Fabrication of Ultrasonic Transducers Using Epitaxial Pb(Zr,Ti)O$_3$ Thin Films on Epitaxial $\gamma$-Al$_2$O$_3$/Si Substrates for Smart Sensors

Daisuke Akai$^{1,*}$, Yasuhiro Oba$^2$, Nagaya Okada$^3$, Mikinori Ito$^2$, Kazuaki Sawada$^{2,5}$, Hidekuni Takao$^{4,5}$ and Makoto Ishida$^{1,2,4,5,**}$

$^1$Venture Business Laboratory, Toyohashi University of Technology, 1-1 Hibarigaoka, Tempaku-cho, Toyohashi, Aichi 441-8580, Japan
$^2$Department of Electrical and Electronic Engineering, Toyohashi University of Technology, 1-1 Hibarigaoka, Tempaku-cho, Toyohashi, Aichi 441-8580, Japan
$^3$Honda Electronics Co. Ltd., 20 Oyamazuka, Ooiwa-cho, Toyohashi, Aichi 441-3193, Japan
$^4$Intelligent Sensing System Research Center, Toyohashi University of Technology, 1-1 Hibarigaoka, Tempaku-cho, Toyohashi, Aichi 441-8580, Japan
$^5$JST-CREST, Kawaguchi Center Building, 4-1-8 Hon-cho, Kawaguchi, Saitama 332-0012, Japan

(Received February 27, 2006; accepted April 3, 2006)

key words: Pb(Zr,Ti)O$_3$, Al$_2$O$_3$, ultrasonic transducer on Si, piezoelectric

Ultrasonic transducers using epitaxial Pb(Zr,Ti)O$_3$ (PZT) thin films on epitaxial $\gamma$-Al$_2$O$_3$/Si substrates were successfully fabricated for the first time. The characteristics of PZT thin films on the $\gamma$-Al$_2$O$_3$/Si substrates were investigated. 240-nm-thick PZT films with various compositions were formed by the conventional sol-gel method. All PZT films were epitaxially grown on the substrates and exhibited ferroelectric and piezoelectric characteristics. Ultrasonic transducers were fabricated on the epitaxial $\gamma$-Al$_2$O$_3$(001)/Si(001) substrates with transducer element of 1 mm square. The transmission and reception characteristics of the ultrasonic transducers were observed in water by a hydrophone. Fabricated transducers can transmit and receive an ultrasonic wave with frequency of 2.5 MHz at distances of 15 and 20 mm. From these results, ultrasonic transducers with the epitaxial PZT/Pt/$\gamma$-Al$_2$O$_3$/Si structure can be applied to Si monolithic ultrasonic smart sensors.

*Corresponding author, e-mail address: akai@vbl.tut.ac.jp
**Corresponding author, e-mail address: ishida@eee.tut.ac.jp