Fabrication of Focused Two-dimensional Grids for Mammography

O.V. Makarova,[1] D.C. Mancini,[2] N. Moldovan,[2] R. Divan,[2] V.N. Zyryanov,[1] C.-M. Tang[1]
[1]Creatv MicroTech, Inc., Potomac, MD, U.S.A.
[2]Advanced Photon Source (APS), Argonne National Laboratory, Argonne, IL, U.S.A.

Introduction

Mammography is the principal method for detecting breast cancer. It uses x-rays with energy primarily in the range of 17 to 35 keV propagating from a point source placed 60 cm above the image detector, centered on the human chest wall. An ideal diagnostic image is produced by local reduction in the x-ray intensity due to differences in attenuation in the penetrated material without recording any scattered x-rays. Because of the large amount of the radiation scattered by the breast tissue, image contrast is lowered, making diagnostics of diseased tissue subjective and difficult. The quality of a mammogram image can be significantly improved by placing in front of the image detector a focused antiscatter grid that provides high transmission of the primary radiation and is opaque to scattered radiation.

We have applied deep x-ray lithography and copper electroforming technique to the fabrication of antiscatter grids for mammography [1-4].

Methods and Materials

In order to obtain a square grid with septa walls oriented toward a focal point, we have developed a double-exposure method [1, 3-4]. An x-ray mask consisting of parallel strips was used, and the substrate exposure was performed twice. The strips on the mask were positioned horizontally and perpendicular to the propagating direction of the x-ray beam. During exposure, the mask-substrate assembly was moving across the narrow x-ray beam with synchronous rotation around the horizontal axis, as schematically shown in Fig. 1.

In the scanning process, the angle gradually increases from the sample centerline, where the x-ray beam is perpendicular to the assembly, toward the sample edges, where the substrate-mask assembly is tilted with respect to the beam. After the first exposure, the resulting pattern consists of strips with walls oriented to a focal line. Then the substrate is turned 90° while the mask orientation is kept the same, and the second exposure is performed the same way. After the second exposure, the resulting square grid pattern has all cells oriented to a focal point. The two exposures should be aligned to each other. To achieve this, the mask is aligned with the substrate before each exposure by using alignment marks.

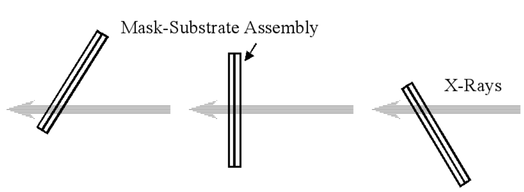

FIG. 1. The position of the mask-substrate assembly at different orientations during the x-ray exposure.

Rotation of the sample during x-ray exposure causes line smearing in the resist layer. To reduce smearing, the absorber layer of the x-ray mask has to be oriented toward the resist, and the mask should be placed as close to the resist as possible. The width of the x-ray beam has to be reduced so smearing at the bottom of the resist layer does not exceed half of the septa width. Conventional hard x-ray masks have the sidewall edges of the gold absorber perpendicular to the mask substrate. Since rotation of the mask-substrate assembly causes x-rays to not be perpendicular to the substrate, the slopes of the gold absorber walls of the x-ray mask should vary in the same way as the slopes of the walls in the final device to avoid variation of the septa widths across the substrate as a function of tilt angle.

Details on sample preparation can be found elsewhere [1-4]. Both soft and hard x-ray exposures were performed at the APS bending magnet beamline 2-BM [5]. Hard x-ray masks used for patterning were fabricated by conformal mask technology [6]. To adjust the high-energy cutoff on the same beamline (2-BM) to lower energies, a Pt-coated mirror with a 1° angle of grazing incidence was used in addition to the Cr-coated mirror with a 0.15° angle of grazing incidence. The hard x-ray mask consisted of 30-μm-wide channels and several alignment marks in a 75-μm-thick gold absorber layer. The channels had gradually tilted sidewalls and were parallel to the diagonal of a square covering an area of 60×60 mm.

To prove the concept of fabrication of square patterned grids with the septa walls oriented toward a single focal point, the exposures were done with a simple alignment method [4]. The alignment accuracy was better than 10 μm. The substrate/mask assembly was mounted on a scanner stage driven by a servomotor that allowed x-y translation and rotation along each axis during exposure. The exposed polymethyl methacrylate (PMMA) was developed by using the GG developing system [7].

Copper electroforming was performed by using a copper sulfate plating bath. After electroforming, the copper microstructures, along with the PMMA mold, were released from the plating base by abrasive removal of graphite. Both sides of the copper microstructure were lapped and polished. Then the PMMA mold was dissolved in acetone, resulting in the finished freestanding metal structure.

Results

Freestanding copper antiscatter grids that focus to the point and are up to 2-mm tall and 60×60 mm in size have been fabricated (Fig. 2). Such grids, with septa walls focused to a single point, can be used in mammography to eliminate scatter and result in improved contrast and significantly better image quality than what can be achieved with the conventional antiscatter grids. This method can be used fabricating various other structures with gradually inclined walls.

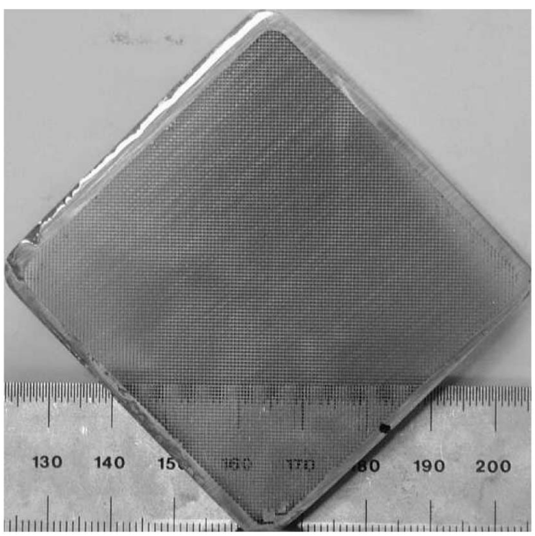

FIG. 2. Photo of a focused copper grid.

Acknowledgments

We would like to thank F. De Carlo for beamline support. We acknowledge J. Yaeger for experimental assistance and J. Arko for technical assistance in this work. The work was supported by the National Institutes of Health (NIH) Small Business Innovation Research (SBIR) Phase II Grant No. R44 CA76752. Use of APS was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

References

[1] O.V. Makarova, N. Moldovan, C.-M. Tang, D.C. Mancini, R. Divan, V.N. Zyryanov, D.G. Ryding, J. Yaeger, and C. Liu, *Society of Photo-optical Instrumentation Engineers Proceedings* **4783**, 148-155 (2002).

[2] O.V. Makarova, D.C. Mancini, N. Moldovan, R. Divan, C.M. Tang, G. Ryding, and R. Lee, Sensor and Actuat. A-Phys. **103**, 182-186 (2003).

[3] O.V. Makarova, C.-M. Tang, D.C. Mancini, N. Moldovan, R. Divan, D.G. Ryding, and R.H. Lee, Microsys. Technol. **9**, 395-398 (2003).

[4] O.V. Makarova, D.C. Mancini, N. Moldovan, R. Divan, V.N. Zyryanov, and C.M. Tang, Microsys. Technol. (submitted 2003).

[5] B. Lai, D.C. Mancini, W. Yun, and E. Gluskin, *Society of Photo-optical Instrumentation Engineers Proceedings* **2880**, 171 (1996).

[6] V. White, C. Herdey, D.D. Denton, and J. Song, J. Vac. Sci. Technol. B **15**, 2514-2516 (1997).

[7] V. Ghica and W. Glashauser, German Patent No. 3039110 (1982), U.S. Patent No. 4393129 (1983).