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Low-Temperature Synthesis of Single-Crystal-Like NiAl for Interconnect Applications

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Background Conventional copper (Cu) interconnects in integrated circuits show significant increases in line resistivity when linewidths decrease below 10 nm. This is due to two reasons: First, scattering of electrons at the interfaces becomes predominant since the linewidth is considerably smaller than the electron mean free path (EMFP) in Cu. Second, the liner and barrier layers occupy an increasing fraction of the line volume, and since the resistivity of the liner and barrier is substantially greater than that of Cu, the overall resistivity of the line increases. Because of this, there is a need for alternate interconnect materials that do not require a liner and/or barrier to enable further downscaling of device dimensions. The properties of NiAl indicate strong potential as an interconnect material. Specifically, NiAl has a relatively low resistivity, a small EMFP, a high melting point, and large cohesive energy, which results in higher electromigration resistance and suppression of interdiffusion and adverse reactions with silicon and silicon oxide. However, NiAl thin films have extremely small grain sizes (<10 nm), which leads to much higher resistivity than for bulk NiAl. Additionally, the annealing temperatures required to induce grain growth in NiAl (>500°C) exceed the maximum permissible temperature for current back-end-of-line (BEOL) processing. Invention Description Research at Arizona State University has led to the development of a method to synthesize single-crystal-like (grain diameter to film thickness ratio > 20) equiatomic NiAl thin films for barrier- and liner-free interconnects at temperatures that are compatible with current back-end-of-line (BEOL) processing requirements, around 400°C. Equiatomic NiAl has low resistivity, small electron mean free path, high melting temperature and cohesive energy, and good adhesion with SiO2. This results in better resistivity scaling with decreasing linewidth and superior electromigration resistance and thermal stability without the need for a liner or barrier layer. Potential Applications • Metallic interconnects for integrated circuits • Semiconductor manufacturing Benefits and Advantages • Method involves low temperatures that are fully compatible with current back-end-of-line (BEOL) processes. Compared to current Cu-based interconnect technology, • NiAl does not require a liner or barrier layer. • NiAl has superior electromigration resistance and thermal stability. • NiAl has the potential for improved resistivity scaling with decreasing linewidths due to significantly lower electron mean free path. Research Homepage of Professor Jagannathan Rajagopalan