A — 6 — 7* Growth parameter and growth model of stripe-shaped large grained silicon on insulator by electron beam annealing

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Silicon on insulator (SOI) structure has become a realistic system for three dimensional IC's. Recrystallization of amorphous (a-) or polycrystalline (poly-) silicon film has been investigated by using cw laser or electron beam annealings by many workers.[1,2] The cw electron beam annealing, however, has following advantages: (1) Beam power and scanning are easy to control. (2) Energy absorption is insensitive to target materials. (3) Interference effect does not occur.

This paper describes (i) growth parameters such as material choise of underlying and covering insulators, and deposition method of silicon film, (ii) experiment on stripe-shaped grain growth and its growth model proposal, and (iii) device characteristics fabricated in electron beam recrystallized silicon film.

Thermally grown SiO_2 was formed on (100) silicon wafers at 1000°C. LPCVD SiN, sputtered SiC, and other substrate materials were deposited on the wafers. LPCVD poly-Si films of 6000 Å thick were then deposited at 600°C by pyrolysis of SiH_4. In addition to them, a-silicon films of 6000 Å were evaporated at R. T. at 10^{-6} Torr. To examine the effect of cover film, CVD SiO_2 of 2000 Å or SiN of 1000 Å was deposited on the LPCVD poly-Si films. The samples were annealed by a scanning electron beam. The annealing conditions were as follows; accelerating voltage of 10 or 15 kV, spot size of 100 to 350 μm, scanning speed of 20 to 200 cm/sec, scanning step of 10 μm, and substrate temperature up to 200°C.

SiN revealed the best result as a underlying materials comparing with other materials examined. As a covering materials, SiO_2 is superior to SiN in growing homogeneously distributed larger grains with high reproducibility. Evaporated a-silicon is better than LPCVD poly-Si, which is considered due to lower melting point[3] or no hydrogen incorporation. These growth parameters will further investigated.

Figure 1 shows a tipical TEM bright-field image from the long stripe-shaped large grained silicon of 0.1 - 10 mm in length and up to 10 μm in width. The angle between crystal stretching direction and beam scanning direction is from 60° to 90°. These stripe-shaped grain growth is distinctive in electron beam recrystallized silicon films on SiN, and it is not found in those on any other insulating materials. Figure 2 shows a photograph of Nomarski interference microscopy for the recrystallized poly-Si film, where beam scan direction is from left to right. Long stripe-shaped grains is seen to stretch to the 70° direction from the scan line.

We propose a new grain growth model for the explanation of the long stripe-shaped crystal growth mechanism. In the first line scan, as shown in Fig. 3 (a), local silicon melting and suc-

cessive periodic solidification result in one-dimensionally connected grain chains. Second line scanning makes the same chains as in the first line, but the grains by the first line and second line scans connect together as shown in Fig. 3 (b). Repeating above growth procedure, long grains grow by a length of the scan line displacement as shown in Fig. 3 (c).

Figure 4 is a tentative characteristics of a MOSFET fabricated in electron beam recrystallized poly-Si film on SiN. A V_T and a surface mobility for electrons of transistor (L= 10 μm, W= 20 μm) with a channel doping of 1×10^{16} cm^{-3} are 2.5 V and 130 $cm^2/Vsec$, respectively. The transistors whose channel direction is parallel with grain boundaries show about 1.5 times larger mobility than that whose channel is perpendicular to boundaries. The maximum mobility is 250 $cm^2/V \cdot sec$ for the transistor (L= 5 μm). The source-drain leakage current is about 10^{-10} A at V_D= 2 V.

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References: (1) H. W. Lam, et al: IEEE Electron Device Lett. EDL-1 (1980) 206. (2) K. Shibata, et al: Appl. Phys. Lett. 39 (1981) 645. (3) W. L. Brown: Laser and Electron-Beam Solid Interactions and Materials Processing (North Holland, 1981).

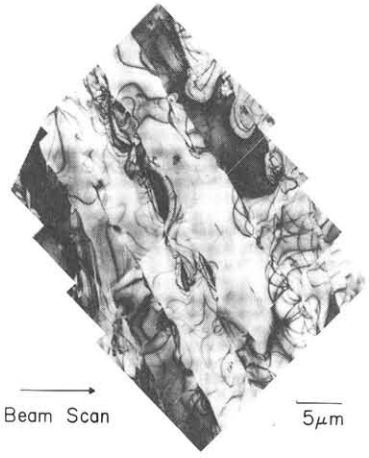

Fig. 1 TEM photograph

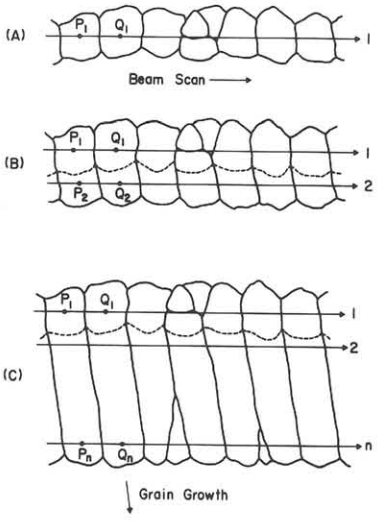

Fig. 3 Growth model

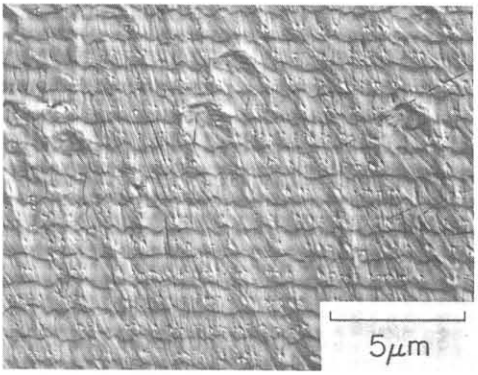

Fig. 2 surface morphology

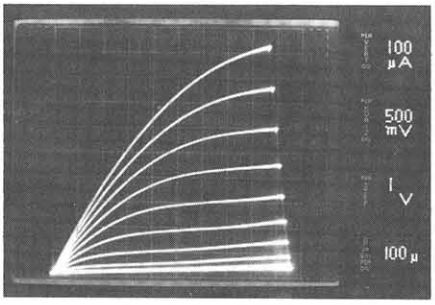

Fig. 4 MOSFET characteristics