Electronic Supplementary Information for "Epitaxial Growth of Heavily Boron-Doped Si by Al(B)-Induced Crystallisation at Low Temperature for Back Surface Field Manufacturing"

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1. The Schematic diagram of AIC process[1, 2]

The basic model of aluminium-induced crystallization process can be presented as Fig. S1:

(1) Si atoms diffused into the Al film through a thin Al_2O_3 permeable membrane between the initial Al and a-Si layers.

(2) Silicon diffuses within the Al layer.

(3) Silicon nuclei are formed within the Al layer and grow in all directions until confined within the Al layer between glass substrate and Al oxide layer.

(4) After confinement the silicon grains grow laterally until neighbouring grains form a continuous poly-Si film on the glass substrate.

(5) Al is displaced and diffuses across the Al oxide interface into the initial a-Si layer.

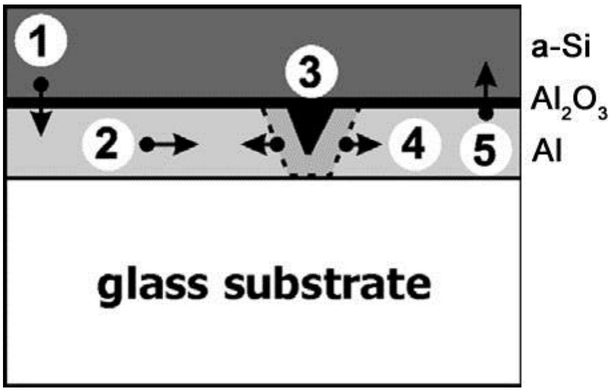

Figure S1.The basic model of aluminium-induced crystallisation process.

2. Electronic characteristic analysis of B-AIC back contact metallisation by transmission line modelling (TLM) method

After B-AIC process, at the upper layer the residual Si may have structure of polycrystalline or amorphous forms, and it has influences on the resistivity of Al layer which will be used as the metal contact. The specific contact resistivity between Al layer and p-type Si film can be determined by the transmission line modelling method (TLM), and the resistivity of Al layer can be determined from Hall measurement. Transmission line modelling measurement (or transfer length measurement, TLM) is a method to measure the contact resistance between a metal and a semiconductor. It works by making a series of metal-semiconductor contact which is separated by different distance. The specific contact resistivity ρ_c (mΩ-cm^2) can be obtained via extracting by fabricating test structures.

The specific contact resistivity between Al contact and Al(B)-BSF silicon layer can be determined by TLM method. First, the Al metal film was etched to be several 20μm x 200μm rectangular forms as a test structure. The distances between each Al square are designed to be 30, 40, 50, 60, 70, 80, 90, 110 and 120 μm. After the resistance between these Al metal patterns is measured by 4 point probe point method, the transfer length (L_T) and the specific contact resistivity (ρ_c) were obtained by TLM analysis. The result of measurement is shown in Fig. S2(a), and will be discussed in detail later. The measurement of specific contact resistivity is confirmed with a second Al test structure which the spaces between Al patterns are changed into 20, 40, 60, 80 and 100 μm. The corresponding result is shown in Fig. S2(b), and the results of specific contact resistivity measured by these two squared structure are shown in Table 2 in the main text. The result shows that the specific contact resistivity between Al and p-type Si produced by B-AIC process is around 1 mΩ-cm^2, and it is not related to the wideness of spaces between Al patterns.

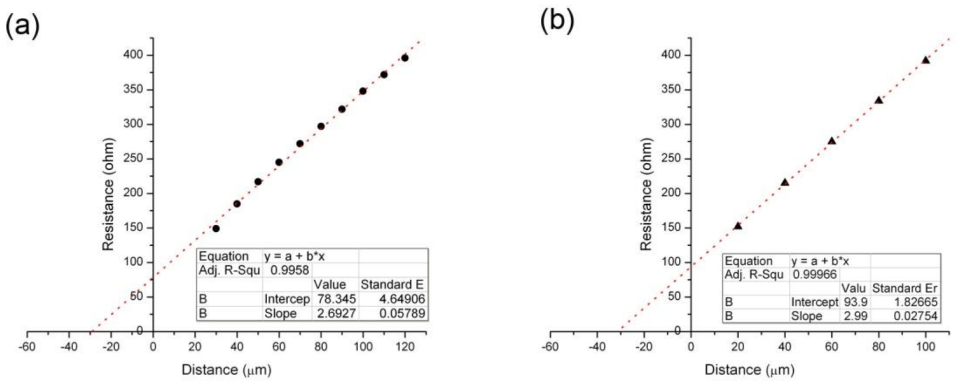

Figure S2. TLM analysis of (a) spaces between Al patterns are 20, 30, 40, 50, 60, 70, 80μm; and (b) spaces between Al patterns are 20, 40, 60, 80, 100μm.

3. Orientation and d-spacing of grown Si thin film and single crystalline Si substrate

The diffraction patterns of grown Si thin film (region 2 in Fig.5a) and Si substrate (region 3 in Fig.5a) was shown in Fig. S3(a) and S3(b), respectively. The diffraction pattern showed almost no difference between grown Si thin film (region 2) and Si substrate (region 3), and indicated that the surface normal of substrate and grown thin film were both along the (100) orientation.

For analysing the d-spacing of the grown Si thin film and the Si substrate,[3] first of all, fast-Fourier transform was applied to transform the HR TEM images of square areas to a reciprocal lattice to acquire the diffraction patterns, as shown in Fig. S4(a) and S4(b). Secondly, the diffraction pattern was then transformed to the intensity projection to calculate the distance between diffraction spot (plane) and zone axis, as shown in Fig. S4(c). Finally, the d-spacing was calculated by equation as below:

$$d=\lambda L/R$$

where λ is the wavelength of the incident electron beam, L is the camera length, R is the separation of the direct (zone axis) and diffracted beams (diffraction spot), and d is the d-spacing. After analysing at several areas of Si substrate and grown Si thin film, the (100)-plane d-spacing of 5.43±0.015Å and 5.48±0.089Å were obtained for Si substrate and grown Si thin film, respectively.

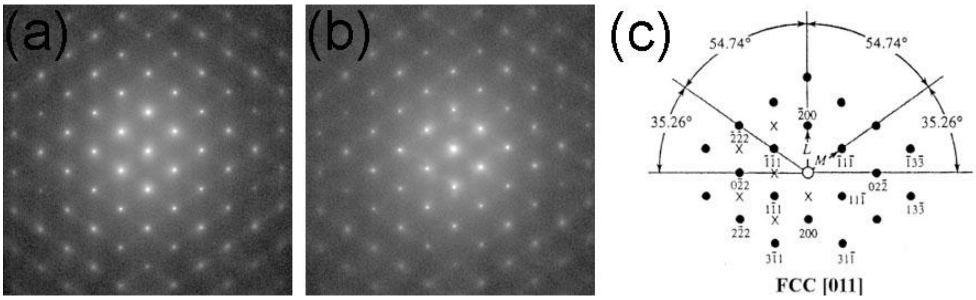

Figure S3. The diffraction patterns of (a) grown Si thin film (region 2 in Fig.5a) and (b) Si substrate (region 3 in Fig.5a), and (c) schematic diffraction pattern of a f.c.c crystal of [011] zone axis.

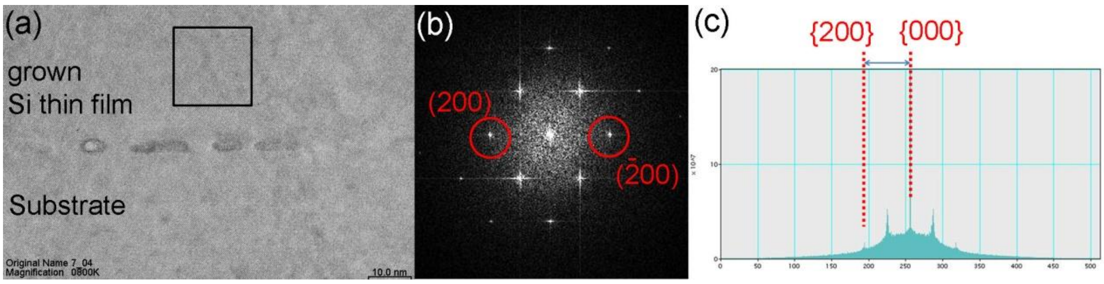

Figure S4. (a) HR TEM image at the interface of the substrate and grown Si thin film of sample F; (b) the diffraction pattern of square area in S4(a) by fast-Fourier transform; (c) the intensity projection of S4(b).

Reference

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2. J. Schneider, J. Klein, A. Sarikov, M. Muske, S. Gall and W. Fuhs, Symposium on Amorphous and Nanocrystalline Silicon Science and Technology held at the 2005 MRS Spring Meeting, San Francisco, CA,

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3. S.-C. Tsai, E. W. Huang, J.-J. Kai and F.-R. Chen, *Journal of Nuclear Materials*.