**Dynamics of Carrier Transport in Nanoscale Materials**

**Koichi Shimakawaa,b)**

a) Department of Electrical and Electronic Engineering, Gifu University, Gifu 501-1193, Japan

b) Faculty of Engineering, Universidate Nacional Timor Lorosa’e, Hera, East Timor

E-Mail: cancio.monteiro@untl.edu.tl

**Abstract:** It is known from the terahertz (THz) spectroscopies that deviation from the Drude law for free carriers is dramatic in most electronically conductive nanomaterials. It is suggested that among a variety of theoretical formalisms, a model of series sequence of transport involving grains and grain boundaries provides a reasonable explanation of Lorentz-type resonance (non-Drude behavior) in nanomaterials. Of particular interest is why do free carriers behave as a Lorentz-type resonance.

**Keywords:** nanomaterial, THz spectroscopy, non-Drude transport

**1. Introduction**

The interaction of THz radiation (0.1 – 10 THz; 0.4 – 40 meV) with charge carriers provides important information on carrier transport in a wide range of materials, when the charge carrier scattering time lies around 10-14 – 10-13 s [1],[2]. In this frequency range, the most prominent change in the frequency-dependent complex conductivity is expected to occur.

Free carriers follow the Drude law if the medium is homogeneous [3]. It is of interest to know what happen in inhomogeneous media. It is known that a deviation from Drude behavior is observed in most electronically conductive nanostructured materials, such as metals [4]-[6], semiconductors [7]-[16], and oxides [17]-[19].



**Fig. 1** Optical conductivity in the Drude relaxation [(a) and (b)] and in the Lorentz

resonance [(c) and (d)].

|  |  |
| --- | --- |
|  | (1) |

where *σ*(0) is the Boltzmann dc conductivity given by e2*n*f*τ*/*m*\*, *n*f is the density of free carrier, *m*\*the effective mass, *τ* the scattering time, and *ω* the angular frequency of external excitation, assumed to be exp(-i*ωt*).

**Table 2.** Proposed CSSAL S-box chip feature summary

|  |  |
| --- | --- |
| Application Area | smart-card, RF-ID tag, Cryptographic-circuits |
| Feature | The peak current of the proposed chip is uniformly plotted which is resistive to DPA attacks |
| Performance | * Pdiss. CSSAL: 0.36 mW @ 125 kHz |
|  | * LSI area: 758 (W) x 614 (H) µm2 |

**References**

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