Requirements for Chip Metallization

- 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?

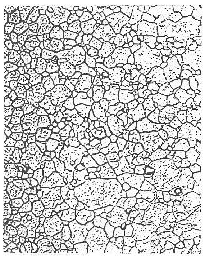
Illustration

Desired Property	**Materials not meeting requirement**
Very good conductivity	All but **Ag**, **Cu**
High eutectic temperature with **Si** (**> 800 °C** would be good)	**Au, Pd, Al, Mg**
Low diffusivity in **Si**	**Cu, Ni, Li**
Low oxidation rate; stable oxide	Refr. Metals, **Mg, Fe, Cu, Ag**
High melting point	**Al, Mg, Cu**
Minimal interaction with **Si** substrate	**Pt, Pd, Rh, V, Ni , Mo, Cr** (form silicides easily)
Minimal interaction with poly **Si**	Same as above
No interaction with **SiO_2**	**Hf, Zr, Ti, Ta, Nb, V. Mg, Al**
But must stick well to **SiO_2**	?
Must also comply with other substrates, e.g. **TiN**	? (see example for **Al** below)
Chemical stability, especially in **HF** environments	**Fe, Co, Ni, Cu, Mg, Al**
Easy structuring	**Pt, Pd, Ni, Co, Au**
Electromigration resistant	**Al, Cu**
.... and many more,...	

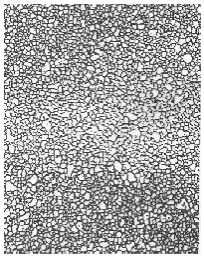
- The winner is: *Aluminum* (with **<1%** of **Si** and **Cu** added).
  - **Al**, in fact, is pretty bad - but all others are worse!
  - Presently (**2001**) a switch to **Cu** takes place (the better conductivity is definitely needed). The industry will pay several **10^9** Dollars to develop the new 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 becasue the rection of **Al** with the **Si** in contact holes with cross sections **< 1 µm^2** 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.



Aluminium layer on top of a **Ta** layer



Aluminium layer on top of a **TiN** layer

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