A-4-9 Novel Low Temperature ($<300^\circ$C) Annealing of Amorphous Si by Scanned High Energy (~ 2.5 MeV) Heavy Ion Beam

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Entirely new beam annealing (HIBA, High energy heavy Ion Beam Annealing) with rapid ($\sim 10^4$ cm/s) scanned high energy (2.5 MeV) heavy ion by a 2.5 MeV Van-de- Graaff accelerator[1] is presented for the first time. In the HIBA, substrate temperature is uniformly heated by ion beam below 300°C (much lower than ordinary solid phase epitaxial growth temperature $\sim$600°C) and is not heated locally or in a short time. Therefore, annealing mechanism is quite different from the coventional furnace, laser (pulsed or CW), electron beam (pulsed or CW) and pulsed ion beam annealing[2].

By HIBA, amorphous layer is epitaxially recrystallized on the Si substrate and As impurity is located on the substitutional site. Figure 1 shows the $\langle 100 \rangle$ channeling spectra of low energy (50 keV) As^+ implantation-formed amorphous layer and HIBA (As^+, 2.56 MeV) annealed layer. After annealing with $1 \times 10^{16}/cm^2$ dose at 3 μA/4 cm^2 dose rate on 3" wafer of (100) orientation, amorphous layer is recovered almost to single crystal, as far as the channeling spectra is concerned. About 90 % of low energy implanted As is located at substitutional site (including tetrahedral interstitial site) and is not redistributed. Substrate temperature is measured to be $\sim$290°C with heat labels attached to the backside of wafer. Obtained maximum substitutional concentration is $\sim 10^{21}/cm^3$ and reaches to As solubility limit at 1200°C.[3]

Amorphous layer recrystallizes epitaxially from the crystalline-amorphous interface and epitaxially recovered layer thickness is proportional to annealing ion beam dose. As shown in Fig. 2, epitaxial growth rate on (100) substrate is $\sim$100 Å/($1 \times 10^{15}/cm^2$). In other words, the growth rate is $\sim$30Å/min at the present dose rate condition (3.0 μA/4 cm^2). This rate is $\sim 10^5$ times larger than the normal solid phase epitaxial growth rate (290°C) estimated from the published data[4]. As shown in Fig. 3, regrowth is inferior on (111) substrate; crystalline orientation dependence is similar to the conventioal solid phase epitaxy.

However, HIBA is not caused simply by ion beam heating. Figure 4 shows that light ion He^+ does not anneal even with the same high energy, the same beam current and the subsequent same substrate temperature. Therefore, HIBA is peculiar to both high energy and heavy ion. Annealing by other ion species is now being experimentally undertaken.

HIBA gives new annealing mechanism and new application of annealing with low temperature, small thermal stress, area selectivity and no impurity redistribution, though HIBA mechanism is not yet clarified.

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Referenses

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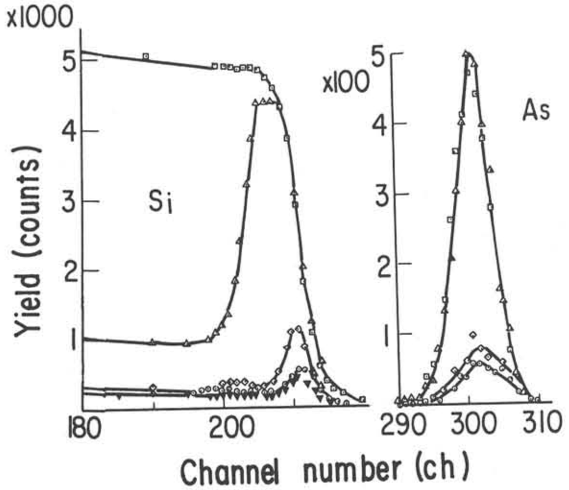

Fig. 1 Dose dependence of HIBA (As^+, E_b= 2.56 MeV) channeling spectra. △ : unannealed, ◇ : $5 \times 10^{15}/cm^2$, ⊙ : $1 \times 10^{16}/cm^2$, ▼ : crystalline.

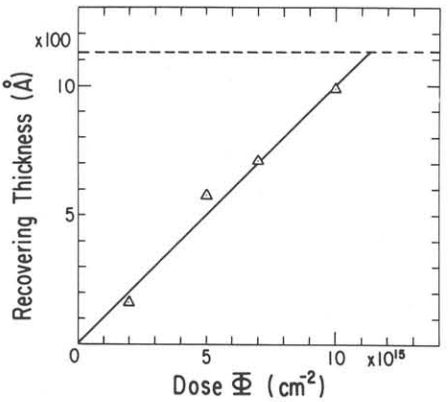

Fig. 2 Dose dependence of epitaxially recovered thickness.

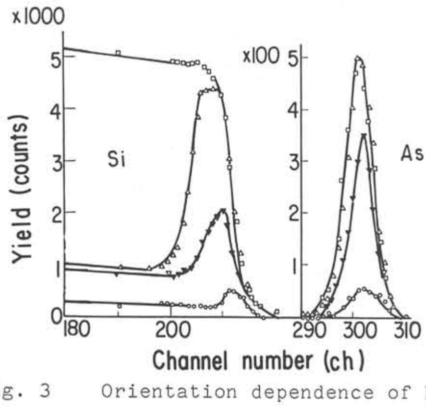

Fig. 3 Orientation dependence of HIBA (As^+, E_b = 2.56 MeV, I_b = 3.0 μA/4 cm^2, Dose is $1 \times 10^{16}/cm^2$). ▼ : (111), ○ : (100).

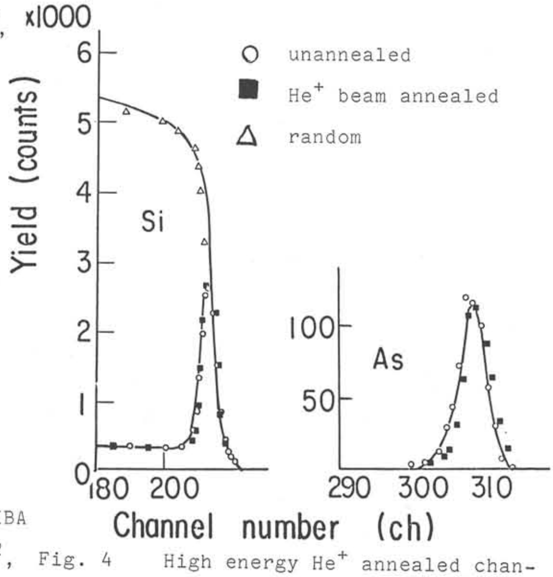

Fig. 4 High energy He^+ annealed channeling spectra. E_b = 2.56 MeV, I_b = 3.0 μA/4 cm^2, Dose is $1 \times 10^{16}/cm^2$.