Free-Charge Carrier Profiles of Iso- and Anisotype Si Homojunctions

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Our Message

• We demonstrate the first desktop THz ellipsometer in the frequency range from 0.1 to 1.5 THz (3 to 50 cm⁻¹) using a rotating analyzer configuration and a tunable backward wave oscillator source.
• THz ellipsometry enables optical determination of low (10¹⁸ cm⁻³) free charge carrier concentrations in silicon bulk and layered structures.
• THz ellipsometry can be used to accurately find the location of an abrupt isotype (p+n or n+p) homojunction as well as the diffused carrier concentration profile.
• Simultaneous analysis of THz and FIR data allows contact-free, non-destructive measurement of complex semiconductor structures.

Motivation

• Optical sensitivity to low carrier concentration levels via THz resonance polarizations provides a new technique to study complex semiconductor structures.
• Integrated Circuit waveguides for photonic computation and integration with optical fiber communications.
• High mobility transistors
• Silicon homojunction interfacial workfunction internal photoemission (HIWIP) far-infrared detectors
• The low THz region is dominated by surface guided waves, present here at ~290 GHz and ~900 GHz.
• The FIR region is dominated by Fabry-Perot oscillations, which damp at high frequency.

Silicon Iso- and Anisotype Example Systems

Model System

Spectral Features

• p+n Sample

P+P+ Sample

N+N+ Sample

N/P+P+ Sample

Analytical Model

Analytical solution to Poisson equation of an isotype homojunction [1]:

\[ \phi(x) = -\frac{2}{\varepsilon_0 \varepsilon_r} \int \rho(x') dx' \]

Assuming semi infinite boundary conditions and substituting the non-degenerate semiconductor expressions:

\[ N(x) = N_{th} \exp(-\frac{\phi(x)}{kT}) \]

\[ P(x) = N_{th} \exp(\frac{\phi(x)}{kT}) \]

Results in a simplified equation if \( N_x = N_{th} \), where \( N_x \) may be determined entirely in terms of \( N_x \), \( N_N \), and a characteristic length \( L \).

\[ N(x) = N_{th} \exp \left[ \frac{1}{\varepsilon_0 \varepsilon_r} \left( \frac{\phi(x)}{kT} - \frac{\phi(L)}{kT} \right) \right] \]

Separate solutions for each side of the abrupt dopant junction lead to an asymmetric carrier profile. Mobility is also given as a function of concentration [2].

\[ \mu = \mu_0 + \frac{\mu_0}{\frac{n}{n_0} + \frac{1}{\frac{p}{p_0}}} \]


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