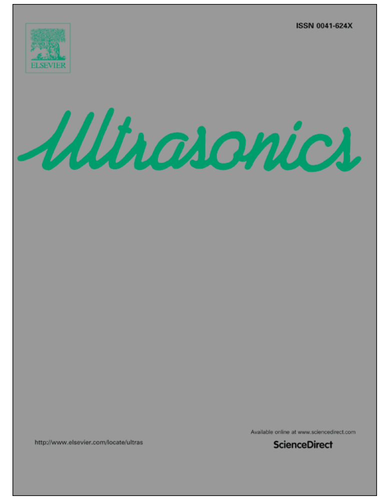
Accepted Manuscript



Picosecond ultrasonic study of surface acoustic waves on periodically patterned layered nanostructures

Michael Colletta, Wanjiru Gachuhi, Samuel A. Gartenstein, Molly M. James, Erik A. Szwed, Brian C. Daly, Weili Cui, George A. Antonelli

PII: S0041-624X(17)30818-1
DOI: https://doi.org/10.1016/j.ultras.2018.02.013
Reference: ULTRAS 5706

To appear in: *Ultrasonics*

Received Date: 28 September 2017
Revised Date: 6 February 2018
Accepted Date: 13 February 2018

Please cite this article as: M. Colletta, W. Gachuhi, S.A. Gartenstein, M.M. James, E.A. Szwed, B.C. Daly, W. Cui, G.A. Antonelli, Picosecond ultrasonic study of surface acoustic waves on periodically patterned layered nanostructures, *Ultrasonics* (2018), doi: https://doi.org/10.1016/j.ultras.2018.02.013

Picosecond ultrasonic study of surface acoustic waves on periodically patterned layered nanostructures

Michael Colletta,[a] Wanjiru Gachuhi,[a] Samuel A. Gartenstein,[a] Molly M. James,[a] Erik A. Szwed,[a] Brian C. Daly,[a†] Weili Cui,[b] George A. Antonelli,[c]

a: Vassar College, 124 Raymond Ave, Poughkeepsie, NY, USA 12604

b: SUNY Maritime College, Throggs Neck, NY, USA 10465

c: Antonelli Research and Technology, 3227 SE Lambert St, Portland, OR,USA 97202

†: corresponding author's email: brdaly@vassar.edu

Abstract:

We have used the ultrafast pump-probe technique known as picosecond ultrasonics to generate and detect surface acoustic waves on a structure consisting of nanoscale Al lines on SiO_2 on Si. We report results from ten samples with varying pitch (1000 nm to 140 nm) and SiO_2 film thickness (112 nm or 60 nm), and compare our results to an isotropic elastic calculation and a coarse-grained molecular dynamics simulation. In all cases we are able to detect and identify a Rayleigh-like surface acoustic wave with wavelength equal to the pitch of the lines and frequency in the range of 5 GHz – 24 GHz. In some samples, we are able to detect additional, higher frequency surface acoustic waves or independent modes of the Al lines with frequencies close to 50 GHz. We also describe the effects of probe beam polarization on the measurement's sensitivity to the different surface modes.

Keywords: ultrafast optics; picosecond ultrasonics; laser ultrasonics; surface acoustic waves

Introduction

The highest frequency surface acoustic waves (SAWs) have to date been generated and detected by ultrafast optical pump-probe techniques.[1,2,3,4] The most common method is to use lithography to fabricate a nanoscale pattern of metallic lines on a substrate and excite those lines by means of an ultrafast laser pulse. The rapid thermal expansion of the lines launches a SAW (often called a pseudo-SAW or leaky SAW since the presence of the pattern on the surface causes radiation of acoustic energy into the bulk) with wavelength equal to the pitch of the lines that propagates perpendicular to the lines. SAWs up to 50 GHz have been generated and detected in this manner.[5] In recent work conducted by two authors of the present article we measured SAWs or related surface vibrations in a complicated structure consisting of TiN wires of nanometer scale cross-section grown on a multilayered stack of porous and non-porous oxides on an Si wafer.[6] These unique samples yielded pitch-dependent frequencies that in some cases compared favorably with Rayleigh-like or Sezawa-like surface waves,[7,8] but in other cases corresponded to