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Direct Observations of Al-Si Junction Interface

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Al-Si 접합부의 직접관찰

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Abstract

Al-Si junctions were made by vacuum deposition of aluminium on to silicon wafers and examined by TEM.

The uneven interfaces of the junctions are formed due to the surface tension of the molten solution resulting in preferential dissolution of silicon in aluminium at some areas. These undesirable uneven interfaces affect the junction shape and so the over-all characteristics of the devices.

INTRODUCTION

Metal-semiconductor junctions are of considerable importance in semiconductor device technology. They are used in making electrical contacts to virtually all semiconductor devices, and they are increasingly being used as active devices in the form of Schottky barrier diodes. Considerable work has been performed on the theory of such metal-semiconductor junctions, and extensive electrical measurements have been made, but there have been few structural studies.

In making Al-Si contacts, evaporated aluminium is brought into contact with a silicon wafer and heat the crystal above the eutectic temperature of the system which is 577°C in an inert atmosphere. During this treatment silicon is dissolved in the aluminium film. On cooling down, precipitation of silicon and various lattice defects are found to occur in the recrystallised layer which plays an important role in the device properties. The penetration depth of aluminium into silicon is determined by the solubility of silicon into aluminium, and it depends on the fusion temperature, time, and the relative weight of the alloyed components1). The Al-Si phase diagram (Fig. 1) is one way of describing the solubility of one component in another as a function of temperature.

SPECIMEN PREPARATION

The Al-Si junction specimens prepared at Mullard Research Laboratories in England have been examined by TEM. Aluminium film of 1.5μ thick was evaporated onto the (111) surface of n-type silicon with the resistivity of 0.5Ω·cm; heated at the temperature of 580°C for 15 min., and cooled down at a rate of about 3°C/min. The silicon substrate was kept at the temperature of 300°C. The aluminium layer was then removed in concentrated phosphoric acid at 60°C and the silicon wafer was chemically thinned from the backside to observe the junction interface parallel to the interface by TEM. And also the thin specimen was prepared perpendicular to the wafer to look into the cross-section of the interface, by ion-beam thinning without removing the aluminium layer.

RESULTS AND DISCUSSION

Fig. 2 is an optical micrograph of the alloyed layer surface after removing the aluminium layer on the top showing the unevenness. Furthermore, this uneven interface of the alloyed layer can be seen in the electron micrographs, Fig. 3 and 4 which were observed in the direction of perpendicular and parallel to the junction interface respectively.

It seems that this may be due to uneven wetting of silicon surface by the molten Al -Si solution during the heat treatment. On heating at 580°C in an inert atmosphere, solid diffusion of silicion into aluminium layer will occur until the eutectic composition is formed. And eventually this layer will melt and wet the silicon surface[2]. This phenomena will further accelerate the penetration of aluminium into silicon broadening the thickness of alloyed region until the equilibrium will be set up at the fusion temperature. When the molten solution wets the silicon surface, there may be uneven contact between the solution and the silicon surface, due to the surface tension of the molten solution resulting in preferential dissolution of silicon in aluminium at some areas. This undesirable uneven interface affects the junction shape and so the overall characteristics of the device.

In Fig. 3 a lot of tiny prostrusions can be seen all over the area. These are silicon precipitates formed during the cooling process. According to the Al-Si phase diagram (Fig. 1), the eutectic composition is Al-12. 3 at. % Si and solid solubility of Si in Al at the eutectic temperature, 577°C, is 1. 59at.%.[3] On cooling down to the room temperature, the silicon solubility in the aluminium drops rapidly far below 0. 008at.% (solubility at 250°C is 0. 008at.% Si, and the exact value of solubility of Si in Al at room temperature is not available). Consequently, large amounts of the silicon precipitates are expected to appear inside the aluminium layer[4]. On the contrary, the solubilities of Al in Si at the eutectic and room temperature are 0. 21 at.% and 0. 02at.% respectively (in fact, there are a number of different reports of the aluminium solubility in the silicon at the eutectic temperature; e.g. 0. 4, 0. 52, 0. 21, or 0. 05at.%)[3]. Since the difference between these two solubilities for Al in Si is not so big as in case of Si in Al, we can not expect much aluminium precipitates in the silicon at the bottom interface of alloyed layer on cooling down to the room temperature. The solubility of Al in Si at the room temperature, 0. 02 at.%, corresponds to the impurity concentration of the order of $10^{20}cm^{-3}$, which means the alloyed layer has been converted to the heavily doped p-type region.

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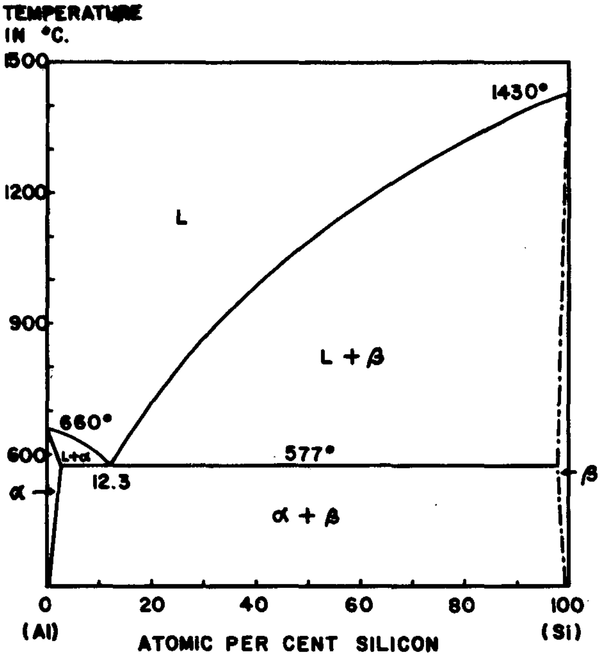

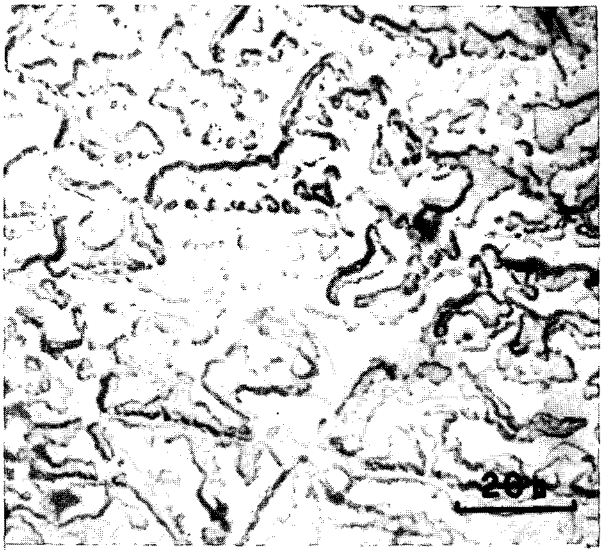

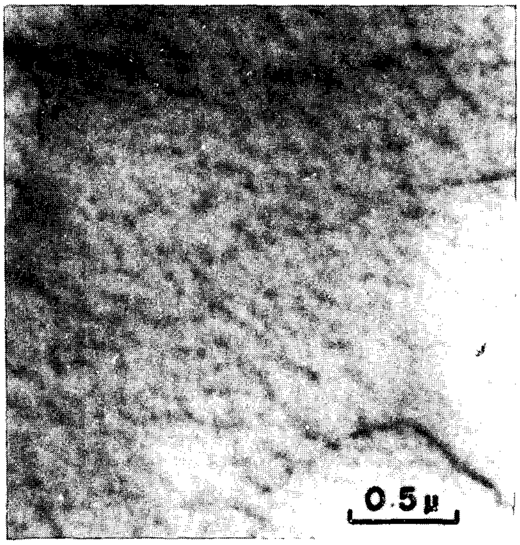

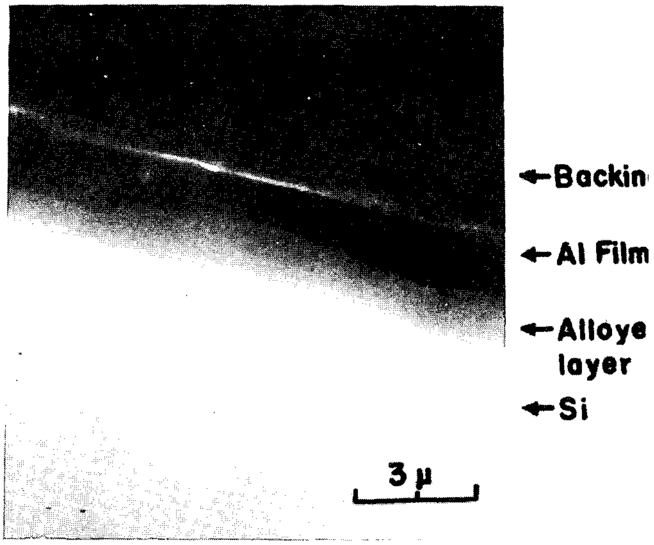

Fig. 1. Al-Si phase diagram.

Fig. 2. Optical micrograph of the alloyed layer surface after removing the Al film.

Fig. 3. Electron micrograph showing the prostrusions due to Si precipitations.

Fig. 4. Cross-sectional view of the junction interface.