Design and fabrication of a miniaturized, integrated, high-frequency acoustical lens–transducer system

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Received 19 October 2001, in final form 7 February 2002
Published 28 March 2002
Online at stacks.iop.org/JMM/12/219

Abstract
High-frequency ultrasound transducers have been developed for high-resolution imaging applications, such as nondestructive testing and medical diagnostics. Several of these devices employ miniaturized acoustical lenses to enhance the resolution of the system; however, research has been limited due to lens fabrication restrictions at or below the millimeter scale, which also increases the difficulty in creating lenses of identical geometric shape. Alignment and assembly problems on the micrometer scale have also necessitated the requirement for developing an in situ integrated transducer–lens system. Thus, the purpose of this study was to employ a new state-of-the-art micromachining technique to fabricate a high-precision, integrated, microacoustical lens–transducer system of identical geometric shape. Concave lenses \((d = 1 \text{ mm})\) were fabricated from either PMMAR- or epoxy using an ultra-high-precision micromilling machine. The lenses were designed for three different focal lengths (3 mm, 4 mm or 5 mm) with a center thickness of \((3/4)\lambda\). After fabrication, each lens was evaluated for compliance with the design criteria using scanning electron microscopy and a roughness/step tester. A total of 28 lenses with identical geometry were successfully fabricated. The errors of the radii of curvatures for all PMMAR- and epoxy lenses were within \(7.5 \pm 5.8\%\) and \(6.0 \pm 6.1\%\), respectively, of the designed values.