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X-ray spectra calculation for different target-filter of mammograms using MCNP Code

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Background: An electron beam generated X-ray spectrum consists of characteristic X-ray and continuous bermsstrahlung. The aim of this research is calculating and comparing X-ray spectra for different target filter of mammograms. ***Materials and Methods:*** Monte Carlo is a very powerful tool to simulate a series of different target-filter assembly in order to calculate the X-ray spectra. MCNP version 4C has been used for simulation set up to calculate X-ray spectra for different target-filter combination of mammograms. ***Results:*** The spectra of different and the most commonly used target- filter in mammography equipments (Mo-Mo, Mo-Rh, Rh-Rh, W-Rh, Mo-Al and Rh-Al) have been calculated. ***Conclusion:*** The computational results can be used to select a suitable X-ray spectrum for mammography as well as for computing the absorbed dose. Also, the Monte Carlo result of Mo-Mo is in good agreement with the published results. **Iran. J. Radiat. Res., 2005; 3 (3): 129-133**

Keywords: *X-ray spectra, target- filter combination, mammography, Monte Carlo simulation, MCNP code.*

INTRODUCTION

Mammography is one of the most important imaging techniques to diagnose breast cancer. It is perhaps the single most important innovation in breast cancer control. The importance of mammography is directly related to its value in the early detection and management of breast cancer. Mammography detects approximately 2-3 times as many early breast cancers as physical exams. Breast cancer is the second cause of women death after lung cancer in USA[1].

Recently, further to Mo-Mo target-filter combination in X-ray tubes of mammograms, other new array of target-filter such as Mo-Rh, Rh-Rh W-Rh, Mo-Al and Rh-Al have also been used[2]. Thilander *et al.*[3] and Jennings *et al.*[4] reported that the average glandular dose to the breast tissue can be reduced about 50% if a W-Rh combination is used instead of Mo-Mo. Also, the Monte Carlo result of Dance *et al.* shows that the W-Rh and Rh-Al combinations are more useful as alternatives to the standard Mo-Mo for digital mammography[2]. In this paper, the X-ray spectra for different target-filter combinations by Monte Carlo method using MCNP code version 4C was calculated[5]. Monte Carlo method is a powerful tool to study and optimize ionizing radiation systems such as mammograms[6, 7].

MATERIALS AND METHODS

The simplified geometry configuration of X-ray tube in mammogram is shown in figure 1 which has been used as input for the MCNP code. A mono-energy electron beam incident to the target with 45° angle, the filter is applied for absorbing the low energy photons in arbitrary distance from the target (15 cm in this calculation).

The X-ray spectra of two clinically

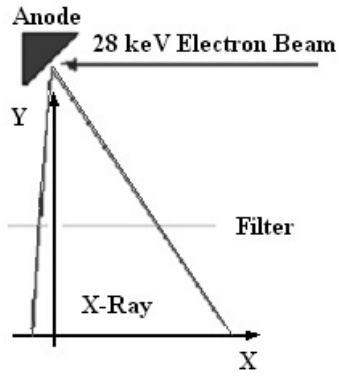


Figure 1. The geometry of X-ray tube in mammography for input of MCNP code.

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mammograms, a Mammomat 3000 (Siemens-Elema, Solna, Sweden) and a Senographe DMR (General Electric Medical Systems, Milwaukee, USA) have been calculated. Both mammograms have had a molybdenum (Mo) anode, which could be used with either a 30 μm Mo filter in Mo-Mo combination or a 25 μm rhodium (Rh) filter in Mo-Rh combination. Also, the X-ray spectra of the other filter-target combination such as Rh-Rh, W-Rh, Mo-Al and Rh-Al have been calculated.

RESULTS AND DISCUSSION

The Monte Carlo X-ray spectra with 0.25keV energy step in [0, 28 keV] energy interval was presented in this section. Figure 2 shows the Mo target X-ray spectra with and without a 30μm Mo filter for the 28keV electron beam at 15 cm distance from the target position. The X-ray spectra of Mo with and without a 25μm Rh filter are shown in figure 3. The characteristic X-ray peaks of Mo (17.5 keV and 19.5 keV) are very clear in these spectra. The Senographe DMR also had a Rh anode with a 25μm Rh filter (Rh-Rh), the spectra of this combination is shown in figure 4. The other target -filter combination of the Mammomat 3000 is tungsten (W) anode with a 50 μm Rh filter (W-Rh), and the Senographe DMR also had a Rh or Mo anode with a 1 mm aluminium (Al) filter. For comparison the X-ray spectra of these anode-filter combinations, all the spectra are shown in figure 5. The X-ray spectra were calculated by F5: p tally of MCNP code.

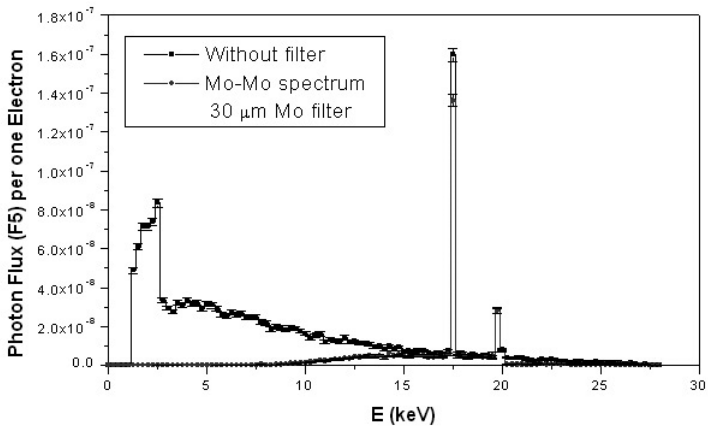


Figure 2. The X-ray spectra of Mo target, with and without Mo filter for the 28keV electron beam at 15 cm distance from the target position.

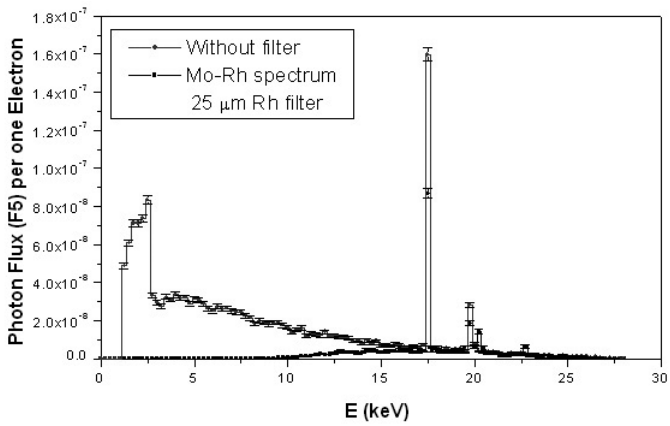


Figure 3. The X-ray spectra of Mo target, with and without Rh filter for the 28keV electron beam at 15 cm distance from the target position.

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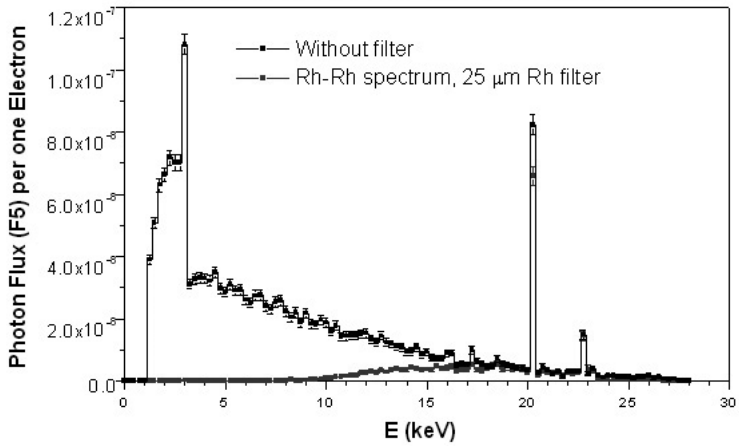


Figure 4. The X-ray spectra of Rh target, with and without Rh filter for the 28keV electron beam at 15 cm distance from the target position.

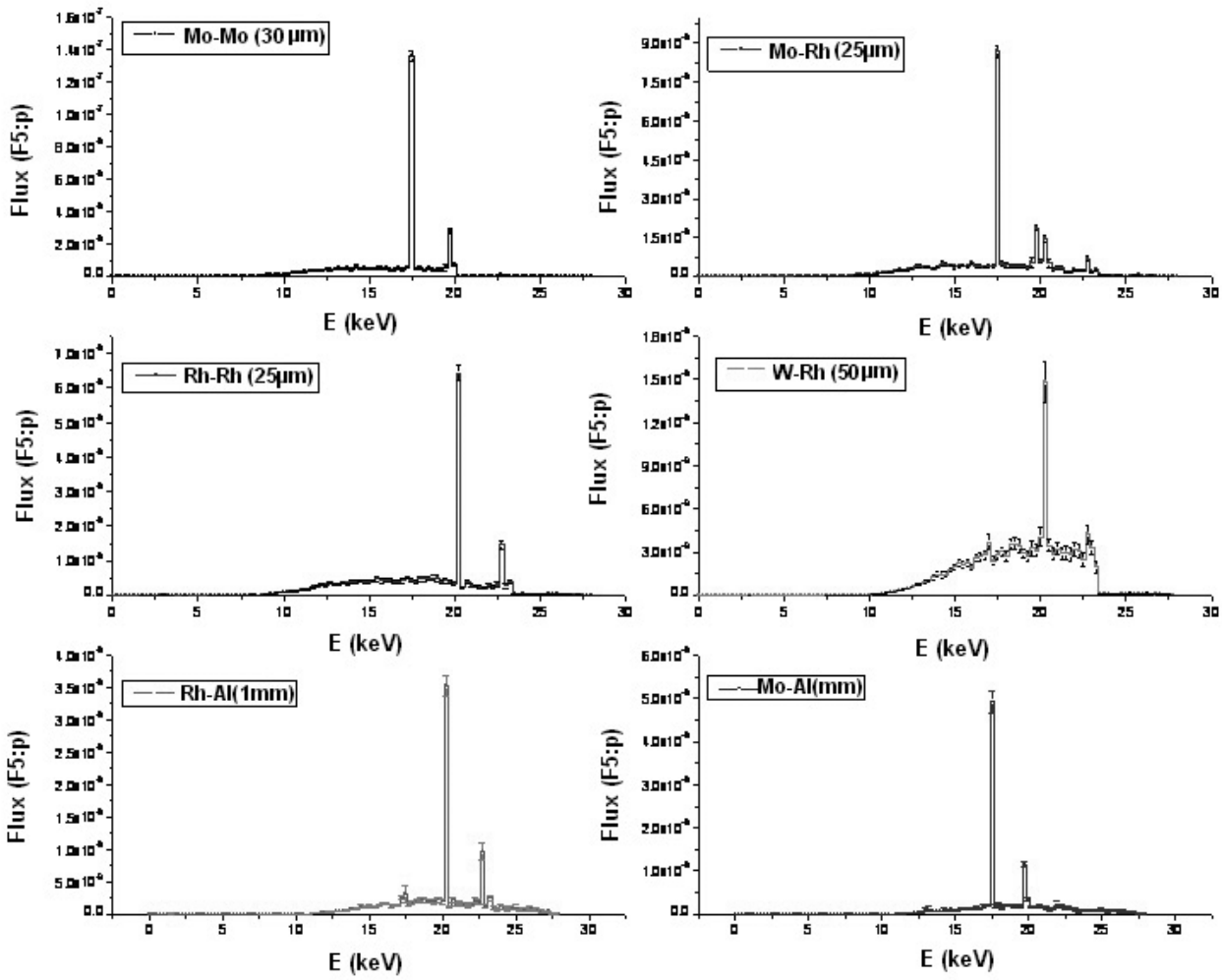


Figure 5. The X-ray spectra of some different target-filter combination for the 28 keV electron beam at 15 cm from the target position.

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It is well known that the photons with energy greater than 15 keV from X-ray spectra are important in breast imaging and the low energy photons only increase the absorbed dose. The 15-28 keV photons flux to total flux ratio for different target- filter has been shown in figure 6. This ratio is minimum for Mo-Mo (0.771) and maximum for Rh-Al (0.932). Also, the variation of total flux of Mo-Mo spectrum and flux of the photons with energy greater than 15 keV via the X axis (figure 1) at the 55 cm distance from Mo-Mo is shown in figure 7.

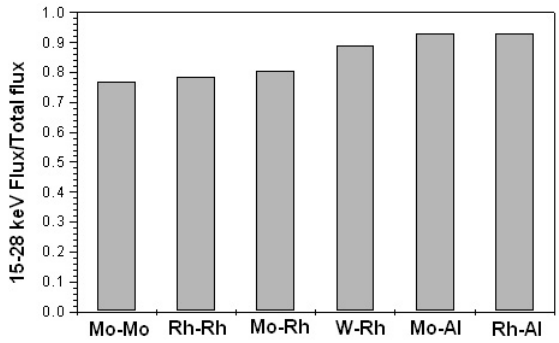


Figure 6. 15-28 keV flux to Total flux ratio for different target- filter.

Figure 8 shows a good agreement between photon spectrum derived and Gaussian spread by MCNP for Mo-Mo combination at 28 keV electron energy beam in this work, and the spectrum measured by Matsumoto *et al.* [8] for Mo-Mo combination at 28 keV.

CONCLUSION

The computational codes based on Monte Carlo method such as MCNP or GEANT are very powerful tools for simulating X-ray spectra with different target- filters combination produced by mammogram's X-ray tube. The calculated spectra can be used in computing absorbed dose in mammography. The flux of the photons with energy greater than 15 keV decreased about 6% from zero to 11 cm displacement in X axis and total flux decrease about 6.5%. The present work demonstrates a useful approach using MCNP code that can be applied in many other fields.

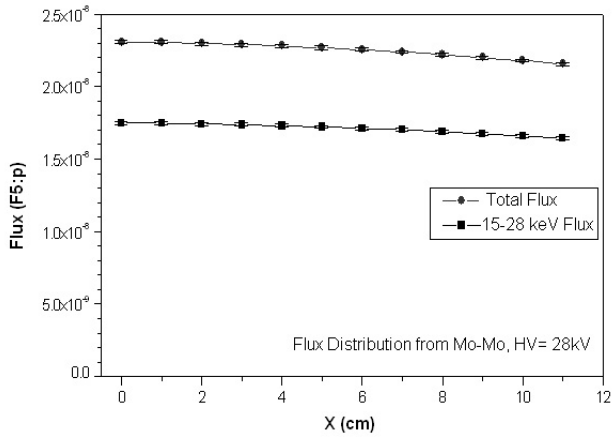


Figure 7. The variation of total flux and 15-28 keV photons flux via the X axis at the 55cm distance from the Mo target.

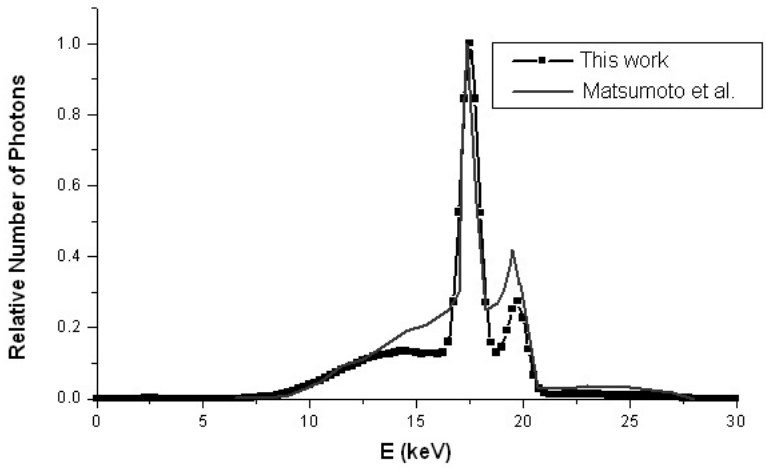


Figure 8. Comparison of photon spectra result for Mo-Mo combination at 28 kV.

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