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INFLUENCE OF THE SUBSTRATE MATERIAL ON TEMPERATURE DISTRIBUTION IN HYBRID CIRCUIT

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KEY WORDS: substrate material, ceramic substrates, hybrid circuits, temperature distribution, characteristic thermal length, thermal conductivity, thermal characteristics, experimentalt research

ABSTRACT: The present paper shows the two-dimensional temperature distribution on the hybrid circuit made on ceramic and the other material substrates.

UTJECAJ MATERIJALA SUBSTRATA NA TEMPERATURNU RASPODJELU U HIBRIDNOM KOLU

Ključne rječi: substratni materiali, keramički substrati, hibridna kola, raspodjela temperature, karakteristička termička dužina, termička prevodljivost, termičke karakteristike, eksperimentalna istraživanja

Sažetak: U radu je prikazana dvodimenzionalna razpodjela temperature u hibridnom kolu realiziranog na keramičnom i drugim substratima.

Introduction

Thermal analysis in microelectronics gained a lot of interest in recent years. One of the reason for growing importance is the high integration density of components.

The ceramic substrates used in hybrid circuits have relative high thermal conductivities and are extremely suited for power electronics. But as will be shown, an increase of thermal conductivity by a given factor will not reduce the temperature rises by the same factor.

The thermal model

It has been already shown(1,2) for hybrid circuits that the two-dimensional temperature distribution T(x,y) satisfies the equation

$$\nabla^2 T - \frac{T}{L^2} = -\frac{p(x,y)}{\lambda d_s}$$

where $L=\sqrt{\lambda d_s/2\alpha}$ is the characteristic thermal lenght (m)

and λ: thermal conductivity (W/mK)

α: convection coefficient (W/m^2K)

p: power dissipated per unit area (W/m^2)

d_s: substrate thickness (m)

Note: Here we use linear thermal model

Thermal length L is radius of heated zone around each component which act as a cooling fin. If the distance between two components is smaller than L, their temperature fields will interfere with each other.

For ceramic and glass substrates with typical parameters value:

for ceramic $\lambda = 30 - 60$ W/mK
$\alpha = 5 - 10$ W/m^2K
$d_s = 0{,}5 - 1$ mm

for glass $\lambda = 1$ W/mK
$\alpha = 5 - 10$ W/m^2K
$d_s = 0{,}5 - 1$ mm

we obtain: L = 3 to 6 cm (for ceramic) which means that large part of a substrate will act as a cooling fin. As a consequence the temperature can be influenced by changing the position of the heat sources (fig.1 and 2.).

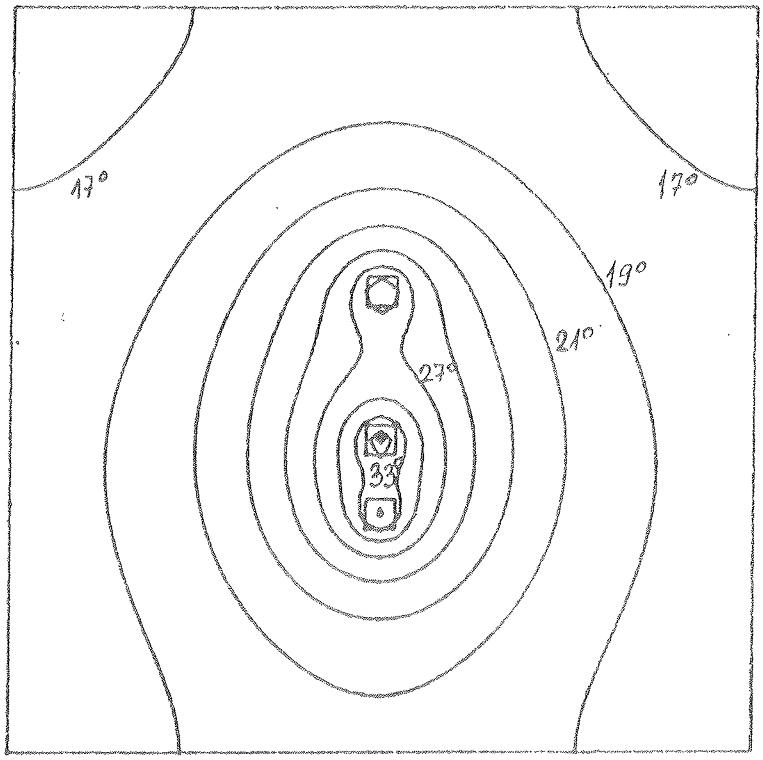
For glass substrates, L = 0.7 cm which means that small area around the heat source will contribute to the removal of the heat. So another placement of the components will have a very little influence on the maximum temperature.

Influence of the substrate material

We made a test circuit with one heat dissipating resistor which has been simulated with program, using different substrate materials (fig. 3 to 8). Here is some data:

	λ (W/mK)	L(mm)
epoxy	0,16	2,2
glass	1	5
alumina (96%)	20	25
Al N	170	71
beryllia	300	95

Substrate dimension is 50x50 mm and it is clear that only a small zone (for glass and epoxy) around the heat source will be heated. It should be noted that the thermal cooling efficiency of substrates is not always proportional to the thermal conductivity λ. For Al_2O_3 a maximum temperature rise is almost 15°C but for BeO is almost 7°C. We can observe a reduction of temperature rise of a factor 2 for an increase in thermal conductivity of 300/20=15.

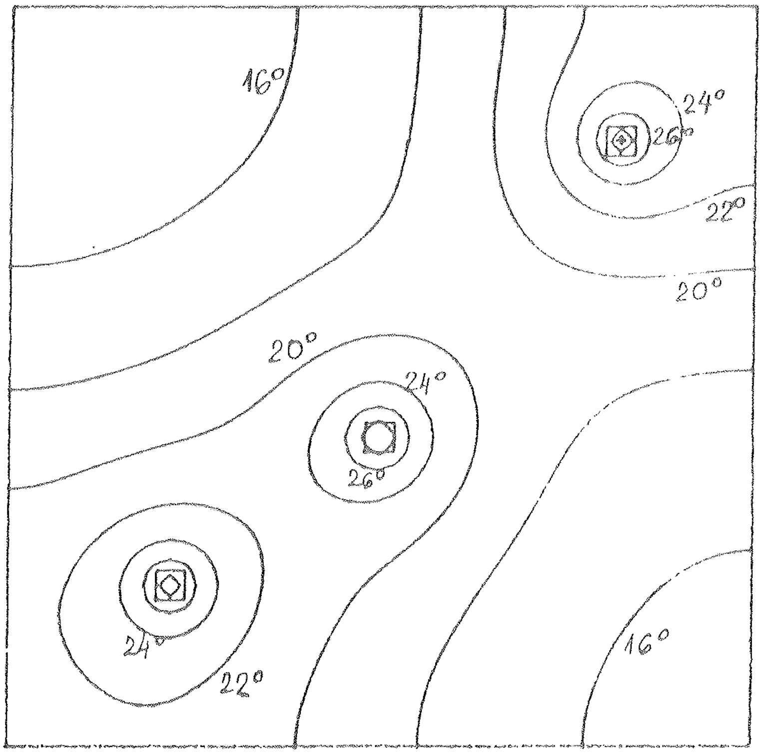


DT = 0.2000E+01
* °C

Tmax = 0.3497E+02

Tmin = 0.1733E+02

Fig. 1



DT = 0.2000E+01
* °C

Tmax = 0.3098E+02

Tmin = 0.1632E+02

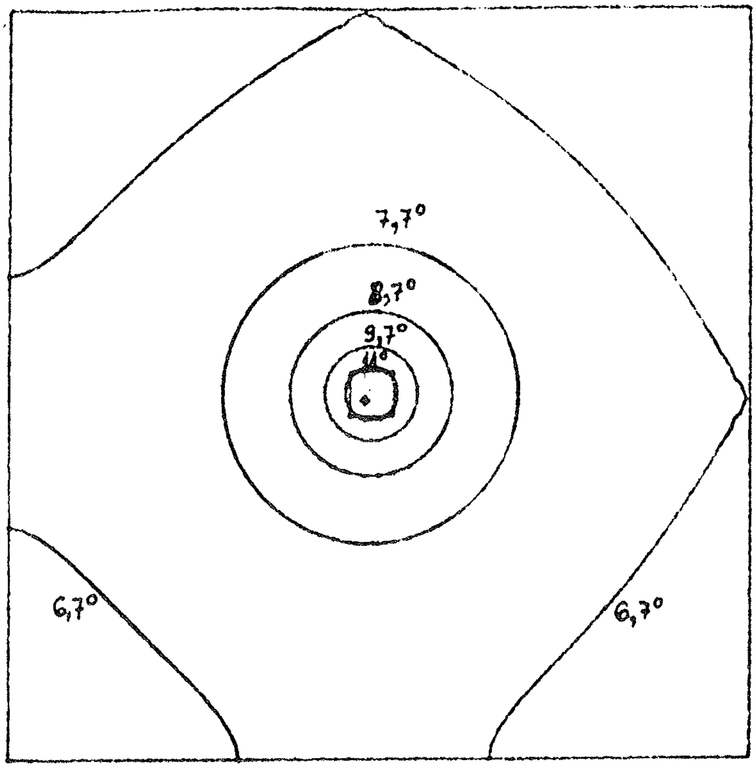
Fig. 2

Fig. 1-2: Changing the temperature distribution by changing the position of the heat sources

Also, the maximum temperature difference between AlN and BeO are negligible because the characteristic length are large in both cases.

Conclusion

Here we have shown the influence of the substrate material on the temperature distribution and that using high quality substrates is not always usefull from the thermal point of view.



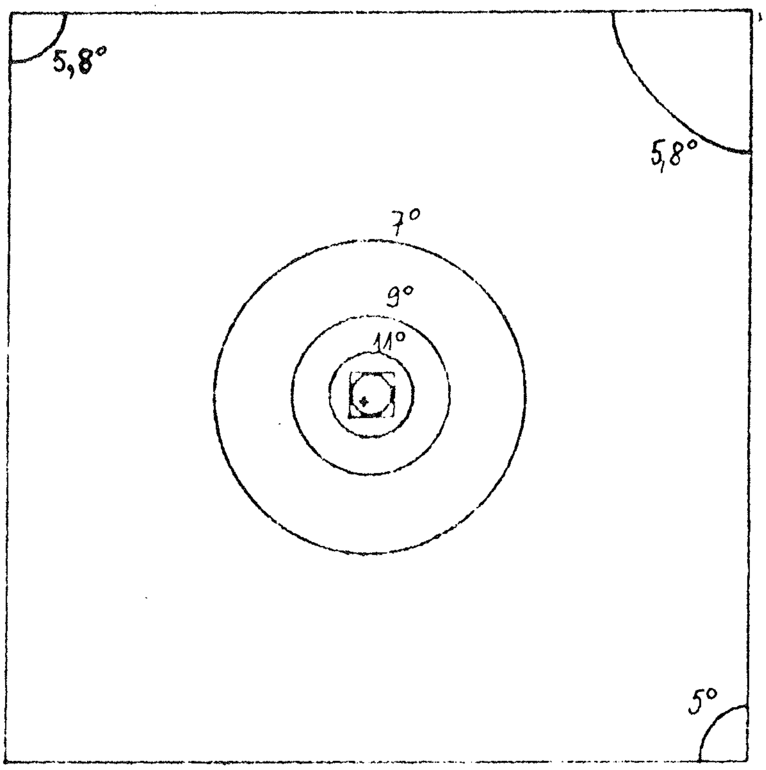
DT = 0.1000E+01

ALUMINA (99%)
λ = 40 W/m°C
L = 30 mm
α = 10 W/m²°C
* °C

T_{max} = 0.1183E+02

T_{min} = 0.6693E+01

Fig. 3



DT = 0.2000E+01

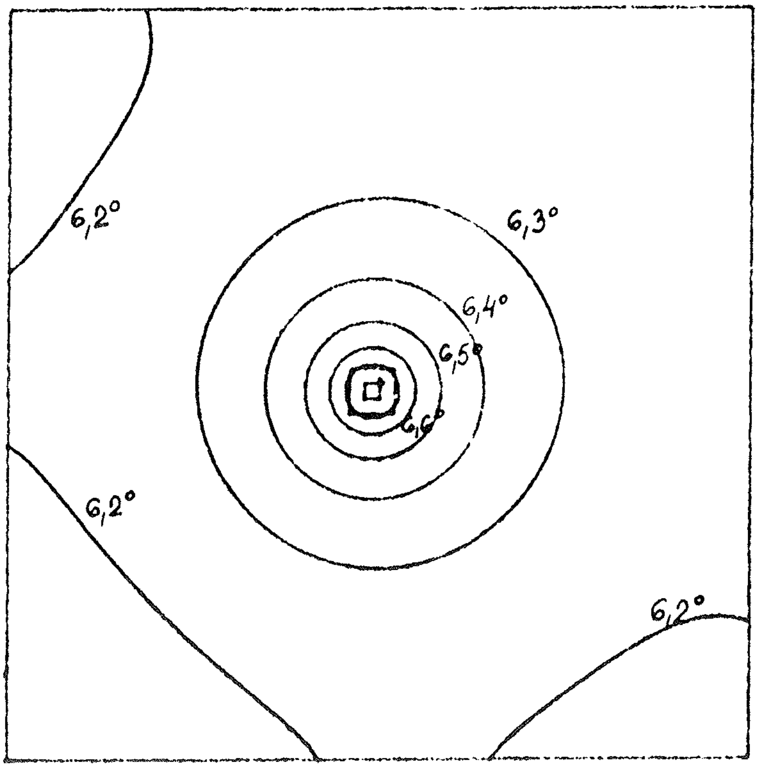
ALUMINA (96%)
λ = 20 W/m°C
L = 25 mm
α = 10 W/m²°C
* °C

T_{max} = 0.1497E+02

T_{min} = 0.5856E+01

Fig. 4

Fig. 3-8: temperature distribution for one dissipated resistor (p=1/4 W) on different substrates



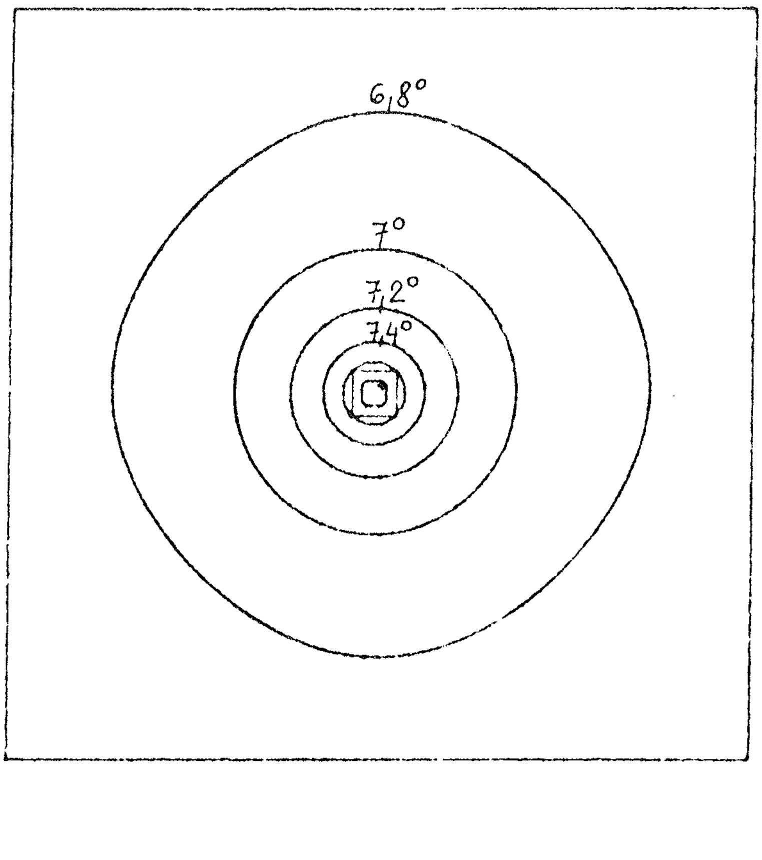
DT = 0.1000E+00

BERYLLIA
λ = 300 W/m°C
L = 95 mm
α = 10 W/m^2°C
* °C

T_{max} = 0.6902E+01

T_{min} = 0.6246E+01

Fig. 5



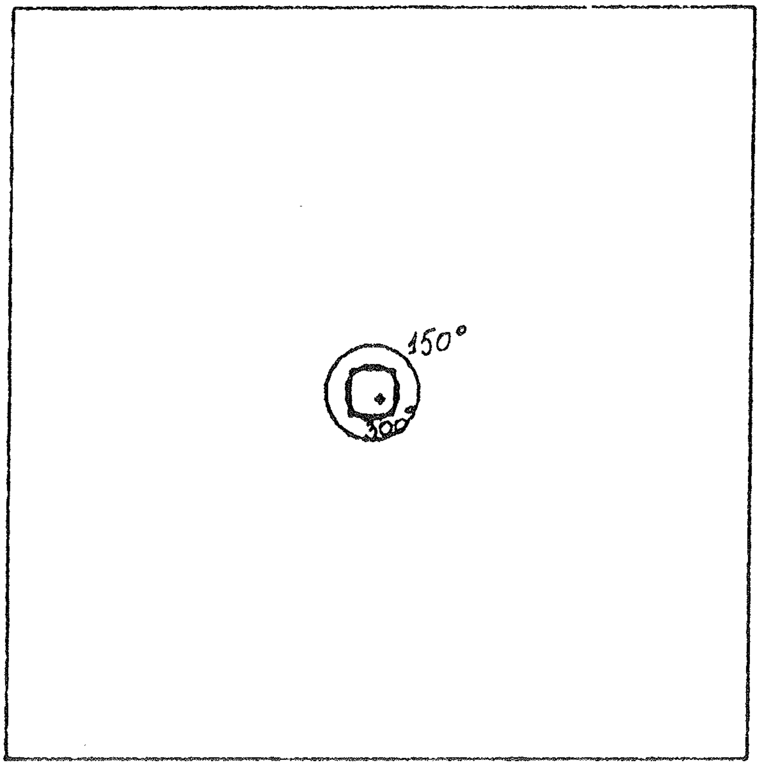
DT = 0.2000E+00

AIN
λ = 170 W/m°C
L = 71 mm
α = 10 W/m^2°C
* °C

T_{max} = 0.8049E+01

T_{min} = 0.6864E+01

Fig. 6



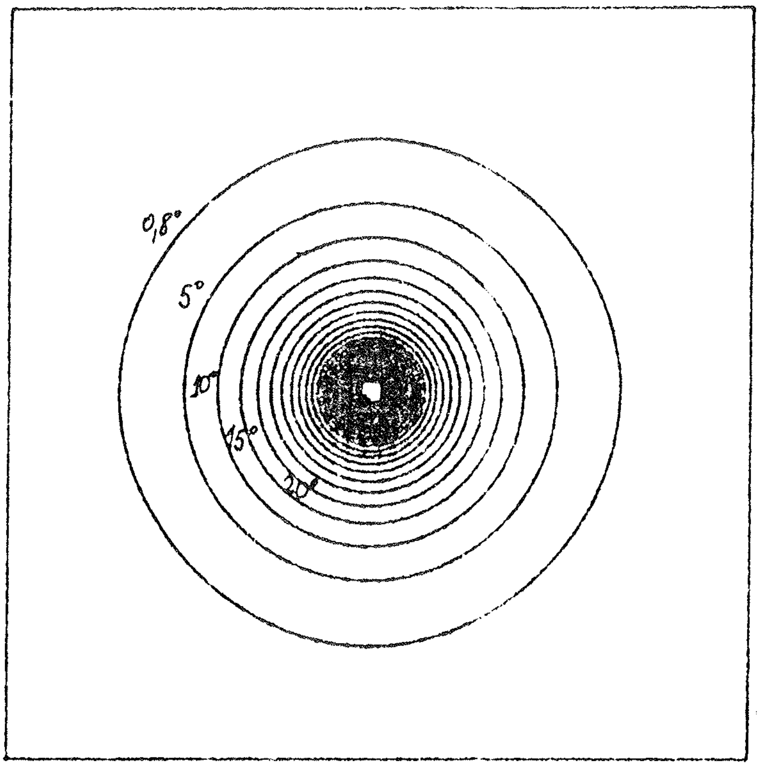
DT = 0.1500E+03

EPOXY
λ = 0.16 W/m°C
L = 2.2 mm
* °C

T_{max} = 0.4483E+03

T_{min} = 0.3719E-03

Fig. 7



DT = 0.5000E+01

GLASS
λ = 1 W/m°C
L = 5 mm
* °C

T_{max} = 0.1293E+03

T_{min} = 0.8386E+00

Fig. 8

Literature:

1. K. Skakic, S. Sirbegović "Temperature distribution in HMC by iterative method", MIEL 1989.
2. K. Skakić, "Termičko modeliranje hibridnih mikroelektronskih kola", Magistarski rad, 1989

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