Abs. 955, 206th Meeting, © 2004 The Electrochemical Society, Inc.

Effect of tensile stress on the growth rate of Ni-MILC

Chih-Yuan HOU, YewChung Sermon WU and Guo-Ren HU

Department of Materials Science and Engineering, National Chiao Tung University, Hsinchu 300, Taiwan, R.O.C.

Ni-metal-induced lateral crystallization (Ni-MILC) of amorphous silicon (a-Si) has been used to fabricate the low-temperature polycrystalline silicon thin film transistors. Three stages have been identified in the Ni-MILC process: (1) the formation of $NiSi_2$ precipitates, (2) the nucleation of crystalline Si (c-Si) on $NiSi_2$ precipitates, and (3) the subsequent migration of $NiSi_2$ precipitates and crystallization (growth) of c-Si[1)]. Before the growth of the needlelike poly-Si grains, there must be an incubation period, which included (1) the formation of $NiSi_2$ and (2) the nucleation of c-Si on $NiSi_2$. It was found that the incubation time could be reduced by tensile stress[2)]. However, the effects of the tensile stress on the growth mechanism of Ni-MILC were still not clear. The principal goal of this research, therefore, has been to develop a series of two-step process to study the effects of tensile stress on the incubation time and the c-Si growth of Ni-MILC. It is found that tensile stress did not enhance the $NiSi_2$ formation and c-Si nucleation stages, but enhance the c-Si growth stage. In this study, a bending fixture (Fig.1) was used to investigate the effects of tensile stress on the growth of Ni-MILC. Figure 2 shows the MILC Si induced by 40 μm-wide Ni lines after 6 h of annealing. The light region at the periphery of the Ni lines was the poly-Si area. These samples were designated as "BENDED". For the purpose of comparison, other samples were also annealed under the same condition but without tensile stress. They were labeled as "UNBEND". To test the effects of tensile stress on these two mechanisms, a series of two-step processes were used in this work. The details of these processes are listed in Table I. From this fact, the enhancement of the c-Si growth by tensile stress is considered as follows. It has been reported that the growth of MILC is governed by migration of the $NiSi_2$ precipitates through the a-Si as illustrated in Fig. 3 (a)[1,3,4)]. Hayzelden *et al*[1)]. suggested that the driving force behind MILC is that the chemical potential of Ni is lower at the $NiSi_2$ / a-Si interface, whereas the chemical potential of Si atoms is lower at the $NiSi_2$ /*c*-Si interface. In order to reduce free energy, the Ni atoms move toward a-Si and they in turn react with a-Si to form new $NiSi_2$. The remaining Si atoms attach to $NiSi_2$ template to form *c*-Si because their chemical potential is lower at the $NiSi_2$ /*c*-Si interface. Hayzelden *et al*[1)]. also showed that growth velocity is inversely proportional to $NiSi_2$ thickness, which agrees with diffusion limited growth. In other words, the growth of MILC is governed by the Ni diffusivity in $NiSi_2$. The diffusivity in materials can be affected by tensile stress[4)]. As illustrated in Fig.3(b), when the Ni atom diffuses through the $NiSi_2$, the Ni atom must pass through a non-equilibrium position, which distorts considerably the positions of adjacent atoms and form an activated complex. This distortion will have an energy cost, so the energy will have a maximum as the atom moves from one site to another as shown in Fig. 3(c). With the increase of tensile stress, the space between atoms increases but the maximum energy required to form the activated complex decreases. Therefore, the Ni diffusivity in $NiSi_2$ increases, which results in an enhancement of c-Si growth.

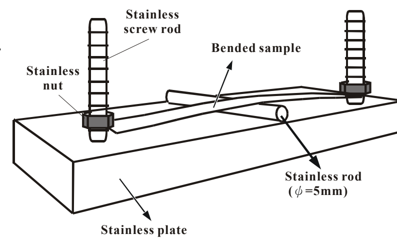

Figure 1 Stainless bending fixture.

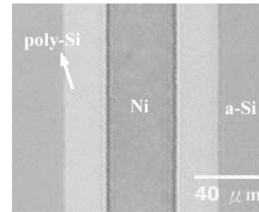

Figure 2 Optical micrograph of BENDED sample annealed at 550 °C for 6 h.

Table I Summary of two-step process to induce the crystallization of a-Si films

	Annealing condition	MILC length (μm)
UNBEND-UNBEND	U 6h (22 μm) + U 6h (22 μm)	44
UNBEND-BENDED	U 6h (22 μm) + B 6h (26 μm)	48
BENDED-UNBEND	B 6h (26 μm) + U 6h (22 μm)	48
BENDED-BENDED	B 6h (26 μm) + B 6h (22 μm)	48

B:BENDED; U:UNBEND

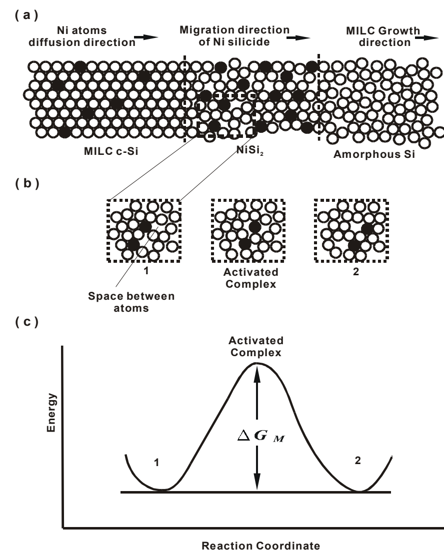

Figure 3 MILC poly-Si formation mechanism. (a) The Ni atoms diffuse to the a-Si region and bond with Si atoms. (b) is the schematic illustration of the atomic jump process. (c) is the schematic illustration of free energy as a function of reaction coordinate as an atom moves from one site to another. In this case the reaction coordinate corresponds to the distance along the path connecting the sites.

Reference:

1.C. Hayzelden et al., J. Appl. Phys. 73 (1993) 8279
2.K. Makihiraa et al., Appl. Phys. Lett. 76 (2000) 3774.
3.S. Y. Yoon et al., Thin Solid Films 383 (2001) 34.
4.C.F. Cheng, et al., IEEE IEDM Technical Digest (2002) 569.