ENHANCED CRYSTALLIZATION OF AMORPHOUS SILICON USING ELECTRIC FIELD

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ABSTRACT

A new technique for low temperature crystallization of amorphous silicon, called field aided lateral crystallization(FALC) was attempted. To demonstrate the concept of FALC, thin layer of nickel(30Å) was deposited on top of amorphous silicon film and the electric field was applied during the crystallization. The effects of electric field on the crystallization behavior of amorphous silicon film were investigated.

INTRODUCTION

Previously, the effect of small presence of metal impurities on the crystallization of amorphous silicon film was researched by Mayer *et al.* One recent report claims that Ni can substantially decrease the crystallization temperature even low as 480°C[1]. It is proven that the nucleation and growth of crystalline silicon are mediated by the formation of $NiSi_2$ and the transformation rate is limited by the diffusion of $NiSi_2$ (Metal Induced Crystallization : MIC)[2]. Moreover, these metallic phases were grown laterally into the metal-free area without further nucleation, thus obtaining large-grained poly-Si films with no metal contamination(Metal Induced Lateral Crystallization : MILC)[3]. But, MILC takes relatively long time since crystallization velocity is determined mainly by sluggish diffusion process and the crystal orientation of the film is not controllable due to the randomness in diffusion of metal silicide.

A notion of this study is originated from the recognition of the role of $NiSi_2$. Being a metallic phase, $NiSi_2$ would be driven by the electric field. Therefore, the deposited metal on amorphous silicon film is electrically biased during the transformation. If it is so, Firstly, the transformation rate can be enhanced due to the enhanced diffusivity of the $NiSi_2$ which is known as the rate determining species for the transformation. Secondly, If one applies an electric field parallel to the specific direction, for example, the grains of the polysilicon film would line up with the field direction.

In this research, therefore, we aimed to demonstrate the idea of low temperature, high speed, and high quality crystallization of silicon which is called FALC.

EXPERIMENTAL

Process sequence of crystallization by FALC is shown in Fig. 1. A thick oxide (5000Å) was thermally grown on p-type wafer with <100> orientation. Amorphous silicon of 1000Å thick was deposited by low pressure chemical vapor deposition at 480°C using Si_2H_6 on that wafer, which was followed by 1000Å thick masking oxide deposition(Fig. 1(A)). For the various pattern definition as shown in Fig. 1(B), windows in the oxide film were opened by standard photolithography and chemical etching. A 30Å thick nickel film was deposited by sputtering at the pressure less than 3×10^{-6}Torr(Fig. 1(C)).

To apply an electric field on the substrate, electrodes were formed at the opposite edges of the each specimen using silver paste. All crystallization process were done at 500 °C in N_2 ambient and the electric field was applied by a DC power supply during the crystallization(Fig. 1(D)).

RESULTS AND DISCUSSION

In case of conventional metal induced lateral crystallization (MILC), T-shaped a-Si pattern shows crystallized area from all the edges toward the center of the pattern as shown in Fig. 2(a) after annealing at 500°C for 80min. This result implies that the metal silicide formed outside the T-pattern diffuses into the metal free region. The diffusivity is fairly isotropic since it diffuses laterally into the amorphous silicon layer which is structurally isotropic. The crystallization velocity of MILC estimated from the picture is about 6.7μm/h. On the other hand, when the electric fields of 25V/cm, 53.5V/cm were applied to the same crystallization conditions, growth rate enhanced significantly(Fig. 2(b, c)). The crystallization velocity is mainly determined by the thermal diffusivity of metal silicide like a typical MILC. FALC also shows the anisotropic nature in crystallization depending on the polarity of the electric field. As previously mentioned, the crystallization at such low temperature is attributed to the formation of $NiSi_2$. However, in FALC, $NiSi_2$ precipitates will be driven by the electric field. This possibility would be very beneficial in relation to the device application.

Fig. 3 presents the effect of the field intensity on the lateral crystallization velocity. All the data shown are taken from the 60μm-width patterns. It is obvious that the enhancement of crystallization velocity is a function of field intensity. As the electric field intensity increases to 53.5 V/cm, the crystallization velocity increases to 21μm/h which is almost 4 times faster than the case for MILC where the average crystallization velocity was 6.7μm/h. This means that the process time for crystallization can be significantly reduced by adopting FALC.

Crystallinity of the poly-Si film was evaluated from the ultraviolet(UV) reflectance measurement[4]. Fig. 4 shows UV reflectance spectra from 5 different specimens of single crystalline Si, poly-Si(700°C, 10h), FALC-Si, MILC-Si and amorphous Si. The relative crystallinity of the films can be typically obtained by comparing the intensity(or area) of the peak near 275nm. It was shown that the crystallization velocity of FALC was much faster than that of conventional MILC.

CONCLUSIONS

The use of applied electric field during the crystallization was proposed and the effect of the field was proven by the experiment. The crystallization velocity was accelerated because of the field aided enhancement in the diffusivity of $NiSi_2$ which is known as a key species for the crystallization. The crystallization velocity increases as the field intensity increases. FALC resulted in higher degree of crystallization rather than MILC in which the crystallization proceeds only by thermal diffusion of $NiSi_2$. Consequently, the concept of FALC is proven to be a useful method for the low temperature crystallization of amorphous silicon film.

REFERENCES

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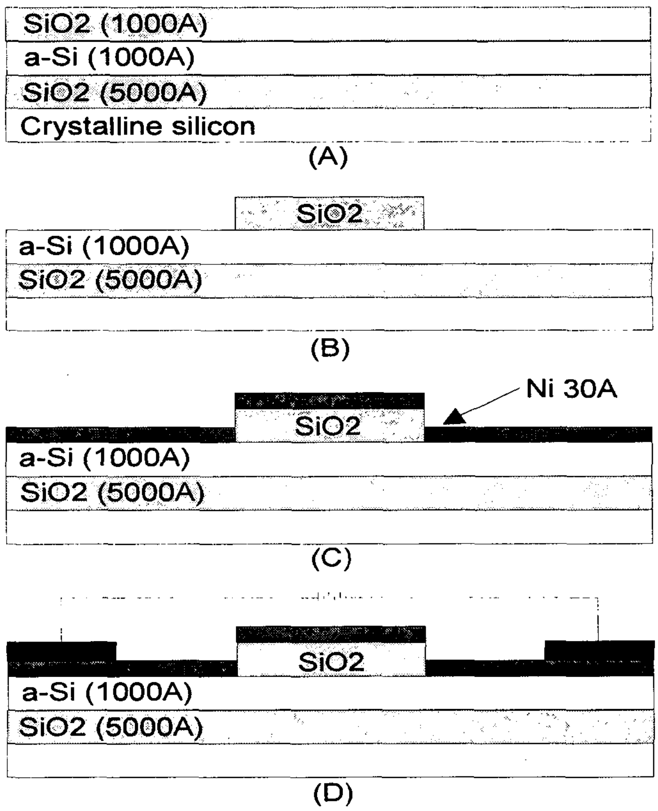

Fig. 1 Process sequence for FALC specimen.

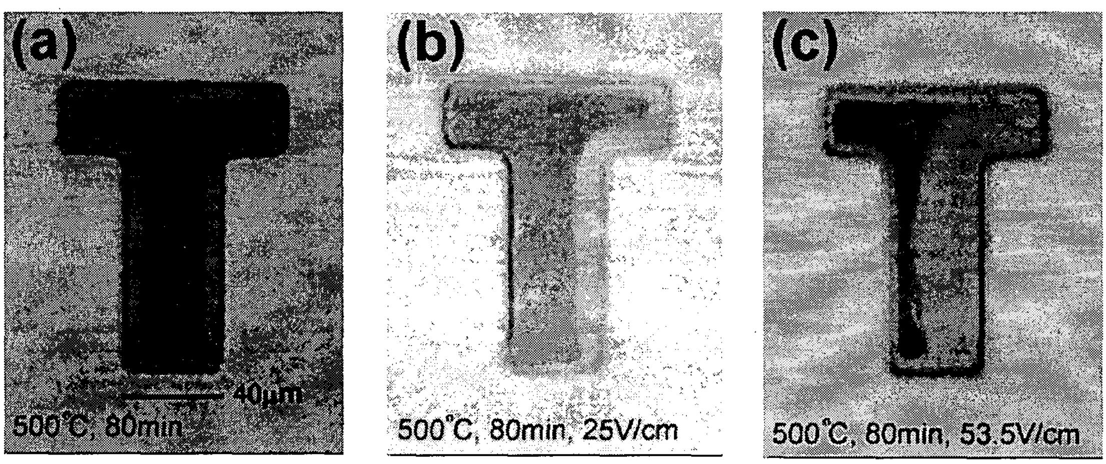

Fig. 2 Nomarski optical micrographs of the partially crystallized patterns taken after annealing at 500°C for 80min. (a)without field(MILC), and (b, c)with field(FALC).

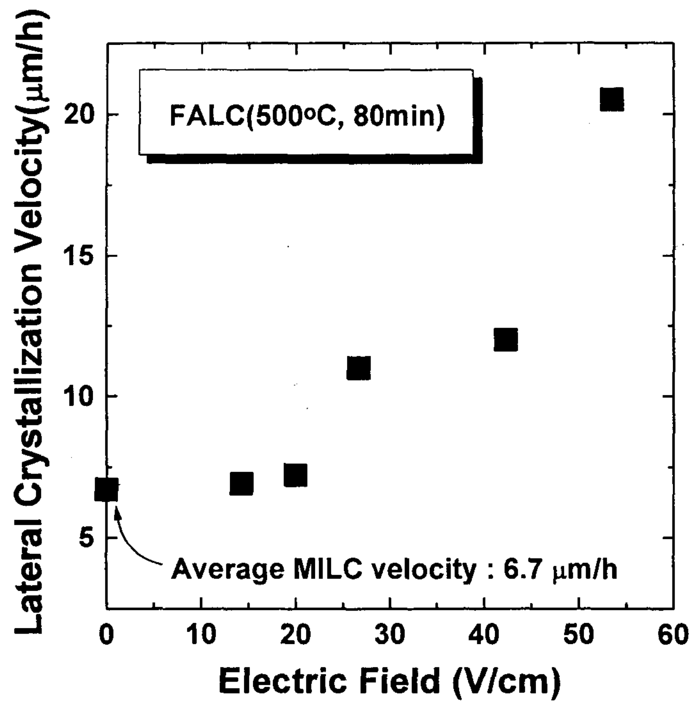

Fig. 3 Variation of lateral crystallization velocity as a function of electric field (Pattern size is 60μm).

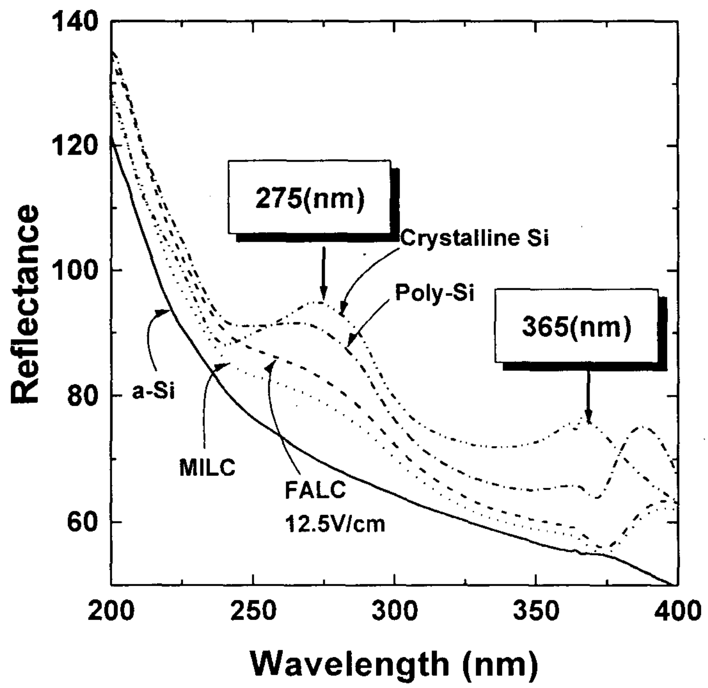

Fig. 4 UV/VIS reflectance spectra of c-Si, poly-Si, FALC Si, MILC Si, and a-Si.