ELECTRONIC MATERIALS

SCIENCE AND TECHNOLOGY

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roles these techniques are playing in advancing semiconductor technology. Specifically, methods and applications of recrystallization, beam deposition, and selective growth are described.

Silicon dioxide and silicon nitride are deposited as glasses in CVD reactors. CVD SiO_2 is frequently called silox. Silox films can be grown thicker at lower temperature, in less time, than an oxidized silicon film. The deposited film is usually of lower quality than the grown film and is rarely used in the active device regions, that is, it would not be used as a gate oxide. One reason for this is that there are many more charge-trapping sites present in the silox layers. This leads to threshold shifts and instabilities in MOSFETs. This does not preclude the use of this film as a thick-field isolation insulator between the first-level interconnect layer and the substrate. The low deposition temperature creates less spreading of shallow junctions and less wafer warpage. In addition, silox can be used as an insulating layer between metal layers or between metal and polysilicon. Similarly, silox is a popular "scratch protection" deposited over the whole wafer after fabrication. Only the bonding pads are exposed in a subsequent etch step.

Another advantage of silox as an interlayer dielectric is the fact that it can be reflowed. For example, assume that we desire a via hole cut from metal-layer 1 to poly. In VLSI technology this contact might be a square 1-2 μm on a side. Some anisotropic etch technique would be used to define it. The side wall or the via would be extremely thick. Metal 1 would be put down using a conventional planetary deposition technique (as described in Chapter 6). For reasons described in Chapter 6, it is very difficult to cover steep sidewalls with evaporated or sputtered metal. It is desirable to "slope" the sidewall somewhat. One way to do this is to heat the silox after via definition. This softens the glass surface and tension causes it to reflow into a smoother configuration. This is shown in fig. 7.22. Addition of phosphorous to the glass during the deposition process, or combinations of boron and phosphorous cause the reflow temperature to lower. Reflow temperatures as low as 750°C have been reported for borophosphosilicate glasses [25].

Phosphosilicate and arsenosilicate glasses can be produced by introducing phosphine or arsene into the feed-gas mixture [1]. Borosilicate glasses are made (particularly in low-pressure reactors) using mixtures of tetrapropoxysilane, tripropyl borate, oxygen, and nitrogen. Borophosphosilicate glasses can be made by starting with a phosphosilicate glass and further doping it with boron in a separate doping step.

Both silox and silicon nitride are used as diffusion barriers. Of the two, silicon nitride is the best diffusion barrier. The use of deposited films as a barrier for various impurities of importance in IC processing is discussed in Chapter 4. The fact that nitride is a better barrier means that thinner films of nitride can be used to achieve the same level of protection. This

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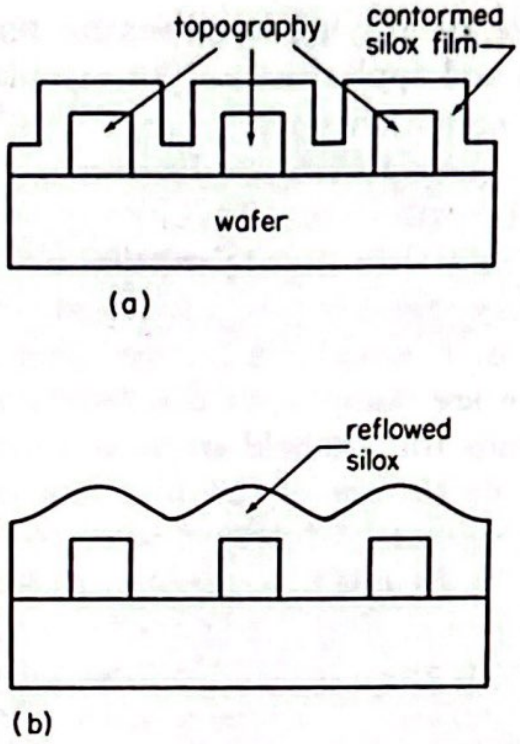


Fig. 7.22. Silox reflow-process: (a) Prior to reflow. (b) Sharp edges round after reflow.

is important in high resolution pattern definition. As a rule, dimensional control varies inversely with the thickness of the layer defined. Thus, nitrides are the barriers of choice when lateral dimension control of the diffusion is important.

Nitride also acts as a diffusion barrier for oxygen. This is the basis of many of the "local" oxidation of silicon (LOCOS) techniques used in VLSI field isolations. A number of variants of the LOCOS process are used in VLSI circuits today. Three of the most common are presented here: straight LOCOS [26], ROX [27], and SILOS [28]. We begin with straight LOCOS, whose process flow is shown in fig. 7.23.

The purpose of LOCOS is to provide a self-aligned field region. The field region provides the boundary between the active channel and the isolation region. As such, it defines the MOSFET channel width, as shown in fig. 1.3. The field is comprised of two elements: a thick field oxide and an inversion-preventing implant. In nMOS technology, the field contains a heavy p-type implant. In older nMOS technology, it is necessary to create the thick field oxidation and the implant in two separate masking steps. The field oxide process sequence shown in fig. 7.23 indicates a technique for doing this in a single mask step. A nitride/oxide dual-dielectric layer is deposited and patterned on the silicon. The oxide is called a "stress-relief" layer. It absorbs some of the stresses generated by the nitride and prevents defect generation and wafer bowing. The patterning resist is used as an implant mask for the p+ layer. After implant, the structure is oxidized to form the thick field region. The nitride film prevents oxidation in the active gate regions of the device. The p+ implant is naturally self-aligned to the field oxide in this way.

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