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X-ray Micro-Tomosynthesis System Coupled with Optical Lens

Heon Yong Jeong [a*], and Sung Oh Cho [a*]

[a]*Nuclear and Quantum Eng., KAIST, 291, Daehak-ro, Yuseong-gu, Daejeon, Republic of Korea*
[*]*Corresponding author: socho@kaist.ac.kr*

1. Introduction

Tomosynthesis was developed to minimize the total rotation angle of the X-ray tube and detector, exposure time and dosage. [1] Tomosynthesis can reconstruct a sliced image of an object or a three-dimensional (3D) image of an object by collecting and integrating multiple two-dimensional (2D) projected images at different projection angles [2]. Compared to conventional computed tomography (CT) techniques, it has the advantage of a small rotation angle. Therefore, it is advantageous for imaging flat-shaped objects. In recent years, X-ray tomosynthesis technology has become one of the most important methods in field of X-ray imaging.

The X-ray imaging system coupled with the optical lens is composed of a scintillator and an optical detector coupled with optical lens. This system can develop high-resolution X-ray image. [3] When this optical detector with optical lens has an effective pixel size from nano to sub-micro meter, X-ray images with micron spatial resolution can be acquired. Since the geometric magnification method is not used, there is no need to use a nano- or micro-focused X-ray tube, so the price is very low and the volume of the X-ray system is small.

In this study, X-ray imaging system coupled with the optical lens applied by tomosynthis technology was developed for acquiring sliced micro X-ray images.

2. Methods and Results

2.1 Developed System

Micro-tomosynthesis system was designed into a high-resolution X-ray imaging system coupled with optical lens. This X-ray system consists of a micro-focus X-ray tube (P030-24-12F100W, Petrick GmbH, Bad Blankenburg, Germay), an optical lens, and a scientific complementary metal-oxide-semiconductors (sCMOS) detector (pico.edge 4.2, PCO, Kelheim, Germany). The operating voltage and current of micro-focus X-ray tube are 50 kVp and 1 mA. The focal spot size is 30–55 μm. A 10x infinity corrected objective lens (f = 200 mm) and a tube lens (f = 160 mm) are used to magnify the X-ray image on scintillator film, and a sCMOS detector is used to develop this image. The sCMOS detector has 6.5 μm suqaure pixel size. The effective pixel size is 812.5 nm. The X-ray tube The X-ray tube rotates about the center of the scintillator. After acquiring 2D X-ray images at various angles, slice images of an object were acquired using the shift and add tomosynthesis method. (Fig. 1) The principle of shift-and-add tomosynthesis is that multi projection images were taken when the x-ray tube was moved. The acquired images are appropriately shifted and added to bring micro-structures in objects in focus, while structure outside the plane of focus blurred across the image. The finally developed system is shown in Fig. 2.

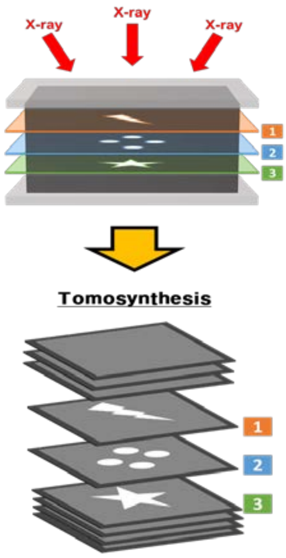

Fig. 1. Mechanism of X-ray micro-tomosynthesis

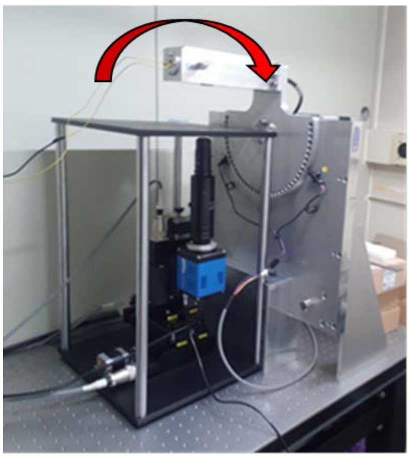

Fig. 2. Developed X-ray micro-tomosynthesis system coupled with optical lens

2.2 Resolution of Sliced X-ray Image

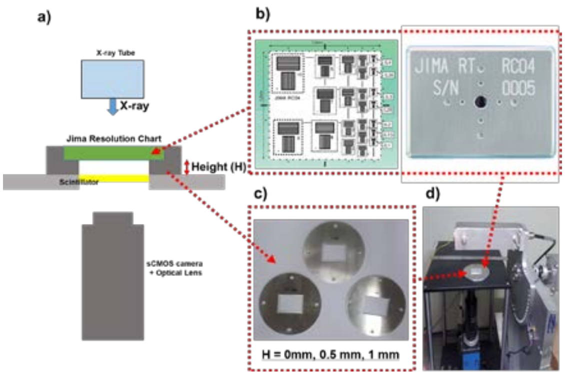

Fig. 3. a) Method of measuring resolution of sliced X-ray image at different heights, b) Rima RT RC-04 Resolution Chart and c) Height holder (H = 0, 0.5 and 1 mm) and d) X-ray micro-tomosynthesis system coupled with optical lens

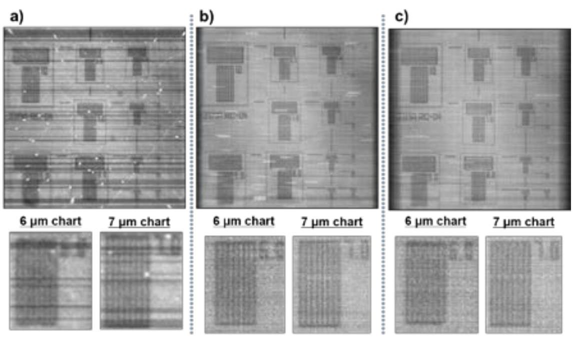

Fig. 4. Micro X-ray images of Rima RT RC-04 resolution chart at different heights of a) 0, b) 0.5 and c) 1 mm

The resolution of sliced tomosynthesis images according to heights was measured as shown in Fig.3.a. The Rima RT RC-04 resolution chart was used to measure the resolution of the sliced X-ray image. (Fig.3.b) The resolution chart was set at different heights using height holders (Fig.3.c), and then the sliced X-ray images were acquired in X-ray micro-tomosynthesis system coupled with optical lens. (Fig.3.d) At all heights, the resolutions of 6-7 um were measured. (Fig. 4)

3. Conclusions

An X-ray micro-tomosynthesis system coupled with optical lens was designed. Although it is not a complete research, this result shows that sliced micro X-ray images can be obtained by using an X-ray imaging system coupled with optical lens and tomosynthesis technology. The further work of this research is to acquire sliced sub-micron X-ray images using a 20x infinity corrected objective lens and a thinner transparent scintillator. This designed system will be applied to the field of physiology or industrial test.

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