別紙４－１（課程博士（英文））

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Abstract (Doctor)

Title of Thesis	Development of three-dimensional physical property imaging method for layered materials using ultrasound

Approx. 800 words

A three-dimensional (3D) physical property imaging using ultrasound is proposed. A focused transducer scans the layered object along *x* and *y* direction and the cross-sectional view of the object is obtained. The reflection coefficient is then calculated by deconvoluting all the reflected waveforms. Unlike the conventional B-mode echography where each region (layers) of the object was only indicated by the intensity of the reflected signal (brightness), this study proposes a quantitative observation by converting each time-dependent reflection coefficient into its physical property such as acoustic impedance.

Conventionally, deconvolution is performed by division in frequency domain. However, in practice, the deconvoluted waveform suffers from the instability of baseline. This can be caused by improper spectrum division (noise divided by noise) which will create a spurious in low-frequency components, resulting in a wavy waveform when the result is brought back into time domain. Since the process of acoustic impedance conversion is similar to the integration along time axis, any instability in baseline will lead to the accumulation of error as integration goes deeper, which will appear as an artifact in acoustic impedance image. In addition, as the depth of measurement target gets deeper, the instability in baseline after deconvolution will also become stronger. It can be concluded that deconvolution process becomes an essential aspect in acoustic impedance imaging.

In conjunction with the above problems, this study proposes an improvement in the deconvolution process. Instead of performing deconvolution only in frequency domain, the calculation is also performed in time domain because spectral division is not required and the generation of spurious in low-frequency parts after deconvolution can be avoided. However, since the calculation speed of time domain deconvolution is directly proportional to the number of samples in the waveform, a down-sampling is performed to speed up the calculation process, with the consequence of the waveform having its high-frequency components reduced. The spurious in low-frequency components as the result of frequency domain deconvolution is then replaced by that calculated by time domain deconvolution by specifying a threshold value. This way of calculation will retain the stability of low-frequency components in the spectrum,

resulting in a waveform with stable baseline.

The first chapter of this study will discuss about the background and history of microscopic imaging by using ultrasound. The target and motivation as well as the contribution of the thesis will also be described.

The second chapter will discuss about the theoretical preparation of the proposed quantitative acoustic imaging method including the process of acoustic impedance interpretation and the concept of conventional and the proposed time-frequency (dual) domain deconvolution method.

The third chapter will discuss about the application of the proposed signal processing method to human cheek skin observation. As the result, each layer of human cheek skin was visible and could be contrasted by its acoustic parameters, which can be correlated to elasticity.

The fourth chapter will discuss about the requirement to perform a 3D calculation (by performing many times of deconvolution process) so that the calculated acoustic impedance data can be sliced in all cross-sectional direction. The improvement and optimal condition of dual domain deconvolution when calculating a stack of acoustic impedance images in order to increase the robustness and quickness of the calculation will be discussed. As a result, 3D reconstruction of human cheek skin and a quantitative skin observation based on the difference of ages and its correlation with the generation of wrinkles will be discussed.

The fifth chapter of this study will discuss about the proposed signal processing for observing the dynamism of cultured cells (Glial cells and Fibroblast cells). As a result, the area of culture liquid, cell and substrate could be distinguished based on its acoustic impedance value. In addition, by stacking all the calculated cross-sectional acoustic impedance images, the dynamism of the cell such as the change in height and shape before and after the treatment (fixation by aldehyde) could be tracked.

The sixth chapter of this study will discuss about the application of the proposed acoustic imaging method for coating film monitoring in automotive industry, as an alternative to the conventional observation by using Terahertz light which is expensive. As a result, not only the thickness but the uniformity of each layer could also be assessed by means of its acoustic impedance distribution. In another section of the chapter, the application of the proposed signal processing to the space charge measurement in cross-linked polyethylene (XLPE) cable by using pulsed electro-acoustic (PEA) device will also be discussed. Since the stability of each waveform can be maintained by dual domain deconvolution, the charge intensity, electric field and potential distribution could then be calculated by integrating all the calculated waveform.

It can be concluded that from the above-mentioned applications, the proposed signal processing method is believed to be advantageous and applicable to many ultrasound-based research fields because many of the applications require an integration process along time axis and when stability and quickness of the calculation can be maintained, the analysis result can be interpreted into something more informative and quantitative.