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1990s
Low-k dielectric materials
~ Discrete Semiconductor/Others ~

As the miniaturization of LSI progressed, signal delay and crosstalk between wirings caused by increase of the Al wiring resistance and the capacitance between wirings became problems. Therefore, in the latter half of the 1990s, Cu, which has a lower resistance than Al, came to be used as the metal for wiring, and a material with a dielectric constant k lower than that of SiO2 (dielectric constant k = 4.2) (Low-k material) came to be used as the insulating material between wirings [1]. Both the coating and the plasma CVD were investigated for Low-k insulating materials deposition.

The coating method was characterized that a liquid material had been rotationally coated (spin-on) and cured with heat. The method enabled to deposit a flat surface insulating film on uneven wiring. In the latter half of the 1980s, Hitachi Chemical developed a siloxane-based organic spin-on glass (HSG-R7) with Si-O as the main chain. It had a dielectric constant k of 2.9 and was used as an interlayer insulating film for Al multilayer interconnections in the 1990s. Various companies developed coating insulating materials for Al interconnections using hydrogen silsesquioxane (HSQ) with a dielectric constant k of around 3 in the 1990s.

Dow Chemical developed aromatic dielectric resin (SiLK) for coating with a dielectric constant k of 2.6 in 1996. SiLK was applied to Cu/Low-k multilayer interconnection process by IBM, Fujitsu, Sony and others in 2000, and became a strong candidate for Low-k material. Subsequently, an alliance of many semiconductor device, manufacturing equipment, and material companies (SiLKnet Alliance) was formed to advance low-k interconnect technologies such as porous SiLK for further low-k dielectric constant, CMP planarization, and dry etching.

The notable technology was developed to add fluorine (F) and carbon (C) to silicon oxide (SiO) for low-k film deposition by plasma CVD. Fluorinated silicate glass (FSG) was explored by various companies since the early 1990s. AMAT announced a technology to deposit FSG films using a high-density plasma CVD in 1999 [(3)].

Carbon-doped glass (SiOC) film deposition also appeared in the late 1990s. AMAT developed SiOC films (Black Diamond) with dielectric constant k = 2.8 to 3 by high-density plasma CVD using trimethylsilane from Dow Corning in 1998. Novellus (later Lam Research) also developed a SiOC film (Coral) with dielectric constant k = 2.7 by plasma CVD using a precursor from Air Products Inc. in 1999.

The low-k film deposited by the coating and the plasma CVD had been continuously improved since

the 2000s, and the dielectric constant k was reduced to around 2.

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