INTRODUCTION

Microscopies such as optical and electronic types are mostly restricted to surface observation of objects. Information required for material research actually not only arises from a surface but is buried more in the bulk. Computerized x-ray tomography (CT) nondestructively provide us image of any cross section of the object, i.e., three dimensional image of the bulk.

Images of element distribution in objects can be obtained by absorption contrast using two monochromatic x-ray beams which straddle its absorption edge. In order to implement this method monochromatic x-ray beams have been used. Monoenergetic sources are obtained mainly with the combination of SR and monochromator, with radioisotopes or with fluorescence from secondary targets. The latter two sources are more accessible than SR but their intensity is mostly poor. Therefore we attempted to utilize polychromatic beams other than monochromatic beams of conventional x-ray sources. We have extended this critical absorption technique to polychromatic x-ray with filter modulation instead of crystal monochromators and have demonstrated its capabilities.

In the present paper the basic idea of our filter modulation technique for x-ray microtomography is described at first and the devices used in this study are briefly explained. Then the experimental results obtained through two different data subtraction processes are discussed.

FILTER MODULATION

Conventional x-ray sources such as sealed-off tubes generate a wide band of white radiation superimposed with characteristic lines of target elements. Filters have been used for crystal diffraction studies to select a suitable line from those characteristic lines. A single filter which has an absorption edge on the just higher energy side of $K_\alpha$ lines of a target suppresses a $K_\beta$ line and a considerable part of white radiation. This filtered spectrum still contains
continuum in the low energy region and in the far high energy. The remained continuum and
the reduced \( K_\alpha \) can be substantially eliminated by the Ross balanced filter technique, which is
a combination of a \( \beta \) filter and an additional filter of proper thickness with an absorption edge
on the just lower energy side of \( K_\alpha \) lines. The difference between the two measurements
obtained with each filter is ascribed to the narrow band between the absorption edges of filters,
\( \ldots \) mainy to the \( K_\alpha \) lines. We have applied these techniques to microtomography in the
simpler condition.

Figure 1 shows schematic representation of continuum x-ray spectra from a conventional
source. Characteristic lines are not essential and are omitted for simplicity. As illustrated in
the figure, \( I_0 \) and \( I \) designate the intensities of the incident and transmitted x-ray fluxes,
respectively. It is assumed that the object contains an element of an absorption edge at the
energy denoted by \( s \) and that two filters of different absorption edges at the higher and the
lower energies denoted by \( f_1 \) and \( f_2 \) are employed for the spectrum modulation of the incident
beam.

**Postreconstruction Subtraction**

Spectra (a) are incident and transmitted ones without filtering. One absorption edge at \( s \)
is illustrated in the transmitted spectrum of \( I \). The contrast corresponding to this absorption
should be involved in the CT image reconstructed from projections with these spectra. In the
case of \( f_1 \)-filter, (b) in the figure, the transmitted spectrum includes a part of absorption curve
from the edge \( s \) but the transmitted spectrum of \( f_2 \)-filter, (c) in the figure, does not contain any
absorbed component due to the edge \( s \). The reconstructed tomograph with filter \( f_1 \) should have
the contrast due to the absorption edge \( s \) but the tomograph with \( f_2 \) should not. The contrast
of reconstructed images are the results calculated from \( I/I_0 \), the ratio of transmitted to incident
intensity, where \( I_0 \) and \( I \) are integrated intensities over the spectra. From the spectra (a), (b)
and (c) it can be expected that the contrast due to the absorption edge \( s \) in reconstructed
tomographs appears to be stronger in (b), moderate in (a) and weak in (c). By comparison of
these three images, simply by subtraction between reconstructed images, the possibility for
element-selective imaging arises. This may be termed "postreconstruction subtraction".

**Prereconstruction Subtraction**

The curves of (d), (e) and (f) in Figure 1 are narrow band spectra obtained by direct
subtraction of (b) from (a), (c) from (a) and (c) from (b), respectively. This may be called
"prereconstruction subtraction". Through this process the low energy envelopes are reduced
in the spectra of incident beams. The transmitted spectra of (d) and (e) have to contain the
absorption due to the edge \( s \) and the fraction of those components are nearly same. The most
monoenergetic spectra are (f), which eliminate polychromatic artifact from CT images. This
combination of subtractions provide highest contrast if the absorption edge \( s \) is equal to \( f_2 \) but
least contrast will be given if the edge \( s \) is equal to \( f_1 \).

**EXPERIMENTAL**

The microtomography system used in the present study consists of an x-ray source, a filter
changer, a sample stage, an image detector (a combination of a fluorescent screen and a cooled
CCD still camera) and a computer, as shown in Figure 2. A personal computer (PC) was
employed to control filtering the incident beam, rotation of the sample stage and to acquire
image data of incident and transmitted x-ray. The PC is connected to a local area network and
is able to access other powerful engineering work stations, which was used for the fast
reconstruction of the cross section by filtered liner back projection using the Shepp–Logan