j=1}^2 \Omega_j(b, \omega) \exp(-k_j x), \quad (40)$$

$$\bar{\varphi}_2(x) = \sum_{j=1}^2 \Omega'_j(b, \omega) \exp(-k_j x), \quad (41)$$

$$\bar{\Pi}(x) = \sum_{n=1}^4 M_n(b, \omega) \exp(-l_n x), \quad (42)$$

$$\bar{\varphi}^*(x) = \sum_{n=1}^4 M'_n(b, \omega) \exp(-l_n x), \quad (43)$$

$$\bar{T}(x) = \sum_{n=1}^4 M''_n(b, \omega) \exp(-l_n x), \quad (44)$$

$$\bar{N}(x) = \sum_{n=1}^4 M'''_n(b, \omega) \exp(-l_n x). \quad (45)$$

Where, $\Omega_j(b, \omega), \Omega'_j(b, \omega), M_n(b, \omega), M'_n(b, \omega), M''_n(b, \omega)$ and $M'''_n(b, \omega)$ are some parameters (unknown) depending on the constants b (wave number) and $\omega = \omega_0 + i\zeta$ which they can be determined when they apply the boundary conditions which are taken at the free surface of the medium. $k_j^2, (j=1,2)$ and $l_n^2, (n=1,2,3,4)$ represent the basic roots of the characteristic equation of equations (38) and (39). Using the main equations (31)-(36) to obtain the relations between $\Omega_j(b, \omega)$ and $\Omega'_j(b, \omega)$, also the relations between the parameters, $M_n(b, \omega), M'_n(b, \omega), M''_n(b, \omega)$ and $M'''_n(b, \omega)$, however the main fields can be represented in terms of Ω_j and M_n as follows:

$$\bar{\varphi}_2(x) = \sum_{j=1}^2 a_j^* \Omega_j(b, \omega) \exp(-k_j x), \quad (46)$$

$$\bar{T}(x) = \sum_{n=1}^4 b_n^* M_n(b, \omega) \exp(-l_n x), \quad (47)$$

$$)48(\quad , \quad \bar{N}(x) = \sum_{n=1}^4 c_n^* M_n(b, \omega) \exp(-l_n x)$$

$$\bar{\varphi}^*(x) = \sum_{n=1}^4 d_n^* M_n(b, \omega) \exp(-l_n x). \quad (49)$$

Where,

$$\left. \begin{aligned} a_j^* &= \frac{k_n^2 - A_3}{a_3}, \quad b_n^* = \frac{d_9(k_n^2 - \alpha_1)}{a_1 d_8 + \varepsilon_1 \omega d_7}, \quad c_n^* = \frac{-\varepsilon_4 b_n^*}{(k_n^2 - \alpha_1)}, \\ d_n^* &= \frac{b_n^* [A_7 d_7 (k_n^2 - b^2) - d_8 (k_n^2 - A_1)]}{d_9 (k_n^2 - \alpha_1)} \end{aligned} \right\}. \quad (50)$$

In the other hand, the expressions of displacement components (using equation (23) into equations (40) and (42)), force stress-strain, coupled stress (equation (7)) and other quantities for the microstretch generalized photo-thermoelastic semiconductor medium take the form:

$$\bar{u}(x) = -(ia(\Omega_1 e^{-xk_1} + \Omega_2 e^{-xk_2}) + l_1 M_1 e^{-xl_1} + l_2 M_2 e^{-xl_2} + l_3 M_3 e^{-xl_3} + l_4 M_4 e^{-xl_4}), \quad (51)$$

$$\bar{w}(x) = -(k_1 \Omega_1 e^{-xk_1} + k_2 \Omega_2 e^{-xk_2}) + ia(M_1 e^{-xl_1} + M_2 e^{-xl_2} + M_3 e^{-xl_3} + M_4 e^{-xl_4}), \quad (52)$$

$$\bar{\sigma}_{zz}(x) = s_1 \Omega_1 e^{-xk_1} + s_2 \Omega_2 e^{-xk_2} + s_3 M_1 e^{-xl_1} + s_4 M_2 e^{-xl_2} + s_5 M_3 e^{-xl_3} + s_6 M_4 e^{-xl_4}, \quad (53)$$

$$\bar{\sigma}_{xz}(x) = r_1 \Omega_1 e^{-xk_1} + r_2 \Omega_2 e^{-xk_2} + r_3 M_1 e^{-xl_1} + r_4 M_2 e^{-xl_2} + r_5 M_3 e^{-xl_3} + r_6 M_4 e^{-xl_4}, \quad (54)$$

$$\bar{m}_{xy}(x) = q_1 \Omega_1 e^{-xk_1} + q_2 \Omega_2 e^{-xk_2}, \quad (55)$$

$$\lambda_z = f_6(d_1^* M_1 e^{-xl_1} + d_2^* M_2 e^{-xl_2} + d_3^* M_3 e^{-xl_3} + d_4^* M_4 e^{-xl_4}). \quad (56)$$

Boundary conditions

To determinate the six unknown parameters Ω_j and M_n , some boundary conditions must be applied at the free surface (at the vertical plan) of the elastic semiconductor material. Boundary conditions vary between instantaneous mechanical (mechanical load) source when the medium is isolated thermally during a recombination plasma processes at $x=0$. In this case the conditions at the boundary can be written as:

$$\sigma_{zz} = -p = -p^* \exp(\omega t + i b z), \quad \sigma_{xz} = 0, \quad m_{xy} = 0, \quad \lambda_z = 0, \quad T = 0, \quad \frac{dN}{dx} = -\frac{sN}{D_E}. \quad (57)$$

Using boundary conditions equation (57) when applies the harmonic wave method (51)-(56) and (46)-(49), the following system of equations can be obtained:

$$s_1 \Omega_1 + s_2 \Omega_2 + s_3 M_1 + s_4 M_2 + s_5 M_3 + s_6 M_4 = -p^*, \quad (58)$$

$$r_1 \Omega_1 + r_2 \Omega_2 + r_3 M_1 + r_4 M_2 + r_5 M_3 + r_6 M_4 = 0, \quad (59)$$

$$q_1 \Omega_1 + q_2 \Omega_2 = 0, \quad (60)$$

$$d_1^* M_1 + d_2^* M_2 + d_3^* M_3 + d_4^* M_4 = 0, \quad (61)$$

$$b_1^* M_1 + b_2^* M_2 + b_3^* M_3 + b_4^* M_4 = 0, \quad (62)$$

$$)63(\quad \cdot (s_7 + l_1)c_1^* M_1 + (s_7 + l_2)c_2^* M_2 + (s_7 + l_3)c_3^* M_3 + (s_7 + l_4)c_4^* M_4 = 0$$

The above system of equations (61-66) can be solved by using method of matrix inverse or Cramer technique the unknown parameters can be obtained.

Validation

The theory of generalized microstretch-thermoelasticity

When the effect of carrier density $N(\bar{r}, t)$ is vanished (i.e. $N=0$), In this case, the problem can be discussed only in the generalized microstretch thermoelasticity theory [18].

The generalized photo-thermoelasticity theory

When the parameters of microstretch are neglected (i.e. $\alpha_o = \lambda_o = \lambda_1 = \varphi^* = 0$), the governing equations discuss the case of generalized photo-thermo-micro-polar elastic medium without stretch.

6.2. Different theories of the microstretch photo-thermoelasticity

The problem is investigated during microstretch photo-thermoelasticity processes which depend on the thermal memories (thermal relaxation times) as follow [35]:

- (I) The C-D theory when $n_1 = 1$, $n_o = \tau_o = v_o = 0$ [39].
- (II) The L-S model is obtained when $n_1 = n_o = 1$, $v_o = 0$, $\tau_o > 0$, [37].
- (III) The G-L model is observed when $n_1 = 1$, $n_o = 0$, $v_o \geq \tau_o > 0$, [38].

Discussion and numerical results

The silicone (Si) and germanium (Ge) materials are chosen as a semiconductor example to make the numerical simulation (using Maple program). To obtain the main obtained results numerically of the basic quantities fields the

physical constants of semiconducting Si medium and Ge are chosen which they given as below [43- 46]:

$$\begin{aligned} \lambda &= 3.64 \times 10^{10} \text{ N/m}^2, \quad \mu = 5.46 \times 10^{10} \text{ N/m}^2, \quad \rho = 2330 \text{ kg/m}^3, \quad T_0 = 800 \text{ K}, \quad \tau = 5 \times 10^{-5} \text{ s}, \\ d_n &= -9 \times 10^{-31} \text{ m}^3, \quad D_E = 2.5 \times 10^{-3} \text{ m}^2/\text{s}, \quad E_g = 1.11 \text{ eV}, \quad s = 2 \text{ m/s}, \\ \alpha_{t_1} &= 0.04 \times 10^{-3} \text{ K}^{-1}, \alpha_{t_2} = 0.017 \times 10^{-3} \text{ K}^{-1}, K = 150 \text{ Wm}^{-1} \text{ K}^{-1}, C_e = 695 \text{ J/(kg K)}, \\ j &= 0.2 \times 10^{-19} \text{ m}^2, \gamma = 0.779 \times 10^{-9} \text{ N}, k = 10^{10} \text{ Nm}^{-2}, t = 0.001 \text{ s}, \lambda_0 = 0.5 \times 10^{10} \text{ Nm}^{-2}, \\ \lambda_1 &= 0.5 \times 10^{10} \text{ Nm}^{-2}, \alpha_0 = 0.779 \times 10^{-9} \text{ N}, \tau_0 = 0.00005 \text{ s}, \nu_0 = 0.0005 \text{ s}, n_0 = 10^{20} \text{ m}^{-3}. \end{aligned}$$

But, the physical constants of Ge material are given below [20, 21]:

$$\begin{aligned} \lambda &= 0.48 \times 10^{11} \text{ N/m}^2, \quad \mu = 0.53 \times 10^{11} \text{ N/m}^2, \quad \rho = 5300 \text{ kg/m}^3, \quad T_0 = 723 \text{ K}, \quad \tau = 5 \times 10^{-5} \text{ s}, \\ d_n &= -6 \times 10^{-31} \text{ m}^3, \quad D_E = 10^{-2} \text{ m}^2/\text{s}, \quad E_g = 0.72 \text{ eV}, \quad s = 2 \text{ m/s}, \quad n_0 = 10^{20} \text{ m}^{-3}, \\ \alpha_{t_1} &= 6.1 \times 10^{-6} \text{ K}^{-1}, \alpha_{t_2} = 5.9 \times 10^{-6} \text{ K}^{-1}, K = 60 \text{ Wm}^{-1} \text{ K}^{-1}, C_e = 310 \text{ J/(kg K)}, j = 0.2 \times 10^{-19} \text{ m}^2, \\ \gamma &= 0.779 \times 10^{-9} \text{ N}, k = 10^{10} \text{ Nm}^{-2}, t = 0.001 \text{ s}, \lambda_0 = 0.5 \times 10^{10} \text{ Nm}^{-2}, \lambda_1 = 0.5 \times 10^{10} \text{ Nm}^{-2}, \\ \alpha_0 &= 0.779 \times 10^{-9} \text{ N}, \tau_0 = 0.00005 \text{ s}, \nu_0 = 0.0005 \text{ s}. \end{aligned}$$

The numerical computational are carry out when using real roots part of field distributions of the basic quantities as (thermal wave (thermo-dynamical temperature distribution), displacement distribution (strain wave), stress which describe the mechanical wave distribution, carrier density distribution (plasma wave), microstress and tangential couple stress). The investigation is studied against the distance x at the plane $z = -2$ when the wave number $b = 1$, and $P^* = 1$ in the context of the generalized photo-thermo-microstretch elastic GPTMSE medium. The complex constant ω can be chosen as $\omega = \omega_0 + i\zeta$, where ω_0, ζ are constants can be taken as $\omega_0 = -2.5$ and $\zeta = 0.05$. The real part of physical quantities fields are presented graphically in the numerical computational. Figures 1-7 show the main physical fields against the distance x under the effect of three different thermal relaxation times according to the C-D, L-S and G-N models at the same

time when using the microstretch photo-thermoelasticity material constants. Figure 1 display the displacement $u=U$, the behavior of wave propagation for two theories L-S and G-N is the same which they increase in interval $0 \leq x \leq 2.5$. In the second range, the behaviors remain constant when distance tends to infinity. Therefore, the wave propagation behavior for the C-D theory increases smoothly in the same interval until reaching equilibrium state at infinity. Figures 2 shows the displacement w relative to the horizontal distance, the wave propagation behavior for two theories (L-S and G-N) takes the same shape which they decrease in interval $0 \leq x \leq 1.5$. In the second rang they remain a constant when distance tends to infinity. But, the wave propagation behavior of the third curve (C-D theory) decreases smoothly in the interval $0 \leq x \leq 1.5$ until reaching to the equilibrium state when distance tends to infinity. Figure 3 exhibits the wave propagation behavior of temperature T , all curves for three theories take the same behavior which they increase in interval $0 \leq x \leq 0.6$ then decrease in second range interval $0.6 \leq x \leq 1.8$ and they increase and decrease again in the third interval. From this figure a very small difference appears between three theories. Figure 4 describes carrier density distribution N with respect to the distance x , the wave propagation behavior for three theories in microstrach-photo-thermoelasticity (C-D, L-S and G-N) is the same which they satisfy the main conditions at the free boundary of the surface. All wave propagation of physical fields decrease in the interval $0 \leq x \leq 0.5$ then increase in second interval $0.5 \leq x \leq 3$ and they decrease again in the third range. Figure 5 shows the normal stress σ_{xx} , x distance horizontal with distribution σ_{zz} wave propagation behavior for three models (C-D, L-S and G-N) has the same shape but, there is very small difference between two theories (L-S and G-N) and third theory (CD) in the interval $0.3 \leq x \leq 0.6$. That the waves propagation are in decreasing in the first interval $0 \leq x \leq 0.4$, then they increase in second range the interval until reminder decrease and increase again in the and they $0.4 \leq x \leq 1$

behaviors remain constant in the last range when distance tends to infinity. Figure 6 displays the rate change in stress component σ_{xz} relative to the horizontal distance x . Figure 6 shows that σ_{xz} always satisfy the surface boundary conditions for all three models (C-D, L-S and G-N) [46]. In this figure, the behavior of wave propagation for two theories (L-S and G-N) has the same shape which they decrease at the beginning as straight line in the first interval $0 \leq x \leq 0.1$ then they increase in the second interval until the behaviors remain constant when distance tends to infinity. In the other hand, the wave propagation behavior for the C-D theory decrease and increase in the same intervals until reaching equilibrium state when the distance tends to infinity. There is very small difference between two theories (L-S and G-N) and the third theory C-D in the interval $0 \leq x \leq 1$. Figure 7 displays the variation of microstress λ_z distribution against distance x , the behavior of wave propagation for three models (C-D, L-S and G-N) is the same which they increase in the first interval $0 \leq x \leq 0.2$ then decrease in the second interval $0.2 \leq x \leq 0.9$, then increase in the interval $0.9 \leq x \leq 2.5$ and decrease in the last interval. Figures (8-14) study the comparisons which are made between the two elastic semiconductor media, Si and germanium (Ge) for main physical quantities at the same time and conditions when using the microstretch photo-thermoelasticity material constants. From these figures, it is clear that the difference of physical constants of semiconductor Ge and Si materials have significant impact on all the waves distribution which they taken in dimensionless ($u, w, T, N, \sigma_{zz}, \sigma_{xz}$ and λ_z). Figures (15-22) show the effect of different values of parameters ($\varepsilon_1, \varepsilon_3$, quantities as displacement) on some main physical ε_5 and ε_4 . The . [45] only S theory-for Silicon (Si) material under L x nce with dista w and u problem is studied in the presence of microstretch photo-thermoelasticity material constants. The wave propagation of displacement component u increases with

increasing different values of parameters ($\varepsilon_1, \varepsilon_3$, ave propagation The w). ε_5 and ε_4 of displacement component w decreases with decreasing different values of parameters ($\varepsilon_1, \varepsilon_3$, has a great effect $\hat{\gamma}$ The volume thermal expansion). ε_5 and ε_4 parameter ε_1 when silicone (Si) material is studied. Carrier diffusion parameter D_E and carrier lifetime. Carrier diffusion ε_3 have an important role on parameter τ coefficient D_E and thermal activation coupling parameter κ have a great influence on parameter ε_4 . The gab energy E_g and photogenerated carrier lifetime have a τ great influence on parameter ε_5 .

Conclusion

The physical quantities as (temperature, displacements, stresses, carrier density, microstress and tangential couple stress) in generalized photo-thermo-microstretch elastic semiconductors for (Si and Ge) solid are studied at small time and in different thermal memories (C-D, L-S and G-N models). The thermal memories have a small effect of wave propagations of the main quantities field due to the effect of microstretch parameters. The comparisons between Si and Ge semiconductor materials are made when using L-S model, the physical constants which depend on the type of material have a great significant on the wave distributions of the basic physical fields for compression between Si and Ge materials. The displacement components distribution through various values of $\varepsilon_1, \varepsilon_3, \varepsilon_4$ and ε_5 under L-S theory is displayed graphically in the generalized photo-thermo-microstretch theory for Si material. The different values of the quantities $\varepsilon_1, \varepsilon_3, \varepsilon_4$ and ε_5 has a great impact on the all physical distributions of the basic fields. The mechanical interaction between the thermal, plasma and mechanical fields in semiconductors has great practical applications in modern aeronautics, astronautics, modern chemical engineering (chemical mechanical planarization) and

nuclear reactors. Classical photo-thermoelasticity theory is not adequate to model the behavior of materials possessing internal structure. Furthermore, the inner microstretch semiconductor elastic model is more realistic than the purely semiconductor elastic (photo-thermoelasticity) theory for studying the response of materials to external stimuli.

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Appendix

The main coefficients of equation (40) take the form:

$$\left. \begin{aligned} A &= A_3 + A_4 - a_7 a_3, \quad B = A_3 A_4 - b^2 a_7 a_3, \quad C = \frac{g_2}{g_1}, \quad E = \frac{g_3}{g_1}, \quad F = \frac{g_4}{g_1}, \quad G = \frac{g_5}{g_1}, \\ g_1 &= a_8, \quad g_2 = d_5 - d_6 - a_8 \alpha_1, \quad g_3 = -b^2 d_5 + \alpha_1 d_6 - d_7 - \varepsilon_1 \omega A_8 + a_8 A_1 A_6 - \\ &a_8 \varepsilon_4 \varepsilon_5 + A_1 A_5 + A_5 A_6, \quad g_4 = d_7 b^2 + d_8 + d_9 + d_{10}, \quad g_5 = -b^2 d_8 - A_1 d_9, \\ d_1 &= A_6 + \alpha_1, \quad d_2 = (1 + \nu_0 \omega) a_9, \quad d_3 = b^2 + \alpha_1, \quad d_4 = a_{11} \varepsilon_1 \omega A_2 + a_{11} a_1 b^2 + \\ &a_8 \alpha_1 A_6 + a_8 a_4 A_7 \varepsilon_4 - a_8 \varepsilon_4 \varepsilon_5 - A_2 A_5 A_7 + A_1 A_5, \quad d_5 = a_1 a_{11} (\varepsilon_4 \varepsilon_5 - \alpha_1 A_6) + \\ &a_{11} \varepsilon_1 \omega (\alpha_1 A_2 - a_4 \varepsilon_4 + b^2 A_2) + a_8 b^2 A_7 (\alpha_1 A_2 - a_4 \varepsilon_4) + A_1 a_8 (\varepsilon_4 \varepsilon_5 - \alpha_1 A_6) + \\ &A_5 (\varepsilon_4 \varepsilon_5 - a_4 A_7 \varepsilon_4 - \alpha_1 A_6), \quad d_6 = a_{11} b^2 (\alpha_1 A_6 - a_1 \varepsilon_4 \varepsilon_5 - \varepsilon_1 \omega \alpha_1 A_2 + \varepsilon_1 \omega a_4 \varepsilon_4) + \\ &A_5 A_7 b^2 (a_4 \varepsilon_4 - \alpha_1 A_2) + A_1 A_5 (\alpha_1 A_6 - \varepsilon_4 \varepsilon_5), \quad d_7 = A_2 (k_n^2 - \alpha_1) + a_4 \varepsilon_4, \\ d_8 &= (k_n^2 - A_6)(k_n^2 - \alpha_1) - \varepsilon_4 \varepsilon_5, \quad d_9 = \varepsilon_1 \omega (k_n^2 - A_1) - a_1 A_7 (k_n^2 - b^2). \end{aligned} \right\}. \quad (64)$$

The values of these main roots (using Mathematica program) can be written as:

$$\left. \begin{aligned}
k_1^2 &= \frac{1}{2}\sqrt{2A+2\sqrt{A^2-4B}}, \quad k_2^2 = \frac{1}{2}\sqrt{2A-2\sqrt{A^2-4B}}, \quad l_1^2 = \sqrt{\frac{1}{4}C + \frac{1}{2}h_6 + \frac{1}{2}h_7}, \\
l_2^2 &= \sqrt{\frac{1}{4}C + \frac{1}{2}h_6 - \frac{1}{2}h_7}, \quad l_3^2 = \sqrt{\frac{1}{4}C - \frac{1}{2}h_6 + \frac{1}{2}h_7}, \quad l_4^2 = \sqrt{\frac{1}{4}C - \frac{1}{2}h_6 - \frac{1}{2}h_7}, \\
h_1 &= \frac{1}{4}C^2 - \frac{2}{3}E, \quad h_2 = -36CEF - 288EG + 108F^2 + 8E^3, \quad h_4 = \frac{1}{3}CF - \frac{4}{3}G - \frac{1}{9}E^2, \\
h_3 &= [81C^4G^2 - 54C^3EFG + 12(CF)^3 + 12C^2E^3G - 3(CEF)^2 - 432E(CG)^2 + \\
&\quad 384(EG)^2 - 18G(CF)^2 + 240CFGE^2 - 54CEF^3 - 48GE^4 + 12E^3F^2 + \\
&\quad 576CFG^2 + 432EGF^2 + 81F^4 - 768G^3]^{\frac{1}{2}}, \quad h_5 = -CE + 2F + \frac{1}{4}C^3, \\
h_6 &= \sqrt{h_1 + \frac{1}{6}(h_2 + 12h_3)^{\frac{1}{3}} - \frac{6h_4}{(h_2 + 12h_3)^{\frac{1}{3}}}}, \quad h_7 = (2h_1 - \frac{1}{6}(h_2 + 12h_3)^{\frac{1}{3}} + \frac{6h_4}{(h_2 + 12h_3)^{\frac{1}{3}}})^{\frac{1}{2}} + \frac{h_5}{h_6}.
\end{aligned} \right\}. \quad (65)$$

The main parameters in equations (51)-(56) can be expressed as:

$$\left. \begin{aligned}
s_1 &= f_1 k_1, \quad s_2 = f_1 k_2, \quad s_3 = f_2 + \lambda l_1^2 - f_3, \quad s_4 = f_2 + \lambda l_2^2 - f_3, \\
s_5 &= f_2 + \lambda l_3^2 - f_3, \quad s_6 = f_2 + \lambda l_4^2 - f_3, \quad s_7 = \frac{sc_2}{\omega^* D_E}, \\
r_1 &= f_5 + f_4 k_1^2 + k, \quad r_2 = f_5 + f_4 k_2^2 + k, \quad r_3 = f_1 l_1, \\
r_4 &= f_1 l_2, \quad r_5 = f_1 l_3, \quad r_6 = f_1 l_4, \quad q_1 = -f_7 k_1 a_1^*, \quad q_2 = -f_7 k_2 a_2^*, \\
f_1 &= -ib(2\mu + k), \quad f_2 = \lambda_0 - b^2(\lambda + 2\mu + k), \quad f_3 = \gamma(1 + d_n), \\
f_4 &= \mu + k, \quad f_5 = b^2\mu, \quad f_6 = \frac{\alpha_0 \omega^{*2}}{\rho C_2^4}, \quad f_7 = \frac{\gamma \omega^{*2}}{\rho C_2^4}.
\end{aligned} \right\}. \quad (66)$$

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Figure 1 Variation of displacement distribution U against the horizontal distance under the impact of three different theories C-D, L-S and G-N.

Figure 2 Variation of displacement distribution w against distance under the effect of three different models C-D, L-S and G-N.

Figure 3 Variation of temperature distribution T against distance under the effect of three different models C-D, L-S and G-N.

Figure 4 Variation of distribution of carrier density N against distance under the effect of three different models C-D, L-S and G-N.

Figure 5 Variation of stress distribution σ_{xz} against distance under the effect of three different models C-D, L-S and G-N.

Figure 6 Variation of stress distribution σ_{xz} against distance under the effect of three different theories C-D, L-S and G-N.

Figure 7 Variation of microstress λ_z against distance under the effect of three different models C-D, L-S and G-N.

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Figures

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The variation of the distribution u against x under different values of ϵ_1 under L-S theory.

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The variation of displacement component w against distance x under different values of ϵ_3 under L-S theory.

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