THERMAL PROCESSES IN THE METALLIZED TRACKS DURING THE FLOW OF CURRENT DISCHARGE PULSE

Evdokimova I. A., Piskun G. A., Alekseev V. F.
Scientific adviser: PhD, associate prof. Alexeev V. F.
Belarusian State University of Informatics and Radioelectronics, Republic of Belarus
E-mail: piskunbsuir@gmail.com

Abstract — The thermal processes that occur in the metallized tracks, organized on semiconductor crystals of integrated circuits, during the discharge pulse of static electricity are considered. The basic formulas of heat exchange for various mechanisms of heat energy transfer are presented.

1. Introduction

Among various types of damage of IC by static electricity discharges, a prominent place belongs to the effect of melting of metallized tracks, which are narrow (with the width of a few microns), thin (thickness is about 0,5 μkm), long (length is 100 μkm) strips of metallization sprayed onto the surface of the oxide protective films [1 - 3].

2. Main part

When calculating the thermal regime, it is enough to consider the process of abstracting the heat flow only from the track (generally, from the most heated area of it), neglecting thermal processes of the contact pad.

Heat abstraction from the track is performed in four ways: by convection, heat radiation, heat transfer along the track and heat transfer in the depth of the semiconductor chip. The amount of heat abstracted from the metallized track per unit of time is:

— by convection (in accordance with Newton's formula) (1)

$$Q_c = \alpha_c S_c (T - T_0), \quad (1)$$

— by thermal radiation (at Stefan-Boltzmann law) (2)

$$Q_r = 4{,}9\varepsilon \left(\frac{T}{100}\right)^4 S_r, \quad (2)$$

— by thermal conductivity of metallized track (in accordance with the law of Fourier) (3)

$$Q_{C1} = \frac{8\lambda S}{l}(T_M - T_0). \quad (3)$$

Formulas (1) - (3) have the following denotions: αc — coefficient of heat transfer by contact (*W*/(cm^2×K)); *Sc* — area of surface participating in the heat exchange (m2); T, T_0, T_M — track surface temperature, ambient temperature and the temperature of track in the hottest cross section respectively (K); ε — emissivity factor of the radiating body; S_r — area of radiating surface (m^2); λ — coefficient of thermal conductivity of track (*W*/m×K); *l* — track's length (m); *S* — cross-sectional area (m^2).

Thermal model of multilayer structures with multiple interacting heat sources on surface is very cumbersome for the analysis of dynamics of the flow of electrothermal processes. A rigorous solution of the problem of thermal transient characteristic of such model is associated with great mathematical difficulties and usually leads to the solution in form of an infinite series [1]. However, the model can be significantly simplified, if we take into account the difference between values of thermal resistance and thermal diffusivity of the individual layers and undesirable spreading of heat flow in the thin layers formed on the chip.

Based on the foregoing, we can make the following conclusions:

— silicon chip, that has a relatively small value of thermal resistance and a large thermal inertia, is an ideal heat abstraction for considerated process;

— sprayed tracks are characterized with negligible warm-up time and can be considered as instantly heating layers with a low thermal resistance;

— the most significant part of thermal resistance is concentrated in the layers of lead-silicate glass and silicon oxide; moreover the value of this resistance, during the flow of current discharge pulse through the tracks, depends strongly on the ratio between the discharge time constant and thermal time constant of these layers.

The main way to increase the thermal stability of metallized tracks on the effects of static electricity discharge is to spray thicker and rather dense layers of metallization of materials with high electrical conductivity [1].

3. Conclusion

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4. References

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ТЕПЛОВЫЕ ПРОЦЕССЫ В МЕТАЛЛИЗИРОВАННЫХ ДОРОЖКАХ ВО ВРЕМЯ ИМПУЛЬСА РАЗРЯДА СТАТИЧЕСКОГО ЭЛЕКТРИЧЕСТВА

Евдокимова И.А., Пискун Г.А., Алексеев В.Ф.
Научный руководитель: Алексеев В.Ф.
Белорусский государственный университет информатики и радиоэлектроники, Республика Беларусь

Аннотация — Рассмотрены тепловые процессы, которые происходят в металлизированных дорожках, организованных на полупроводниковых кристаллах интегральных схем, во время импульса разряда статического электричества. Представлены основные формулы теплообмена для различных механизмов переноса тепловой энергии.