

## Requirements for Chip Metallization

### Illustration

The metal lines connecting transistors or other components on a **Si** chip must meet many, partially conflicting, requirements. Below is a list, including some materials that do *not* meet the particular requirement very well.

Can you guess the winner?

Desired Property	Materials <i>not</i> meeting requirement
Very good conductivity	All but <b>Ag</b> , <b>Cu</b>
High eutectic temperature with <b>Si</b> ( <b>&gt; 800 °C</b> would be good)	<b>Au</b> , <b>Pd</b> , <b>Al</b> , <b>Mg</b>
Low diffusivity in <b>Si</b>	<b>Cu</b> , <b>Ni</b> , <b>Li</b>
Low oxidation rate; stable oxide	Refr. Metals, <b>Mg</b> , <b>Fe</b> , <b>Cu</b> , <b>Ag</b>
High melting point	<b>Al</b> , <b>Mg</b> , <b>Cu</b>
Minimal interaction with <b>Si</b> substrate	<b>Pt</b> , <b>Pd</b> , <b>Rh</b> , <b>V</b> , <b>Ni</b> , <b>Mo</b> , <b>Cr</b> (form silicides easily)
Minimal interaction with poly <b>Si</b>	Same as above
No interaction with <b>SiO<sub>2</sub></b>	<b>Hf</b> , <b>Zr</b> , <b>Ti</b> , <b>Ta</b> , <b>Nb</b> , <b>V</b> , <b>Mg</b> , <b>Al</b>
But must stick well to <b>SiO<sub>2</sub></b>	?
Must also comply with other substrates, e.g. <b>TiN</b>	? (see example for <b>Al</b> below)
Chemical stability, especially in <b>HF</b> environments	<b>Fe</b> , <b>Co</b> , <b>Ni</b> , <b>Cu</b> , <b>Mg</b> , <b>Al</b>
Easy structuring	<b>Pt</b> , <b>Pd</b> , <b>Ni</b> , <b>Co</b> , <b>Au</b>
Electromigration resistant	<b>Al</b> , <b>Cu</b>
.... and many more,...	

The winner is: **Aluminum** (with **<1%** of **Si** and **Cu** added).

**Al**, in fact, is pretty bad - but all others are worse!

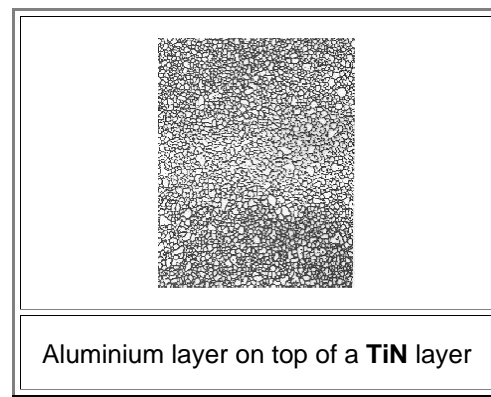
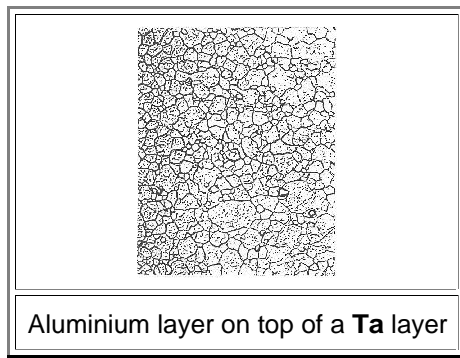
Presently (**2001**) a switch to **Cu** takes place (the better conductivity is definitely needed). The industry will pay several **10<sup>9</sup>** Dollars to develop the new material technology and change the production facilities.

## Al Grain Structure on Different Substrates

Around the late eighties, the necessity came up to use a **diffusion barrier** between the **Al** - metallization and the **Si** substrate because the reaction of **Al** with the **Si** in contact holes with cross sections **< 1 μm<sup>2</sup>** became a problem. One material of choice was **TiN**, another one **Ta**.

The grain structure of the **Al** layer (and with it other properties, e.g. the electromigration resistance, depends significantly on the substrate).

Below you can see the representative pictures (identical scale) that illustrate this point.



Close examination revealed that the substrate influences:

1. Grain size.
2. Grain size distribution.
3. Texture.
4. Degree of **Si** precipitation.
5. Macroscopic stress.
6. Microscopic stress.

All of these properties may influence the performance of the **Al** conductor - and this gives you an idea of what it means to introduce a new material into a fine-tuned product.