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Improvement of the Laser-Recrystallized SOI Structure by a New Crystal Growth Mode

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INTRODUCTION :

The laser recrystallization of Silicon-On-Insulator (SOI) layers is one of the most promising candidates for a 3-Dimensional IC fabrication technology. For this laser recrystallization, the use of the anti-reflective capping stripe (ARF) method[1] confines the location of the residual defects by modulation of the laser induced thermal profile, and significantly limits the required number of seeding areas. Conventional laser-recrystallized SOI structures use <100> oriented ARF on (001) Si seed crystal since this condition results in the largest defect-free growth distance, up to 1mm from the seed[2]. The major limitation for the widespread use in the IC field, however, is a large gradual crystal orientation change with increasing lateral growth distance[2]. For the conventional structure, this orientation change can be described as a rotation of the crystal with [010] rotation axis perpendicular to the ARF, and the rotation angle is typical 10-20° at 100μm from the seed[2]. This value is much higher than can be tolerated for the uniformity of the device characteristics. In addition, the ARF pitch is limited to 15μm.

We propose a new recrystallization method, which alleviates the constraints of the conventional technique by strongly reducing the crystal orientation change and by enlarging the ARF pitch. Also, some important new aspects of the crystal orientation change are revealed.

EXPERIMENTAL :

We investigated the recrystallization of 1 μm thick SOI (Fig.1) instead of 0.55 μm in the conventional structure, since the use of thicker SOI films is known to improve the crystal quality in case of the periodic-seeding recrystallization method[3]. It is considered that a thicker film improves the stability of the solid-liquid interface by increasing the lateral heat flow (higher thermal gradient). Different orientations and recrystallization conditions were examined. Recrystallization was performed by a circular Ar^+ laser beam, with scan speed of 25 cm/s and preheat temperature of 450°C.

Best results are obtained for <110> oriented ARF and scan direction 45° to the ARF. Although this condition on 0.55 μm SOI resulted in only 100-200μm defect-free growth distances[2], for 1 μm SOI defect-free growth distances up to 500μm from the seed are obtained even for the double ARF pitch of 30 μm (Fig.2). Moreover, from ECP measurements, the crystal rotation is only 2-3° at 100μm from the seed (Fig.3). This small misorientation does not affect the device characteristics.

DISCUSSION :

From the location and shape of the melting temperature isotherm, the reconstructed solid-liquid interface[4] can not be composed of crystal {111} facet planes, as for the conventional <100> ARF structure (Fig.4). This indicates a new stable growth mode, with an atomically rough interface. The long defect-free growth without the (stabilizing) faceted interface may be attributed to the increased Si film thickness, by increasing the growth stability or by reducing the in-film stress. This stress reduction may also reduce the crystal rotation, which is believed to be caused by elastic deformation of the crystal[5]. However, experiments with <100> ARF and 1 μm SOI film revealed a crystal rotation of 7-8° at 100 μm from the seed at the same recrystallization conditions (Fig.3), and the strongly reduced crystal rotation for <110> ARF can not be attributed to the increased film thickness only.

The existence of a new crystal growth mode is further supported by the different crystal rotation direction (Fig.5), compared to the rotation parallel to the <100> ARF conventionally. It is believed that the actual nature (faceted or rough) of the solid-liquid interface is a key point in controlling the orientation change, as e.g. the close alignment of the rough type solid-liquid interface to the melting isotherm, compared to the substantial undercooling required for a faceted interface[4], may reduce the thermal stress over the growth interface. On the other hand, the crystal orientation anisotropy of the deformation mechanisms of Si may also play a role.

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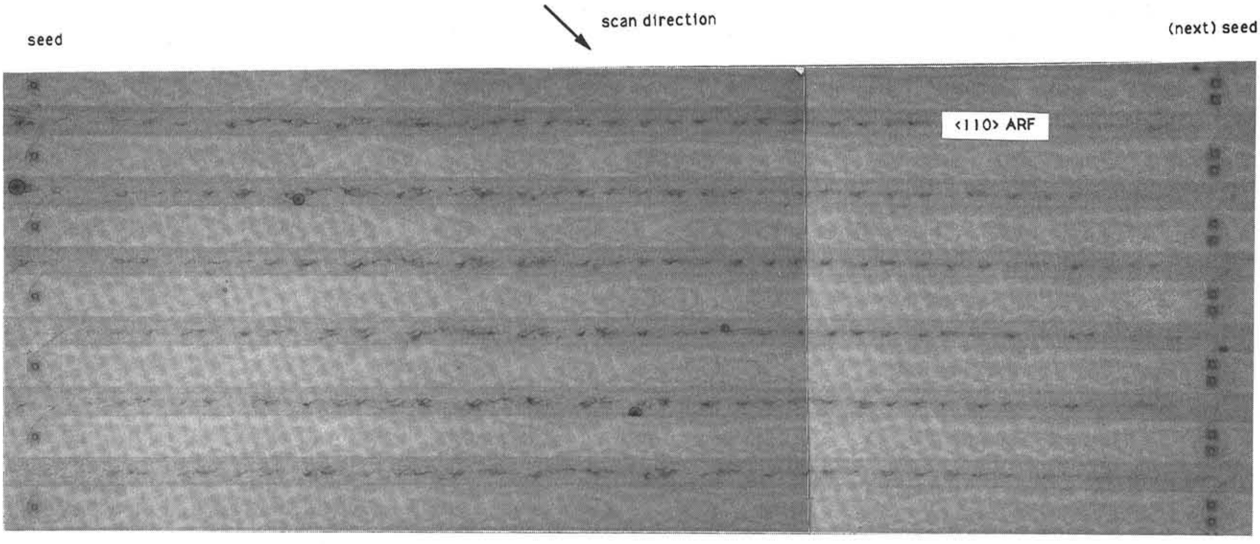

Fig.2 : Optical micrograph of laser-recrystallized SOI layer with <110> ARF and 1 μm SOI layer (after cap layer removal and Secco etching). ARF pitch is 30μm, seed pitch is 500μm. Scan direction at 45° to ARF, scan speed = 25cm/s, step = 10 μm, laser power = 11.5W, preheat temperature = 450°C.

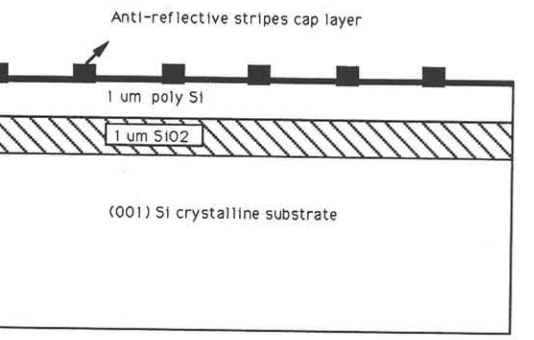

Fig.1 : Cross-sectional sample structure (schematic). Capping stripes are parallel to the <110> surface orientation, and at regular intervals dot-seeds connecting the poly-Si layer to the crystalline substrate are provided.

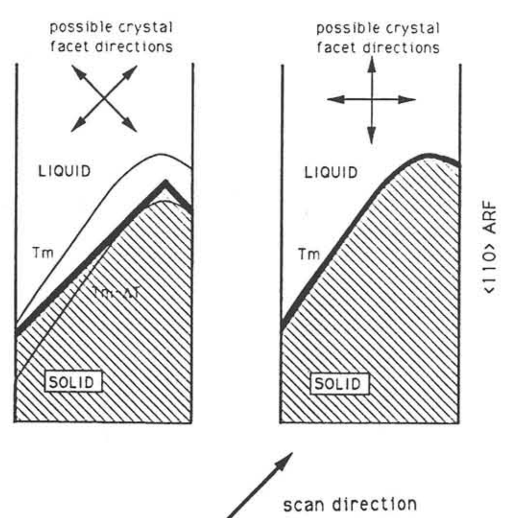

Fig.4 : Schematic of the solid-liquid interface (thick solid line) during recrystallization using <100> ARF (faceted) and <110> ARF (non-faceted).

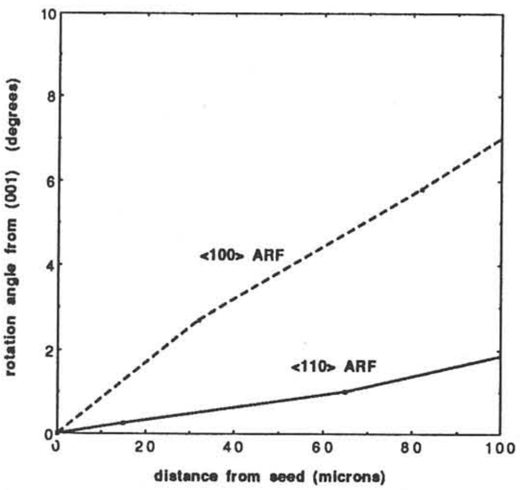

Fig.3 : Crystal orientation change vs. lateral growth distance from the (001) seed crystal, as measured by Electron Channeling Patterns (ECP). Measurements are given for both <110> and <100> ARF with 1μm SOI thickness, 15μm ARF pitch and scanning at 45° to the ARF. Scan speed = 25cm/s, step = 10 μm, laser power = 12-13W, T = 450°C.

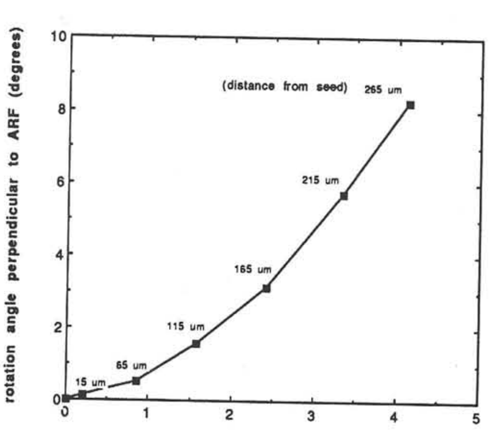

Fig.5 : Crystal axis rotation direction relative to the direction of the ARF capping stripes, for <110> ARF and 1 μm SOI, 15 μm ARF (same conditions as in Fig.3).