Formation of single-crystal Si islands via continuous-scan Sequential Lateral Solidification

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Abstract

We have previously shown that single-crystal Si regions on glass substrates can be obtained by crystallizing as-deposited a-Si films using a specific version of the SLS process, referred to as dot-SLS. Such single-crystal islands can, for instance, be used for manufacturing of high-performance TFTs that are expected to become increasingly more relevant in the future. In this paper, we demonstrate that the dot-SLS process can be implemented using a continuous-scan SLS scheme that enables the attainment of high crystallization rates that are desired for industrial applications. We will furthermore report on recent experimental findings regarding the nature of the defects that can be created during the process.

1. Objective and Background

Sequential lateral solidification (SLS) is a pulsed-laser based thin-film crystallization process [1] that is well suited for crystallizing as-deposited a-Si films on glass substrates for thin film transistor (TFT) devices. It is a flexible method in that, among other things, it enables the microstructure of the films to be manipulated by tailoring the details of the process (i.e., the shape of the projected beam pattern and the microtranslation sequence between laser pulses). A variety of microstructures, ranging from uniform polycrystalline films to large single-crystal regions, can be obtained.

We have previously demonstrated two specific SLS schemes for obtaining location-controlled single-crystal materials: 1) SLS using chevron shaped beamlets [2] and 2) SLS using an open mask consisting of an array of shadow spots (this scheme is referred to as "dot-SLS") [3]. Single-crystal-Si TFTs that were fabricated on the chevron processed materials have shown high performance device characteristics commensurate with the quality of the material [4].

An efficient and rapid way of implementing SLS is via a particular version of SLS, referred to as continuous-scan SLS, wherein the crystallization and irradiation sequence is carried

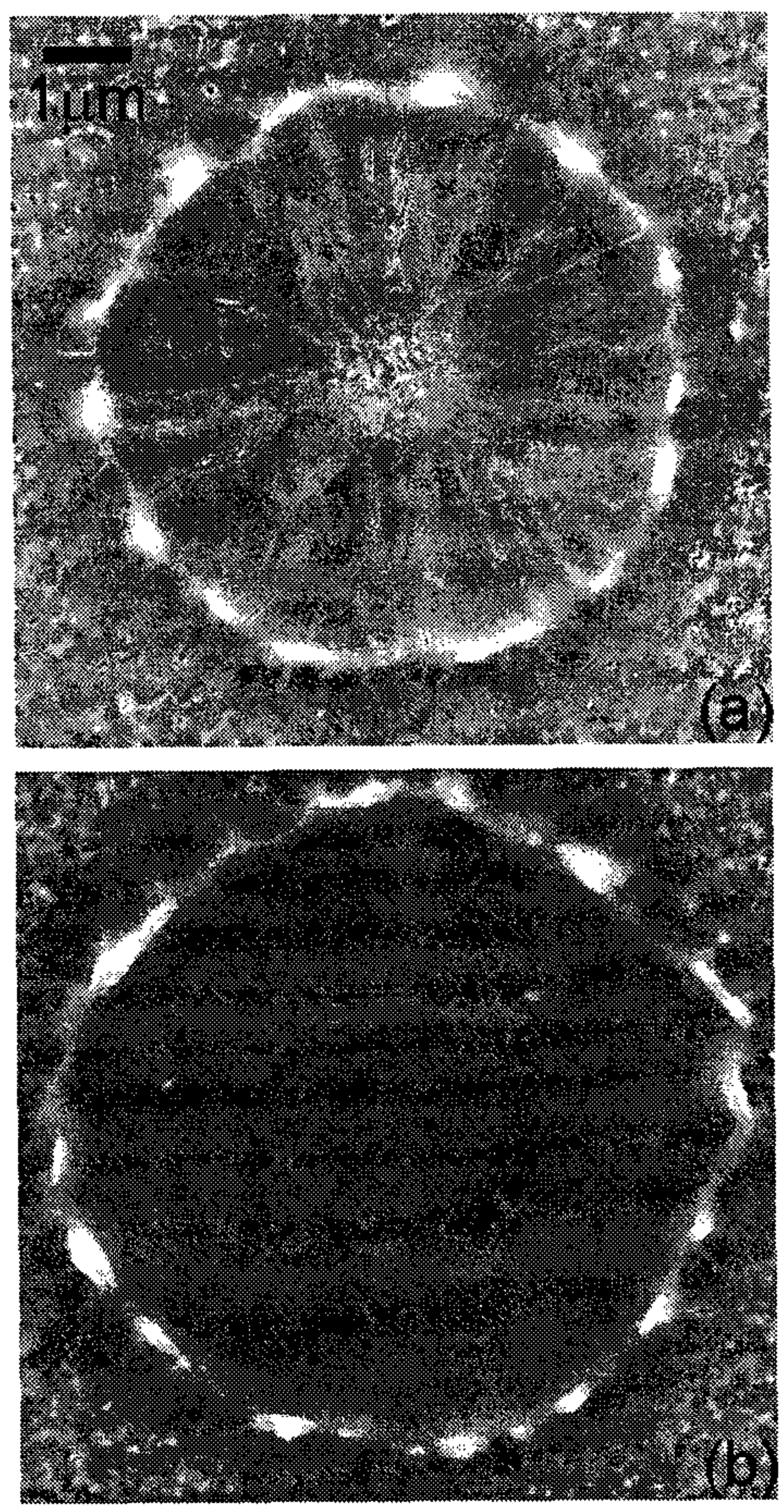

Figure 1. Defect etched SEM micrographs showing (a) the microstructure obtained by single pulse dot-patterned irradiation of 1500 Å a-Si with grains growing radically from the shadowed region, and (b) the microstructure obtained with a 4-shot dot-SLS process.

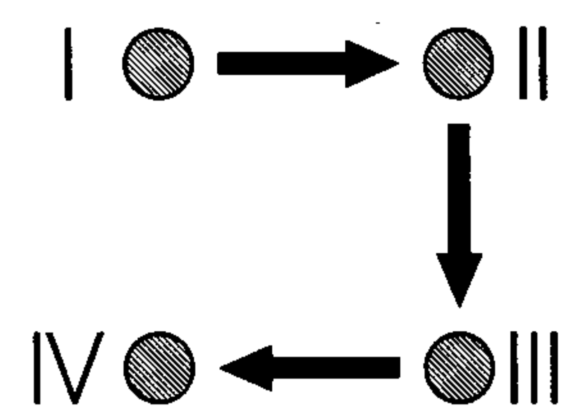

Figure 2. Schematic diagram illustrating a microtranslation scheme for a 4-shot dot-SLS process. The perpendicular translation motions illustrated above are preferred as the sequence leads to an optimized process. The roman numerals indicate the position of the shadowed region during each laser pulse, and the arrows indicate the direction of microtranslation between the consecutive pulses.

out without pausing or stopping for repositioning. An effective way to further optimize this continuous-scan approach is by subdividing the beam width by the total shot number of the particular process under consideration wherein the patterns in each domain are explicitly positioned so as to permit microtranslation required in SLS to take place subsequently during a single continuous scan over the substrate [5]. As it stands, it is of interest to find out whether or not dot-SLS can be implemented using this continuous-scan technique, as the approach would lead to the realization of obtaining defect-free single-crystal islands efficiently at high crystallization rates.

2. Results

Here, we present recent findings from dot-SLS experiments that have been carried out using the continuous-scan scheme. In terms of characterizing the process, we have conducted experiments in which the following parameters were varied: energy density, dot dimension, dot spacing, and microtranslation distance. Microstructural analysis of the processed materials was conducted by performing scanning electron microscopy (SEM) on defect-etched samples, and the orientation analysis of the single-crystal regions was carried out using the electron backscatter diffraction (EBSD) method.

The experimental results, the specific details of which will be presented elsewhere, enable us to conclude that 1) the process can be readily implemented as a result of possessing a well defined process window, 2) the approach is effective in removing random and high-angle grain boundaries, 3) the single-crystal islands formed using the approach have a random distribution of crystallographic orientations (when a-Si precursor films are used), and 4) the primary extended defects found within the processed regions are predominantly of the Σ3 coincident-site-lattice type boundaries (such

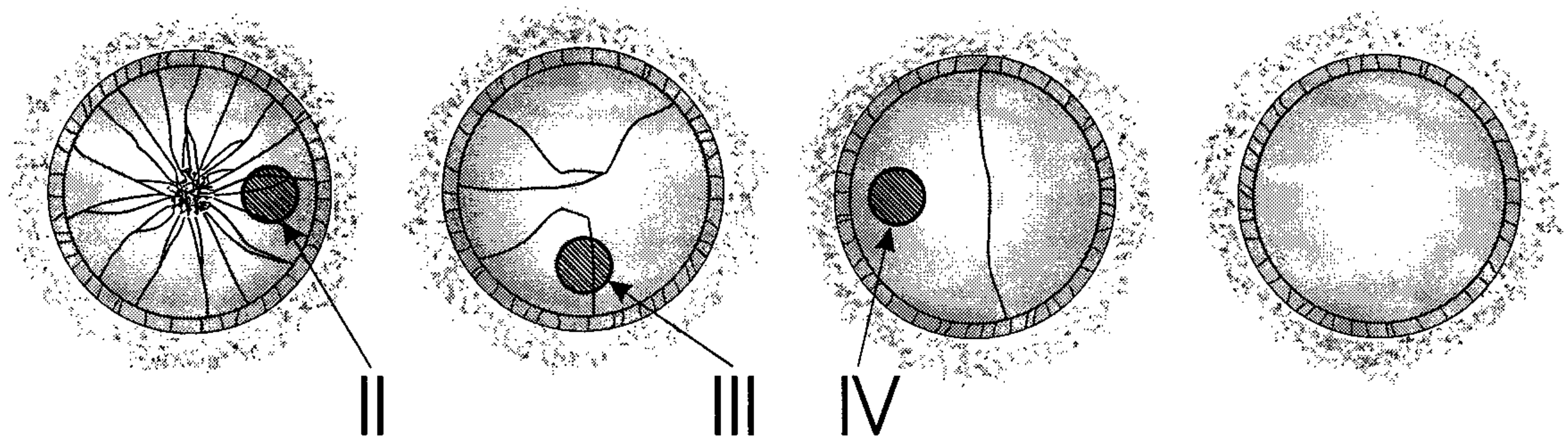

Figure 3. Schematic drawings of the microstructures that are obtained after subsequent irradiation during a 4-shot dot-SLS process according to the microtranslation sequence example given in figure 2. The illustration shows how the number of random high-angle grain boundaries (represented as dark lines inside the islands) is reduced with each iteration.

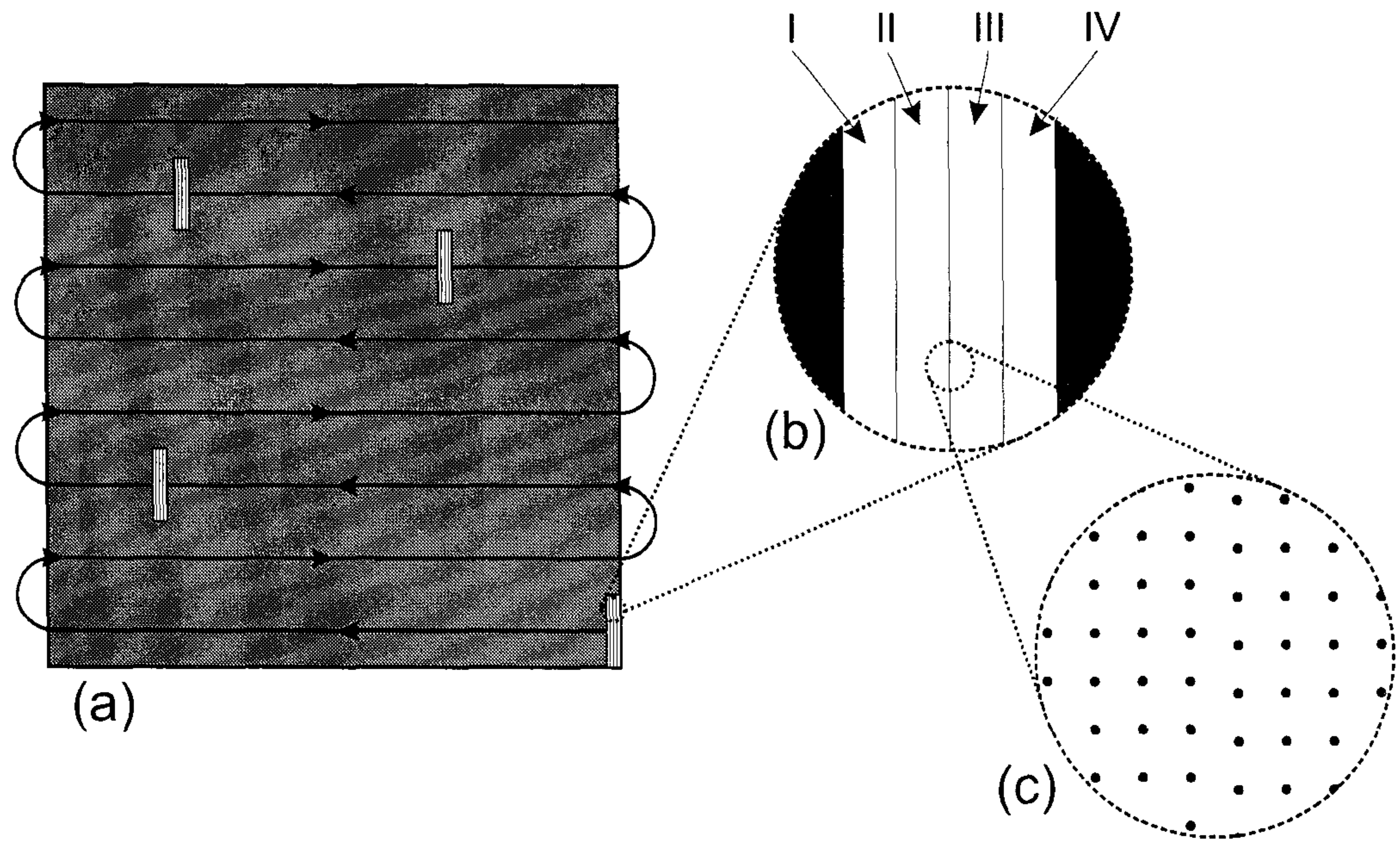

Figure 4. Schematic illustrations showing an example of a 4-shot continuous-scan dot-SLS process: (a) the sample is translated with respect to the beam in such a way that crystallization is carried out without pausing for repositioning; (b) the beam is subdivided into 4 areas; (c) detail of the mask pattern showing arrays of dots.

boundaries do not, presumably, negatively impact the performance of resulting TFT devices [6]), and 5) the islands with near (100) surface orientations tend to be free even of Σ3 boundaries.

3. Impact and Summary

Dot-SLS has been demonstrated using a continuous-scan version of the SLS method, thereby permitting realization of obtaining single-crystal Si regions at high-throughput rates. The high crystalline quality of the materials obtained using the method bodes well for producing high performance TFTs under demanding manufacturing environments. Such TFTs, in turn, should enable the development of a number of advanced macroelectronics and microelectronics products, such as system-on-glass and three-dimensional integrated circuits.

4. Acknowledgements

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