A Study of the Internal Structure of Gallstones Based on the Differences between the Interactions to Elements of Thermal Neutrons and X-Rays†

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Many investigations at the structure of gallstones have been carried out for the purpose of elucidating the process of the gallstone's formation. Some of the investigations included the classification of the structures of the outer and cut surfaces including shapes*1. Investigations by instrumental analysis including polarization microscopy, scanning electron microscopy, and magnetic resonance imaging have been reported*2.

Recently, a few biological applications of thermal neutron radiography have been studied*3. We examined the application of radiography to determine the internal structure of gallstones. We found that appreciable information concerning the process of gallstone formation could be obtained from a comparison between neutron radiography and X-ray radiography. Much information concerning the three dimensional structure of gallstones were obtained by comparing both radiographies from the x-, y-, and z-axes of the gallstones.

Gallstones used for radiography were removed surgically in the Department of Surgery, Nippon Medical School Second Hospital. For neutron radiography, we used an intense thermal neutron flux, $3.8 \times 10^6$ n$_{th}$/cm$^2$.s$^{-1}$. Exposure time was from 40 min to 1 h. Beam uniformity was less than ±7.4%. We performed the neutron radiography on a horizontal type NR facility of TRIGA Mark II Reactor at the Institute for Atomic Energy at Rikkyo University. The neutron radiography images were taken on Kodak mono-layer SR film with a gadolinium converter. For X-ray radiography, we used an Akoma apparatus (MX 400) operating at 27 kV, 100 mA. Exposure time was 0.6 – 2.0 s. The image was recorded on Kodak X-Omaf TL film.

The analysis of both radiographic images was performed by drum scan densitometer (2606; Abe Sekkei Inc.) with a 50 µm aperture (square) as the reading apparatus. The signal
of optical density obtained was stored on a floppy disk in a personal computer (PC-9801 VX41; NEC Corp.). The stored image was analyzed with a MICRO CIPS (Abe Sekkei Inc.) software program on the computer.

It is known that there is a large difference between the interactions for elements of thermal neutrons and X-rays. In the case of neutrons, the attenuation coefficient is very high for hydrogen. In the case of X-rays, the attenuation coefficients for calcium and phosphorous are relatively high. Consequently, substances which contain hydrogen, for example, cholesterol and water, are opaque in neutron radiography, and substances which contain calcium and phosphorous are opaque in X-ray radiography. We investigated the internal structure of gallstones with reference to the difference in the coefficients between thermal neutrons and X-rays.

Figures 1 and 2 show color-coded images from the upper side and the flank of the same gallstone. The principal component in the gallstone used was identified as cholesterol from an infrared spectrum. The neutron radiographies in Fig. 1 and Fig. 2 indicated that the difference in the permeability of the thermal neutron arose mainly from a difference in the thickness of the cholesterol layer. On the other hand, the X-ray radiographies in Fig. 1 and Fig. 2 indicated that the cholesterol layer for X-rays was transparent, but the difference in permeability was caused by a difference in the amount of substances which contained calcium.

It was found from Fig. 1 and Fig. 2 that cholesterol was surrounded by substances containing calcium in the cylinder state. It was also found that cholesterol surrounded the outside of the cylinder.

The internal structure of gallstones can not be determined from observation of their cut surfaces. However, the internal structure was revealed by a comparison of neutron and X-ray radiographies.

Substances which were contained in subdivided parts of gallstone are being analyzed at present time.

References