

2000s

Adoption of low-permittivity (k) materials for the films between interconnect layers

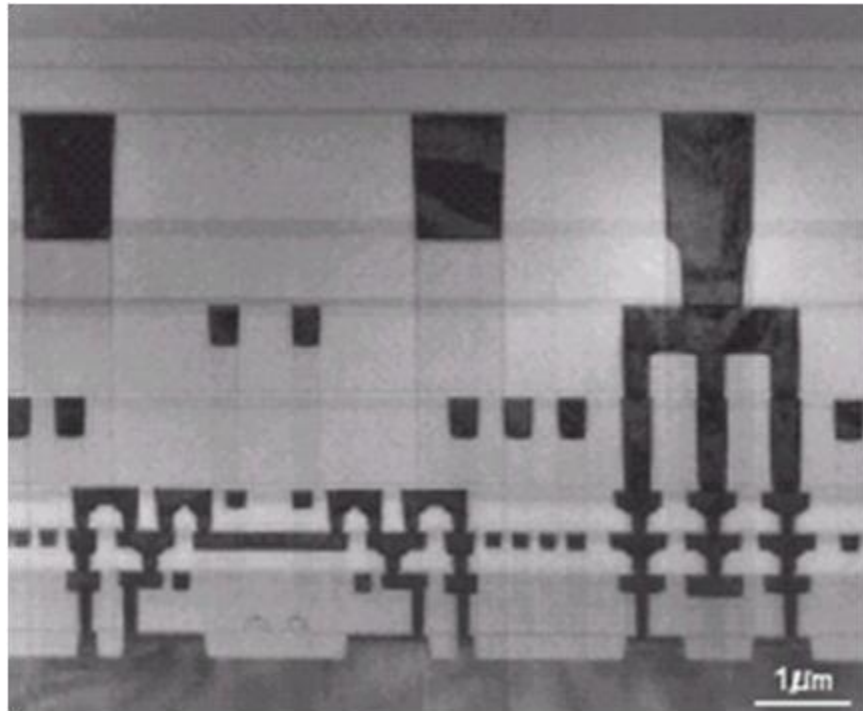
~ Process Technology ~

Historically, CVD films or coating films of silicon oxide type had been used as insulating films between interconnect layers, but as the miniaturization progressed, a signal delay and inter-wiring cross talks caused by the increase of RC (the product of the interconnect resistance R and the stray capacitance C), and power loss due to the increase of resistivity of power line wiring came to influence the LSI performance. As a countermeasure against signal delay and inter-wiring crosstalk, low dielectric constant (low-k) films have been used as insulating films between Al interconnects since the mid-1990s. Initially, low dielectric constant was realized by doping oxide films with fluorine (SiOF). Furthermore, Cu damascene interconnect has been put into practical use since around 1998, and power loss and signal delay countermeasures were taken by interconnect resistance reduction. Since SiO₂ was used as the insulating film of the initial Cu damascene process, the lowering of the dielectric constant of the inter-Cu wiring insulating film was accelerated as the miniaturization progressed.

Examples of the low-k materials after SiOF include organic polymer type and porous silica type. In the former, lower dielectric constant was aimed by lowering density and lowering the dielectric polarization, and in the latter, it was aimed by lowering the density of the film. IBM adopted the low-k film at an early stage, and in 2000, it commercialized the first 130nm device to which organic polymer was applied. Also in Japan, Fujitsu commercialized a 130nm device to which organic polymer was applied like IBM in 2001. However, in the devices after 90nm, many manufacturers employed porous silica materials with higher mechanical strength and easier integration process than organic polymers.

As the methods of forming the low-k films, there are plasma CVD, coating formation and so on. For plasma CVD, there are equipment manufacturers such as Applied Materials, Novellus, ASM, etc. and in the source gas development, Air Products and Dow Corning have developed materials suitable for each technology nodes. In the coating method, Dow Chemical, JSR, etc. have provided materials. As the related equipment, curing equipment using EB and UV, equipment and materials necessary for damage repair, which will be described later, are also required.

In the Low-k film development, the issues were the increase in k value due to process damage such as etching, the mechanical strength due to porosity, the deterioration of adhesion and so on, and these problems were solved by optimization of damage repair, appropriate material design of porous structure and the optimized curing condition.



Example of cross section of Cu multi-layer interconnects using low-k material

Version 2019/1/13