Surface Contaminants in Semiconductor Manufacturing

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Surface of semiconductor wafer gets contaminated during device processing. Contaminants originate from the ambient air, storage ambient, as well as from process gases, chemicals, materials, and water, used in the fabrication processes. Furthermore, manufacturing tools as well as personnel operating them in the clean-room are also sources of contamination. The most common and proven very harmful contaminants that are present in semiconductor processing environment are as follows.

Particles

The most prevalent contaminants are particles. Any particle that is allowed to adsorb at the wafer surface may cause a catastrophic failure at virtually any stage of device manufacturing process. In a standard ambient air particle size distribution shows peaks at around 5 μm and 0.1 μm; the former are eliminated from the clean-room air in which particle size distribution peaks at about 0.1 μm [*T. Hattori, private communication*]. However, even such ultra-small particles are large comparing to critical dimensions of advanced ICs, and hence, can cause catastrophic damage to the device structure. Fig. 1a shows 0.1 um particle on 65 nm half-pitch interconnect lines while Fig. 1b compares such particle to 1.5 nm gate oxide.

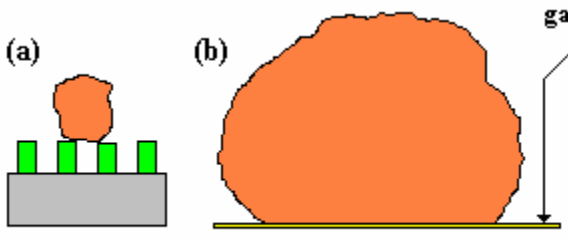

Fig. 1

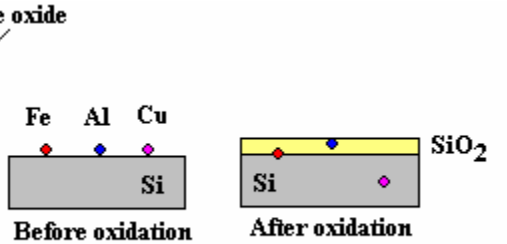

Fig. 2

Metallic contaminants

Metallic contaminants originate primarily from liquid chemicals and water as well as from metal parts of the process tool, plumbing, tubing, etc. The most common metallic contaminants are iron (Fe), aluminum (Al), copper (Cu), nickel (Ni) as well as ionic metals such as sodium (Na) and calcium (Ca). They degrade MOS gate stacks, reduce carrier lifetime, etc., depending on the kind of metal. Figure2 illustrates different behavior of common metallic contaminants during thermal oxidation of Si.

Organic contaminants

Volatile organic compounds are present in ambient air, including clean-room air, in very high amounts. Furthermore, wafers are exposed to organic volatiles originating from storage and shipping containers. Organic compounds readily adsorb at the semiconductor surfaces and if not removed they will adversely affect a number of material and device properties (see also SN-3 "Lamp Cleaning"). The same applies to solid organics remaining on the surface after photoresist removal.

Native/Chemical Oxide

Although strictly speaking not a contaminant, in Si technology an SiO_x oxide grown on the Si surface in uncontrolled fashion is often considered as such. Its removal is a part of every cleaning sequence.

Moisture

Moisture from the ambient air as well as a residue from the wet processes has a destabilizing effect on the chemical condition of semiconductor surfaces and as such is being considered as a contaminant. It must be carefully controlled in order not to alter thin film deposition processes and to assure adequate reproducibility of manufacturing process in general.

Each type of contaminant has a potential for interfering with fabrication process as well as for adversely affecting device performance. As total elimination of contaminants from process environment is not possible, elaborate methods of semiconductor surface cleaning and conditioning are employed throughout the device manufacturing sequence (see SN-15 "Surface Cleaning in Semiconductor Manufacturing").