Anomaly detection in optical floating zone single crystal growth

Yu He[1]
Department of Applied Physics, Stanford University, SUID 05667751 [a)]

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I. BACKGROUND AND MOTIVATION

A vital component to the rise of the semiconductor industry is the viability of sizable high quality single crystal silicon, which is predominantly obtained via Czochralski or the floating zone method [1]. The latter is also widely employed in many cutting-edge materials research including novel superconductors and artificial ruby/sapphire synthesis. In this method, the precursor mixture is pressed into a rod, melted at one end (usually above 1000 degree Celsius), and the heating source sweeps the molten zone slowly to the other end to enable high quality crystal formation in the re-crystalized region.

The the stability of the molten zone is thus of paramount significance in the entire process, whose maintenance is often empirical driven and demands 24/7 attendance of manual intervention, especially in the early stage of new materials development. Recently, the industry begins to make effort to apply more computer vision aided approaches to reach better consistency and reduce human labor cost [2]. The Stanford Institute for Materials Engineering and Sciences (SIMES) oversees three such growth systems and has video camera on each of them to monitor such process. High demand for human attention, slow and subtle growth evolution and low rate for actual anomaly occurrence make the operation one of the most challenging and least attractive task in the entire research chain.

II. PROJECT GOAL

The goal of this proposal is to apply video surveillance based anomaly detection algorithm to ease the repetitious workload on the researchers[3], and send preventative alarm to the experimenter group when it detects any early sign of molten zone instability, therefore reduce the risk for irreversible disruption such as zone breaking. Such instabilities often features well defined visual character as indicated in Fig.1, including swelling zone bottom (overheating), wobbly material rod (underheating), feed rod cracking (inhomogeneity) and change of zone volume (feed speed mismatch).

The plan is to use *matlab* to read the video stream and perform the following procedures:

- build a short queue of 'normal' growth frames, set control points and ROI on the molten zone
- identify the molten zone and the zone boundary
- extract the hue, luminosity, volume, eccentricity and smoothness/curvature of the molten zone, register their time sequence
- properly align new frame with the recent frame queue, detect any salient difference based on Markov chain or Kalman predictor
- make corresponding adjustment of growth parameters or trigger alarm when anomaly is detected

[1] A. Crll, F. Szofran, P. Dold, K. Benz, and S. Lehoczky, "Floating-zone growth of silicon in magnetic fields. ii. strong static axial fields," Journal of Crystal Growth **183**, 554 – 563 (1998).
[2] Y. Sun and H. Li, "Diameter detection for crystals growth based on image processing," in *Intelligent Human-Machine Systems and Cybernetics (IHMSC), 2014 Sixth International Conference on*, Vol. 2 (2014) pp. 64–66.
[3] A. Patcha and J.-M. Park, "An overview of anomaly detection techniques: Existing solutions and latest technological trends," Computer Networks **51**, 3448 – 3470 (2007).

[a)] Electronic mail: yuhe@stanford.edu

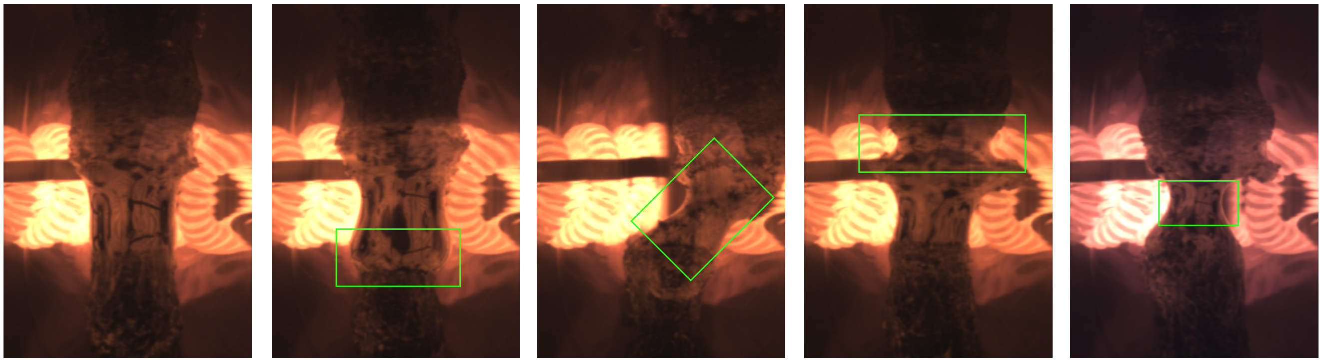

FIG. 1. Illustration of instances of molten zone instabilities. From left to right: normal growth, swelling molten zone bottom, wobbling feed rod, cracking feed rod, shrinking zone volume. The green box highlights the anomalous region.