B

Introduction to Thin Film Technology

Until recently thin film technology was considered esoteric and cost prohibitive for all but a few demanding applications where miniaturization and performance against cost was of paramount importance. However, with increasing demands on space, performance and cost, KOA Speer Electronics, Inc. has introduced its line of integrated passive components that offer design engineers a unique solution to tackle these problems.

The technical benefits of thin film integrated networks has been well established. Tremendous progress has occurred in deposition, film materials, photolithography, laser trimming, testing and the ability to combine with active components. These advances have made the technology economically competitive compared to traditional passive component technologies.

Today’s high frequency, high-speed applications have increased demand for thin film integrated passive devices. KOA's integrated products offer significant performance, space and cost advantage over competing technologies.

The KOA Speer data book is designed to help circuit designers and component engineers improve their understanding of these dynamic products so they can capitalize on their many and significant benefits.

Application Advantages

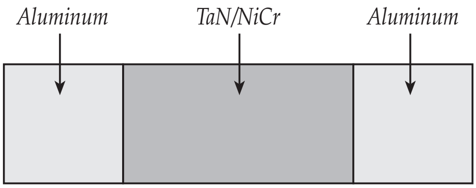
- Extremely close matching of all elements in a network, ensuring close tracking over temperature and throughout life
- Low profile, high-density, multi-element construction for significant real estate savings on PCB
- Higher frequency stability
- Greater packaging density
- Repeatable and consistent characteristics device-to-device and lot-to-lot
- Low inductance
- High reliability
- No thermoelectric effects
- Low power consumption
- Installed cost less than discretes
- Advance termination and filtering solutions with combination of active components using CMOS fabrication

Construction

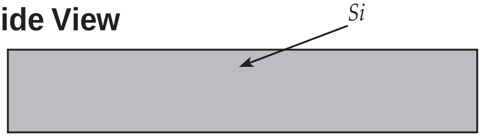
An integrated passive device is a grouping of resistors, resistor-capacitors or active-passive components, such as resistor-capacitor-diodes.

Thin film is a standard semiconductor processing technique, using either cathode sputtering or vacuum evaporation, to deposit a very thin layer of resistor material and conductor metal on a suitable substrate to the form desired pattern for interconnections and components. The patterns are formed by photo lithography and etching. The resulting fine-line patterns are particularly suited to high density interconnections and high frequency applications. The process of developing a pattern using thin film process is shown below.

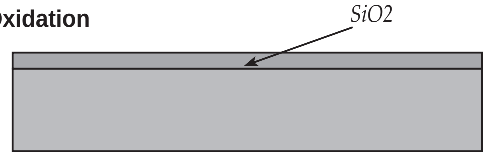
Top View



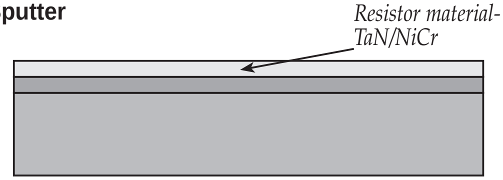
Side View

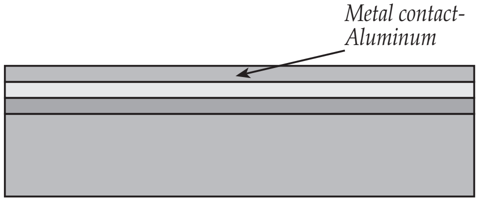


Oxidation

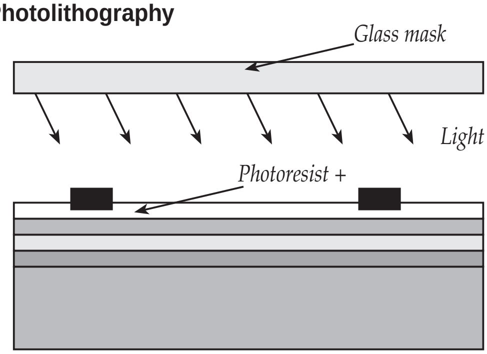


Sputter

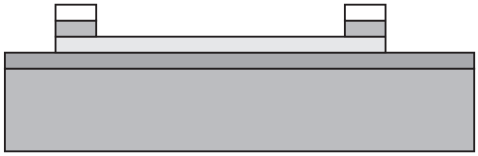




Photolithography



Metal etch



KOA's integrated devices are silicon based thin film networks. Silicon substrate offers the following advantages:

- High electrical insulation (>10,000MΩ) which prevents current leakage between closely spaced conductor lines
- Low dielectric constant (E = 3.9)
- Low dissipation factor and loss tangent, ideally required for high speed, high frequency electrical circuits
- High thermal conductivity (150 W/m/C), aiding heat dissipation
- High thermal stability, which prevents outgassing at high temperatures
- Low coefficient of thermal expansion (2.6 x 10^{-6}/°C) which minimizes stress and avoids cracking during thermal cycling
- Low porosity and high purity, which prevents moisture and contaminant entrapment, arcing and metal migration
- Can be made conductive by doping, a property utilized to build KOA's standard back contract RC networks
- Higher resistance to harsh chemicals used in normal semiconductor processes, such as chemical etching
- High degree of surface smoothness for fine line widths
- Can be backlapped to fit industry's smallest and low profile IC packages, such as SOT and QSOP

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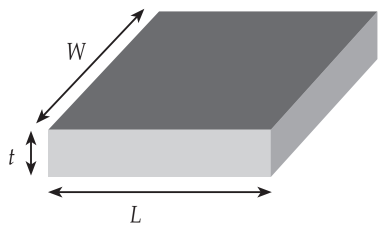
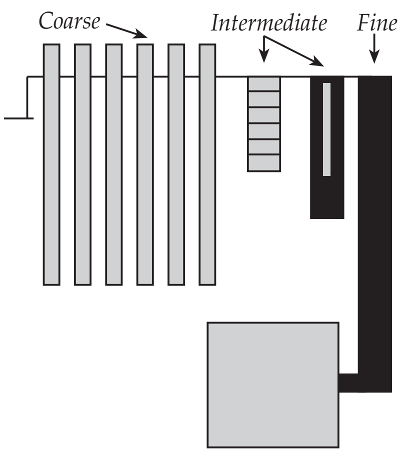
Resistor Networks

Photolithography enables precision patterning to give designers a wide range of resistance values in the smallest possible area. The total resistance achievable is a function of sheet resistively of the material and pattering. Typical thin film resistive materials have sheet resistively between 50 to 500 ohms/square, and highest precision is found between 100Ω to 100KΩ.



\# Of squares (n)=L/W
p= Intrinsic resistivity in Ω-cm
Rs= Sheet resistivity (*p*/t in Ω/☐)
Resistance (R)= n x Rs

Precision laser trimming and special design techniques enable KOA to adjust resistors to achieve precise absolute tolerance down to 0.01% or ratio tolerance as low as 0.005%. This is an inherent advantage of using thin film technology for integrated devices, which exhibit superior electrical and mechanical stability, compared to discrete components, because any change is common to all elements in the network.



Resistor Materials

The selection of thin film resistor materials depends on TCR, VCR, resistance noise, stability, achievable sheet resistivity, allowable power density and compatibility with other materials and film deposition methods. Based on the considerations mentioned above, KOA's integrated networks are manufactured using either Nichrome or Tantalum Nitride, depending upon the customer's specific requirements.

Some properties of TaN compared to NiCr

Film Material	**Deposition Technique**	**Sheet Resistance** Ω/∏	**TCR** ppm/°C
NiCr (80:20)	Evaporation	10-400	100-200
TaN	Reactive Sputtering	10-100	-85

TCR (Temperature Coefficient of Resistance) is a unit change of resistance per unit change in temperature, expressed in parts per million per degree centigrade (ppm/°C).

TCR = R2-R1/{R1(T2-T1)}x10^6

R1= Resistance at room temperature

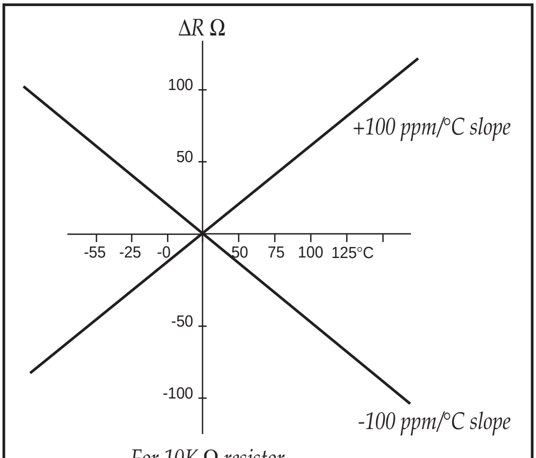
R2= Resistance at operating temperature

T1= Room temperature

T1= Operating temperature

When the resistance change is linear over temperature range the TCR is constant.
For some materials, such as NiCr, the TCR slope is non-linear. In such cases, the TCR is expressed as the slope of the line connecting two points on the resistance-temperature curve between, -55°C to +125°C (Mil-Std 202). It is therefore imperative to specify TCR over a specific temperature range.

Linear TCR Slope for Thin Film Materials



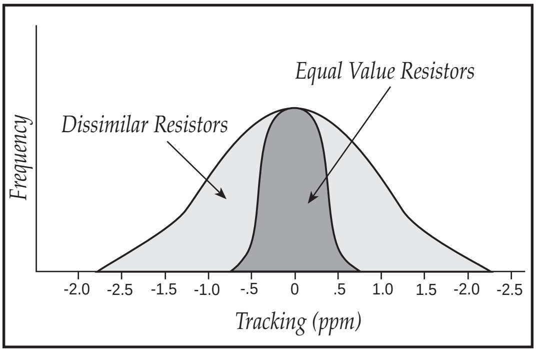
$$\text{TCR in ppm/°C} = \frac{\Delta R}{R} / \Delta T\ (1\text{x}10^6)$$

Thin film integrated networks possess excellent tracking compared to discrete resistors. In discretes, the tracking between matched pairs may be as great as twice the specified absolute TCR. However, for thin film integrated networks, the tracking TCR is independent of the absolute TCR.

KOA's resistor networks deliver an absolute TCR of 25ppm/°C and easily obtain TTCR of 10ppm/°C or less. This is because all KOA networks are precisely laid out using sophisticated design tools, and manufactured using state-of-art process controls and measuring equipment.

Tracking Distribution

(IPD Networks)

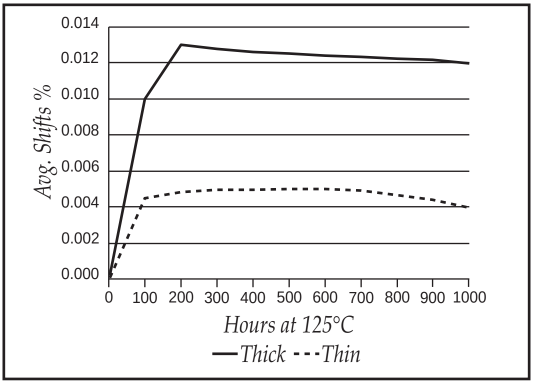


Stability

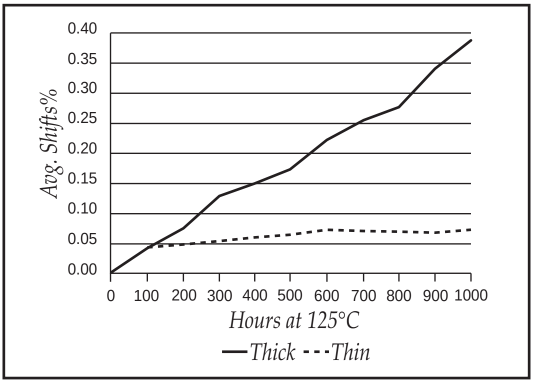
Temperature and long-term stability are key to resistor networks. Thin film resistor networks, as opposed to thick film networks, exhibit different electrical characteristics over time and temperature.

Most precision networks are used in a ratio mode requiring precise tracking over different environmental conditions. KOA Speer's thin film resistor networks are trimmed to tight tolerance, and with precise material control and process technique, will maintain the initial tight tolerance throughout the life of the network.

Thin Film Resistor Tracking



Thick vs. Thin Film Resistor Shifts



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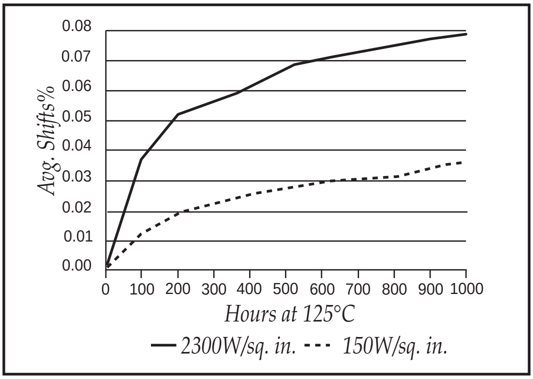
Thin Film Resistor Shifts vs. Power Density



The rate of change of resistance over time is a single valued function of temperature, ambient or power loading. KIPCO networks exhibit superior stability and the change in absolute and resistance ratios is minimal.

Power Rating

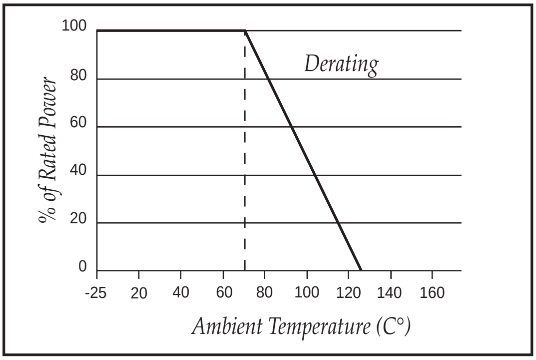
Proper network design ensures uniform power density.

Typical operating temperature is 125°C (max). This is the maximum temperature at which the network can operate for a specified period of time, eg. 1000 hours, with minimum change to the initial value.

Maximum power rating is the power required to raise the surface temperature beyond the ambient temperature, 70°C, to its maximum operating temperature.

This, however, depends upon the rating of individual resistors and if they are operating at the time.

Power Derating Curve



Some of the other advantages of thin film networks is low VCR and current noise.

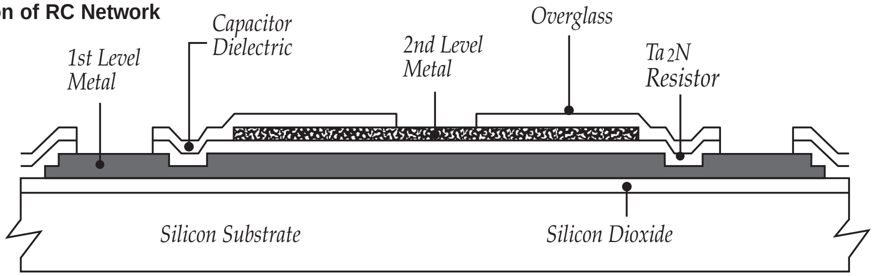
Voltage Coefficient of Resistance (VCR) is the unit change in resistance per unit change in voltage, measured as ppm/volt and is typically less than 0.1 ppm/v for values over 1MΩ.

Current noise, for thin film networks, is typically less than –25dB.

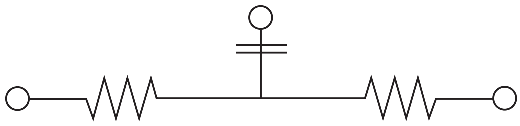
RC Networks

RC networks are widely used for EMI/RFI filtering, noise reduction and as termination networks. Thin film RC networks offer greater stability, performance and cost advantages compared to some existing alternatives, such as thick film and discrete RC filters. Typical layout of a thin film RC Network:

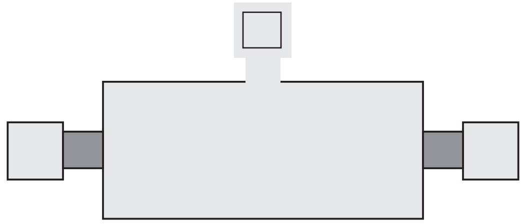
Cross Section of RC Network



Electrical Schematic



Layout for a Thin Film Resistor and Capacitor Network



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Introduction to Diodes

There are several types of diodes, the basic ones being: pn Junction Diode, Schottky Diode, Zener Diode, P-i-N Diodes and Photo-Junction Diodes.

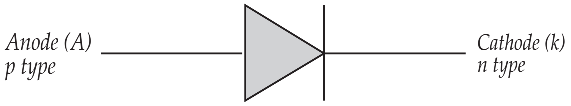
pn Junction Diodes

This is the most basic type of diode.
Among its features are:

- Simple fabrication process
- Widely used in all IC's
- Reverse breakdown inversely proportional to concentration of lightly doped region
- Typical forward voltages are 0.3 to 0.7V
- Typical reverse voltages are 10V to 20V (or ~100V for Well diodes)
- Typical TRR (Reverse Recovery Time) @ 10mA is ~10µS

Common Applications

- ESD protection
- Decoupled pull-up resistors
- Decoders
- Free wheeling diodes for inductive loads

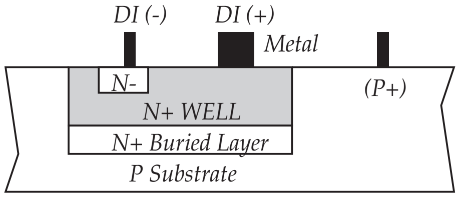


Schottky Diodes

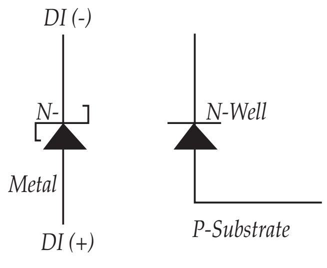
The Schottky diode has very little junction capacitance, and therefore it can be operated at much higher frequencies than the typical *pn* junction diode. The reduced junction capacitance also results in a much faster switching time, because of this Schottky diodes are used more and more in digital switching applications.

Low junction capacitance and the high-switching-speed capability of the Scottky diode are the result of more complex processing compared to simple pn junction diode.

- Typical Vf is 0.35V @ 1mA, and ~1V@50mA
- Typical VBD 15 to 25V
- Typical TRR (Reverse Recovery Time) @ 10mA is 10 ~ 50nS



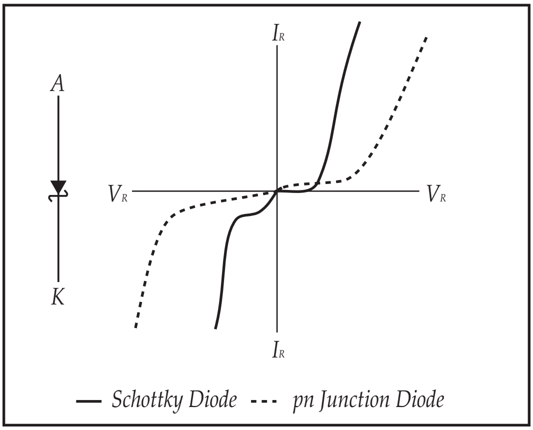
P-Substrate must always be defined as the most -ve potential, eg. Vss



Common Applications

- Signal clamping to remove overshoot and undershoot
- Digital switching applications
- Applications, like high efficiency rectifier, that require low Vf
- Low current switching circuits where it is capable of operating at frequencies>20GHz

Schottky Diode Characteristic Curve



Zener Diodes

The Zener Diode is a special type of diode that is designed to work in the reverse breakdown region of the diode characteristic curve. This diode has a relatively constant voltage across it, regardless of the value of current through the device.

Typical breakdown voltage is from 1V to 80V. Typical voltage for KIPCO Zener diodes is >5V@1mA.

Common Applications

Specifically used for the purpose of maintaining constant voltage, regardless of variation in load current.

- Internal reference voltage with low current
- Not suitable for power clamping applications

Reverse Breakdown Characteristics