Generation and detection of surface acoustic wave decay on an electron-beam patterned substrate with a conformal metal coating

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Surface acoustic waves (SAWs) are acoustic modes that propagate while confined within a very shallow penetration depth, enabling a broad range of applications in nondestructive material characterization, surface detection and signal processing. The generation, detection and decay of this SAWs can provide valuable information regarding the damping of the SAWs due to interactions with various nanostructures and surfaces. The use of ultrafast laser pulses to impulsively heat a sample, inducing lattice expansion so that SAWs are launched, provides a unique platform to examine SAW interference and damping by employing a pump-probe geometry. With advances in nanofabrication and lithographic patterning, the ability exists to generate and detect the SAW wave dynamics of a surface with wavelengths on the order of the periodic structure. However, the traditional approaches to create this SAW rely on patterning of small metallic (i.e., optically absorbing) features while leaving the remainder of the surface uncoated. This can lead to interference of the reflected light, leading to complications of interpreting the reflectivity associated with the acoustic wave separately from the optical response of the substrate. In this work, we described a method to generate and detect surface acoustic waves with picosecond resolution by directly patterning the SAW grating on the surface of the substrate. We used electron beam lithography to create periodic gratings on the surface of silicon with periodicities of 800 nm, 1.2 μm, and 1.6 μm. We conformally coated the surface of the patterned silicon with Al films about 80 nm thick. We used a pump-probe technique with sub-picosecond laser pulses to monitor the decay of the SAW on the surface of the sample. In this technique, the pump pulses (SAW generating) are 400 nm and the probe pulses (SAW detecting) are 800 nm. The metal film thickness is greater than the optical penetration depth of the light at these wavelengths, so all of the optical energy that is then converted into the SAW signal is absorbed within 15-20 nm of the sample surface, allowing for true nanoscale resolution of the decaying SAW into the depth of the silicon. This method of SAW generation and detection improves upon traditional material geometries and patterns by demonstrating that SAWs can be generated with conformal metals.

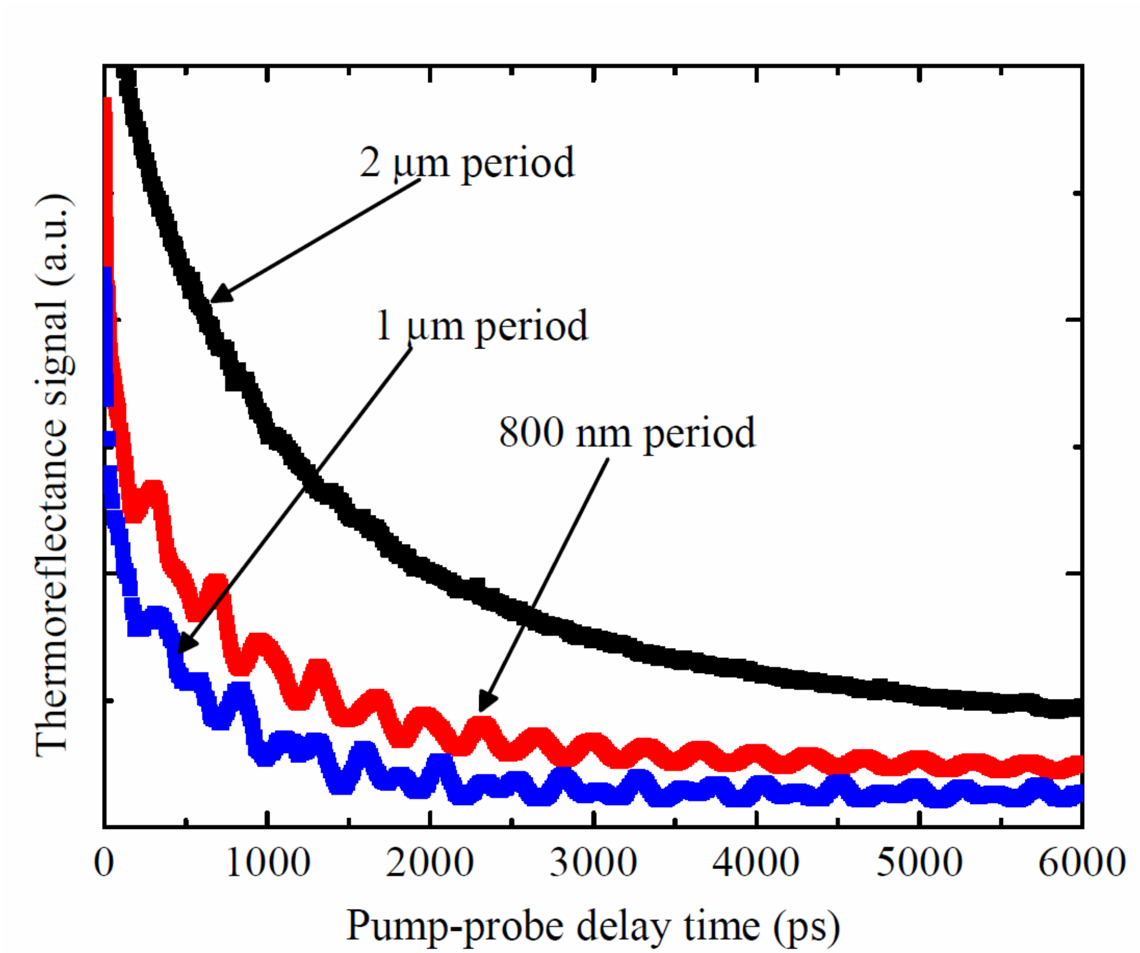

Figure 1, TDTR Data: The figure shows time dependent thermoreflectance data for Si sample grating patterns formed with electron beam lithography and dry etching. The samples are coated with 80 nm Al films. The data for the 800 nm and 1 μm period show, a periodic ringing. This indicates the generation and detection of surface acoustic waves.