The Properties of Thin Platinum Silicide Films

The crystallography, morphology and kinetics of formation of PtSi films has been the subject of much active research due to the ability of these films to form near-ideal n- and p-type ohmic contacts and also Schottky contacts on substrates of silicon in the manufacture of various semiconductor devices.

R. M. Anderson and T. M. Reith of I.B.M. System Products Division, Hopewell Junction, New York, have now carefully investigated the close relationship between the microstructure, electrical characteristics and deposition parameters of mainly sputter- but also electron beam-deposited thin films on {001}, {011} and {111} silicon wafers (*J. Electrochem. Soc.*, 1975, **122**, (10), 1337–1347).

The key finding as to the quality of the final PtSi microstructure lies in the cleanliness of the substrate before platinum deposition. Platinum deposited on a properly cleaned silicon surface will in fact begin to form a satisfactory PtSi film in the course of deposition or subsequent heat-treatments even without substrate heating; unreacted platinum on silicon films is due primarily to the presence of a contamination layer between the platinum and the silicon which prevents the formation of PtSi even after extensive heat-treatments. When analysed by X-ray microprobe and ESCA methods the contamination film is found typically to consist of oxygen as SiO_2 and of carbon. The sequence of the phases formed when platinum is deposited on clean silicon and heat treated in situ for electron microscopic examination is $Pt+Si \rightarrow Pt_3Si \rightarrow Pt_2Si \rightarrow PtSi$, the complete reaction taking about 20 seconds at a temperature of 450°C.

Care should be taken to ensure that the film is less than 200Å thick or a double layer is formed consisting of PtSi covered by a layer of porous platinum which is inferior microstructurally to the PtSi layer beneath.

The best PtSi films based on microstructural and electrical properties are formed most consistently by sputter deposition at a substrate temperature of 450°C after in situ r.f. sputter cleaning; chemical cleaning plus in situ sputter cleaning gives consistently superior results to chemical cleaning alone. Also, it was found that heat-treating of the film after, as opposed to during, deposition produces microstructurally and electrically superior contacts than heat-treating externally in nitrogen, but best of all was in situ heating during deposition.

The microstructure and the electrical sheet resistance of a PtSi thin film are additionally dependent on whatever dopant is used in the silicon and on any subsequent heat treatment at 750 to 950°C. For a given heat treatment the best microstructures occur on the lowest doped silicon, and the lowest sheet resistances on the highest doped silicon. For films formed with any dopant species and surface concentration thereof, the sheet resistance decreases at 750 to 850°C, but increases at 950°C due to the formation of discontinuous clusters of large PtSi grains and the complete destruction of any stoichiometric heteroepitaxial PtSi.

This direct relationship established between the microstructural and electrical properties of PtSi films should be particularly valuable from the semiconductor manufacturers' point of view, as it is now possible to establish by a microstructural examination alone whether or not a PtSi contact is likely to give a satisfactory electrical performance. Furthermore by measuring the electrical characteristics of material on the production line, it becomes possible to detect the occurrence of unsatisfactory microstructures and make the necessary adjustments to prevent their formation.

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