Crystallization of a-Si Induced by Ni-Si oxide source

Z. Meng[1], Z. Liu[1-2], S. Zhao[2], C. Wu[1], M. Wong[2], H. Kwok[2] and S. Xiong[1]

[1] **Institute of Photo-electronics, Tianjin Key Laboratory of Photo-electronic Thin Film Devices and Technology, Nankai University, Tianjin, 300071, P. R. of China.**

TEL:86-2350-1620, e-mail:xiongsz@nankai.edu.cn.

[2] **Department of Electronic and Computer Engineering, Hong Kong University of Science and Technology, Hong Kong, P. R. of China**

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Abstract

Metal induced crystallization of a-Si with a source of Ni/Si oxide was studied. Its mechanism to induce crystallization was discussed. It was found that new source behaves an effect of self-released nickel and reducing nickel residua, so can provide a wider process tolerance; improve the uniformity and stability of TFTs.

1. Introduction

With the development of full-color high resolution AMLCD and AMOLED, high quality active layer for TFT, such as low-temperature poly-Si with high mobility, is desired [1]. Poly-Si film obtained by metal-induced lateral crystallization (MILC) [2] has many merits of high uniformity and low cost, so it has been attracted with much considerable attention.

Normally the optimum inducing metal Ni is formed by evaporation or sputtering of pure Ni metal. Thus prepared poly-Si contains comparatively high nickel residue with order of magnitude of $\sim 10^{-3}$ of the ratio of Ni/Si [3]. The investigation on MILC poly-Si has been trended to pay more attention on how to decrease the residual nickel concentration [4]. The chemical solution-based Ni-source was one of the methods to reduce the residual nickel [4-5]. According to the data from reference [4] it can be reduced to below $\sim 10^{-4}$ because of the controllability of Ni-salt concentration. In this paper, a new kind of inducing source has been proposed, and why it effectively depresses the Ni residue in crystallized poly-Si is discussed.

2. Sample preparation

New Ni/Si oxide inducing source was prepared by sputtering method. The target is an alloy of Nickel and Silicon with component ratio of Ni: Si=1:9 and the sputtering is operated in ambience of Argon mixed with appropriate content of Oxygen.

For Si thin film preparation, at first a layer of silicon oxide was deposited on glass substrate as a barrier layer, then amorphous silicon (a-Si) was deposited by low pressure chemical vapor deposition (LPCVD) as a crystallization precursor. After that a thin layer of low-temperature oxide (LTO) was deposited as barrier layer, and the inducing hole was patterned. Two different kinds of nickel source were deposited on the surface, respectively by sputtering and e-beam evaporation. Afterward, the samples were

annealed in nitrogen atmosphere at the temperature higher than 500^0C for 2-4 hours to conduct the crystallization of a-Si. The properties of the resulted poly-Si thin films prepared with the two sources were compared and characterized by AFM, TOF-SIMS. P-type TFTs were fabricated with the Ni-Si oxide source and their performances were characterized.

3. Result and discuss

3.1 Ni-Si oxide as reactive released Ni source

Fig.1 shows the crystallization rate vs. thickness of nickel source under the same annealing conditions. The relationship of the crystallization rate with the thickness of two nickel source is quite different. For the Ni-Si oxide source, the crystallization rate reached to a constant when the thickness is more than 10Å. But for pure Ni source, the rate varied with the thickness obviously. It means that the process tolerance of Ni-Si oxide source is better than one of pure Ni metal.

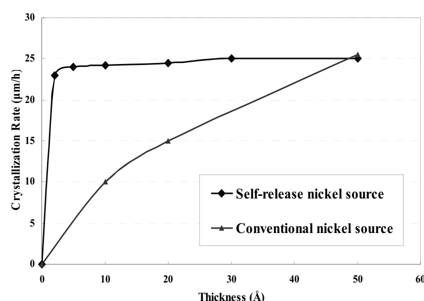

Fig.1 crystallization rate vs. thickness of Ni source layer

The components in Ni-Si oxide source on a-Si surface were analyzed by X-ray photoelectron spectroscopy (XPS). As shown in Fig.2, the peaks at the binding energies of 852eV, 533eV, 103eV and 155eV are corresponding to the amount of Ni_{2p}, O_{1s}, Si_{2p} and Si_{2s}, respectively. It implies that Si and Ni atoms are surrounded by oxygen atoms. The ratio of atom concentration of O, Si and Ni is 64.18:34.19:1.63 (i.e. 40:21:1), as shown in Fig.2. So we would like to suppose that sputtered film of Ni/Si would be as $19SiO_2$:Si_2NiO_2 alloy structure, in which Si_2NiO_2 probably consists of Si_2O-NiO mixed structure and its molecular concentration is just 5% in

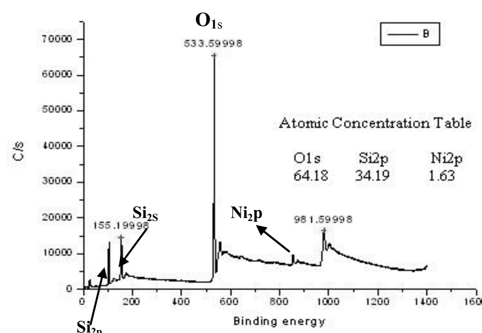

Fig. 2 XPS spectrum of oxygenated Ni-silicide

the sputtered Ni/Si oxide. As all have known [8], the bond strength of Ni-O is just 93.6±0.9 K car/mol, which is lower than that of Si-O (190.9±2 K car/mol) but higher than one of Si-Ni (76±4 K car/mol) [6]. By inter-comparing these bond strengths, we suggest the induced crystallization mechanism would be as following. The Si atom in a-Si neighboring with the Ni/Si oxide has ability to despoil the Ni from the Si_2O-NiO, which is self-oxide as SiO_2 and releases a monatomic Ni. At the same time, the released Ni atom will react with Si in a-Si to form Ni-silicide. This reaction can be described as $Si_2O\text{-}NiO+Si \rightarrow SiO_2+NiSi_2$. $NiSi_2$ as the crystallization media will be directly to induce crystallization of a-Si sequentially.

In this crystallization process, Ni/Si oxide source just act as a supplement effect of Ni to form the $NiSi_2$ of crystallized media by a relative rate. This kind of Ni-source is tardily provides inducing media $NiSi_2$ by direct reaction of Si with Ni-Si oxide. In contrast, pure Ni source provide abundant pure Ni atoms, then it need to react with a-Si to form inducing media $NiSi_2$. So the crystallization rate by pure Ni source will depend on the nickel thickness as shown in Fig. 1. The content of Ni by self-released reaction is according to the crystallization requirement so Ni residue in poly-Si would be decreased.

3.2 characteristics of the poly-Si thin films induced crystallization by self-released Ni

In order to study the process tolerance and compare

the performances of crystallized poly-Si, we prepared three different nickel sources on the same amorphous silicon precursors called samples A, B and C, respectively. Sample A, B were sputtered with power of 7W but time of 3 minutes and 60 minutes, respectively; sample C is the pure nickel deposited by e-beam evaporation with the thickness of 50Å. Then three samples were fully crystallized to poly-Si by annealing at 550℃ for 4 hours. Table 1 lists the electrical properties of the three poly-Si samples doped by Boron implantation. The sample C is a little bit worse than other two.

Table Ⅰ Electrical properties of three samples doped B

Parameter / Sample	h_e(cm^2/V.s)	n_p(e^{+19}/cm^3)	Ω/□(e^{+03}ohm/sq)
Sample (A)	27.2	3.08	1.49
Sample (B)	27.1	3.05	1.52
Sample (C)	26.4	3.03	1.56

The optical microscope photographs of the three samples after etched by 25% TMAH are shown in Fig.3. These photos show that the grains have almost the same orientation which likes an epitaxy from the inducing hole. Their crystallization rate is nearly the same (~24μm/hr) but for thin oxide source, it has a smooth crystalline grain in induce hole (see Fig.3 (a)).

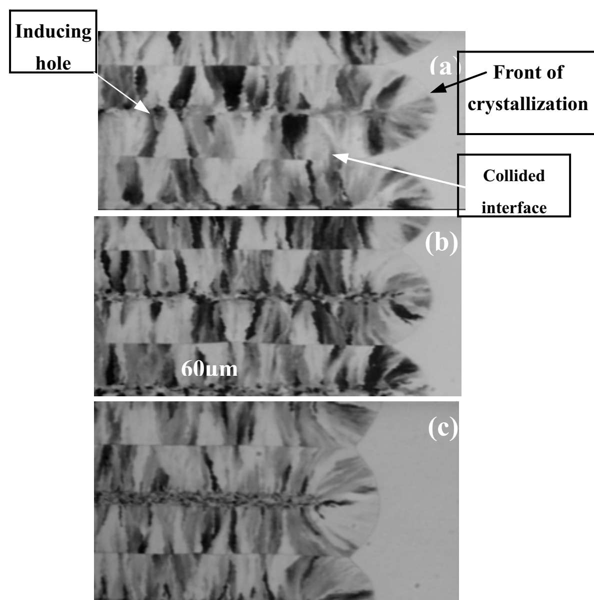

Fig.3 photos of three samples etched by 25% TMAH: (a) sputtering for 3mins, (b) sputtering for 1hr, (c) e-beam 50 Å

The micro-Raman spectra of the three samples are shown in Fig.4. They show very sharp peaks nearby 518.44cm^{-1} and no 480m^{-1} signal can be observed, which means amorphous silicon was completely crystallized into poly-Si [7].

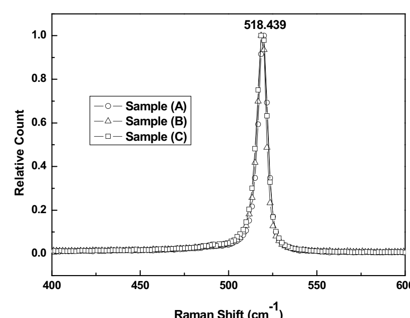

Fig. 6 Raman results of three samples.

3.3 Ni residue in poly-Si

The residual Ni distribution in three crystallized poly-Si were measured near inducing hole along the film depth vertical to film surface by TOF-SIMS. The result is as shown in Fig. 5.

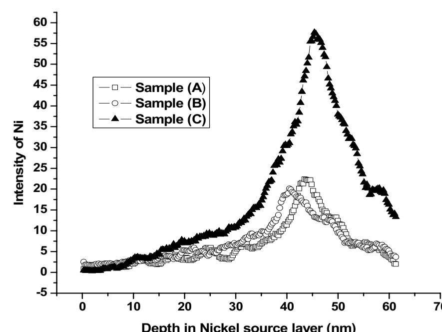

Fig.5 nickel distributions in three samples

Their distribution in three samples is not uniform. The peak of nickel residue is close to bottom of a-Si near glass and the Ni residue in sample A and B is almost same and lower than that in sample C by half of order of magnitude. It implies that thickness of inducing source is not an effective factor to affect Ni residue, but the initial nickel content at the interface neighboring a-Si film will be responsible for the content of residual nickel in poly-Si.

Fig.6 is the three dimension images of nickel distribution. The X and Y axis represent the directions

parallel to surface of poly-Si film and Z-axis represents in depth direction of film. The bright dots in the image represent signals of surviving nickel collected by ten times. From the images, in any case of inducing hole (indicated by bright strip) or grain boundaries (gloom bright strip)， the content of surviving nickel in sample C is much higher than that in sample A and B. Specially, in A and B samples less

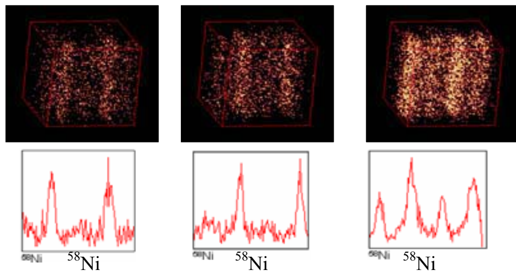

Fig. 6 Three-dimensional map of nickel distribution in three samples (a) sputtering 3′ (b) sputtering 1hr (c) e-beam 50Å

Ni residue is at grain boundary, that means the crystallization front has much less of surviving nickel. Therefore the TFT made by crystallized poly-Si induced using oxide nickel source would have better performances, whether it was fabricated on grain boundary area or inducing hole. It means Ni-Si oxide source would have better process tolerance, and could have the ability to improve the uniformity of TFT array.

4. Performance of poly-Si TFT

Fig.7 shows transfer characteristics of p-channel poly-Si TFTs, which were made with poly-Si crystallized by Ni/Si oxide source and by pure Ni source. The TFTs have W/L=30μm/10μm.

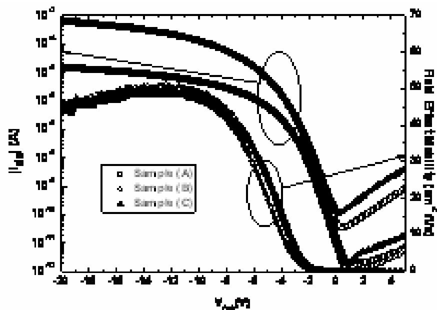

Fig.7 Transfer characteristics and μ_{FE} of three types of TFTs. (a) sputtering 3′ (b) sputtering 1hr (c) e-beam 50 Å

The device properties of these three types of poly-Si TFTs are shown in Table 2. As we can see, the mainly merit of the Ni/Si oxide is to decrease the off-state current (I_{off}) and the gate-induced drain leakage current (GIDL), and to improve the uniformity and stability as shown as in Fig. 8. The improvements would be resulted from lower residual Ni content shown in Fig.6.

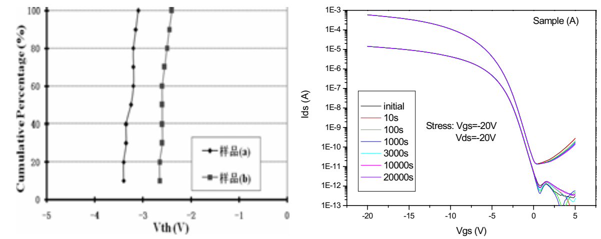

Fig.8 The uniformity and stability of TFTs made by sample A: (a) Vth, (b) stability

5. Conclusion

We have developed a new type of self-released Ni-Si oxide source suitable for MILC poly-Si preparation. Using this kind of nickel source, the nickel residue in poly-Si film was efficiently reduced. The new source can prevent the effect of the process fluctuation between batches on performances of poly-Si TFT so can provide a wider process window.

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