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High speed infrared thermography of freezing onion-skin cells

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Abstract

Non-contact quantitative thermal imaging in micro-scale is attractive to realize the non-contact thermal analysis during phase transitions. It visualizes both the temperature field and heat transfer. Here we review the system of IR camera equipped with an original optics and temperature calibration algorithm, which is applicable to achieve the high-quality and fast thermal imaging. The Infrared (IR) optical lens design has been optimized to each wavelength band of the photon type and the thermal type detectors of IR FPA. Typical applications to observe the freezing biological cells are presented. The most recent system enables to visualize the thermal imaging of freezing onionskin cells at 10,000 frames/s during rapid cooling process.

1. Introduction

The cryopreservation of biological tissues is an indispensable technique in biological engineering. The control of intracellular ice formation or glass formation and dehydration with an extracellular solution are important for cryopreservation, because biological cells are easily damaged by the volume change of ice formation. According to a typical thermodynamic rule, the 1st-order phase transition is accompanied by not only a volume change but also latent heat. Morikawa et al. found that the thermographical imaging was applicable to the thermal analysis of biological cells on the unit cell scale for measuring latent heat release and thermal diffusion during freezing. [1-2] In this study the most recent technique of high-speed infrared camera is applied to analyze the freezing onionskin cells.

2. Experimental

2.1 Subheading (Arial, 9pt, bold)

To investigate the dynamics of temperature distribution in freezing onionskin cells under cooling was studied by high-speed IR camera as a tool of non-contact thermal imaging for the two-dimensional thermal analysis. A high-speed high-resolution IR camera (640 x 512 matrix of InSb photodetectors) with the normal and the original-designed microscopic lens (magnification x 7) were used. The images of the infrared radiation intensity from the top view of the tissues were studied. The images were taken at 1500Hz – 10,000Hz, and the spatial resolution was 4.29 μm - 35 mm per pixel. The detailed measuring conditions are listed in Table 1.

Table 1. *Measurement conditions of temperature scan at 250 – 300 K (for onionskin cells), and 320 – 500 K* (for *Poly Butylene Terephtalate (PBT).*

Temp. scan condition	250 K – 300 K by 5 K /s	320 K – 500 K by 2,000 K/s
Camera type	FLIR X6900sc InSb 3 – 5 μm	FLIR X6900sc InSb 3 – 5 μm
Frame rate	1,500 Hz @ 320 x 256	10,000 Hz @ 160 x 36
Integration time	600 μs	80 μs
Spatial resolution	35 μm	35 μm
Angle of view	11 mm x 9 mm	2.6 mm x 1.26 mm

2.2 Specimens

Phase change of two different materials were investigated; 1. Onionskin cells on freezing, measuring temperature range was 250 K – 300 K controlled by Peltier element cooler , 2. Melting and crystallization of Poly Butylene Terephtalate (PBT) at 320 K – 500 K.

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3. Results and analysis

Figure 1 shows an example of the thermographical image of latent heat of freezing onionskin cells in cooling observed at 1,500 Hz by InSb IR camera. Temperature rise from each single onionskin cell, separated by a cell-wall, is caused by the 1st order phase transition in cooling. Onionskin cell freezes one time in cooling, even observed by a high-speed at 1,500Hz, however, he thermal diffusion from outside from the cell influences on the temperature distribution inside the cell. This effect is clearly shown in Fig. 2 where the thermal diffusion effect on temperature are seen as the multiple peaks in one cell.

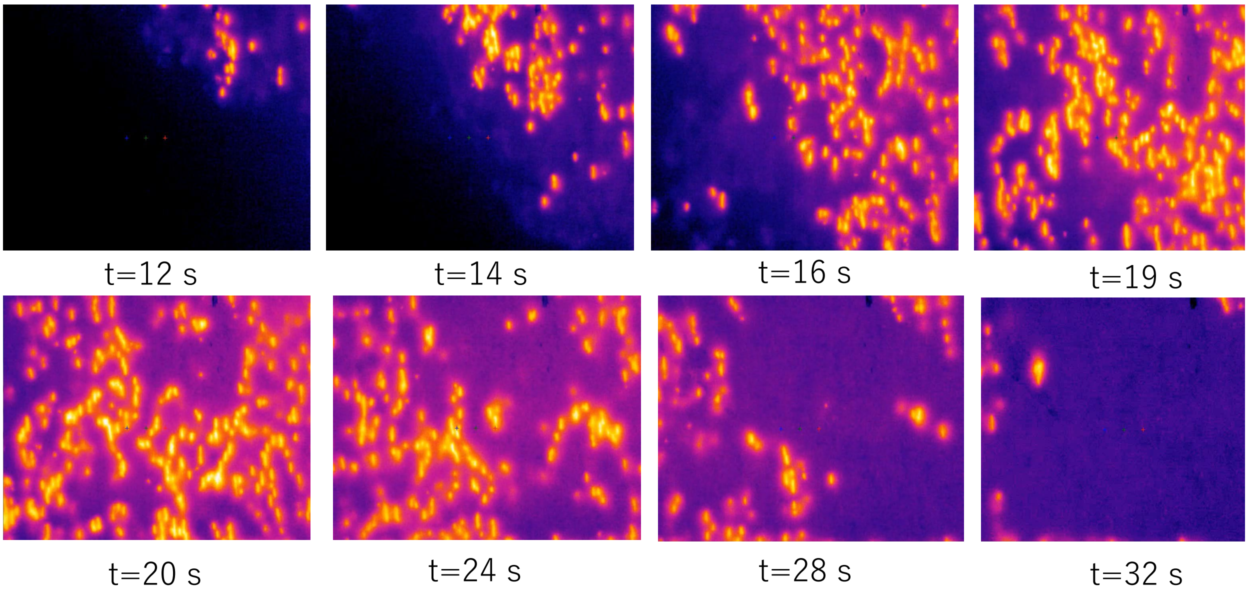

***Fig. 1:** Latent heat of freezing onionskin cells in cooling observed at 1,500 Hz, InSb I camera. Thermal diffusion on the tissues are clearly observed.*

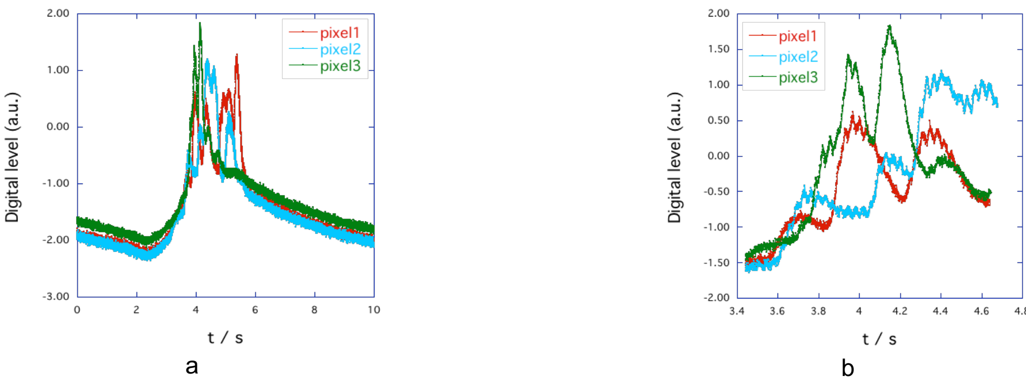

***Fig. 2:** Temperature (digital level) at chosen three pixels in different onionskin cells in cooling **a**, the magnified plot in **b**.*

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