Feasibility of performing 2D mammography using CNT source array designed for tomosynthesis

A stationary digital tomosynthesis system (s-DBT) utilizing field emission CNT source array has been reported to achieve high spatial resolution and faster scanning speed than conventional tomosynthesis system. We investigated the feasibility of performing 2D mammography using the s-DBT system. To perform a 2D mammography, we need an exposure capability of 50mAs in the shortest time possible. The minimum goal is to find out whether our system can perform a 50mAs mammography in 4s. However, the anode heat loading and cathode capability to deliver high current are the two issues need to be addressed.

**Anode heat load:** Anode heat load around the focal spot area is an important issue needs detailed study. The bombardment of high energy electrons on the anode generates a high temperature distribution at the focal spot area. We have developed a reliable simulation model to evaluate the thermal load of the anode. Temperature distribution on the anode was simulated using Ansys Workbench 12.1 (Ansys Inc. Canonsburg, PA). Simulations were done for the anode used in our s-DBT system. The anode is made of an 8mm diameter and 2mm thickness tungsten anode embedded in a copper holder. Anode voltage is 28kVp. Focal spot size (FWHM) after projection was experimentally determined to be 0.61mm x 0.64mm. Figure 1(a) shows the simulation results of maximum temperature profile for an x-ray source operating at 50mAs and 100mAs in 4 seconds. Simulation results show that the anode is in the safe range ($T_{\text{max}} < 3000$ K for tungsten anode) when the x-ray source is operated at 100mAs in 4s. This suggests that performing a 2D mammography for 50mAs in 2 seconds is feasible. With shorter scanning time, image quality can be improved by reducing artifacts from patient motion.

![Anode heat load simulation results](image)

Figure 1 Anode heat load simulation results. Figure (a) shows the maximum anode temperature profile for a 4s scan delivering 50mAs and 100mAs respectively. The max temperature for a 100mAs imaging in 4 second is in the safe range ($T < 3000$K for tungsten anode), which suggests that we can perform a 2D mammography at 50mAs in 2s by using the CNT x-ray sources in the s-DBT system. Figure (b) shows the temperature distribution on the anode for a 4s 50mAs image.

**Cathode stability study:** We configured a testing chamber to mimic the s-DBT system to study the feasibility and stability of CNT cathode operating at high current. Three CNT cathodes of size 13mm x 2.5mm were placed in the x-ray unit structure which has similar geometry to the s-
DBT system. The tube was operated at 35kVp. Figure 2 shows that the CNT cathode can easily reach the minimum requirement of 50mAs in 4s for a 2D mammography, and can deliver 50mAs in a 3 second pulse width. The maximum cathode capabilities were observed at 48.5mAs in a 2s pulse width. The results indicate we can reliably perform 2D mammography at 50mAs in 3 second.

![Diagram of x-ray unit structure mimic to the s-DBT system.](image1)

![Graph showing cathode voltage vs. exposure.](image2)

(a) 50mAs with 3s pulse width
(b) 54 mAs with 4s pulse width
(c) 50 mAs with 2s pulse width

Figure 2 (a) shows the x-ray unit structure mimic to the s-DBT system. (b) shows that x-ray tube can easily reach 50mAs in 4s pulse width, the subplot shows the anode current waveform. (c) shows that the tube can stably run at 50mAs in 3s pulse width. (d) shows the tube can reach 48.5mAs in 2s.

Innovation/Impact: This study shows the feasibility of expanding the capabilities of current CNT s-DBT technology to 2D mammography. This study suggests the possibility of improving the mammography screening time to 3 seconds with 50mAs dose. Based on this study, we see possibility to improve the scanning time of our current s-DBT system, which is worth doing further study to prove it.

Conclusion: We demonstrated that 2D Mammography at 50mAs in 3 seconds is feasible by using CNT s-DBT sources.