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Imaging surface acoustic wave propagation on crystal spheres

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1. Introduction

Surface acoustic wave (SAW) imaging on crystals has proven to be an effective and revealing way to study effects such as dispersion, phonon focusing and refraction. The study of SAW propagation on curved surfaces, while useful in applications such as sensing, non-destructive evaluation and seismology, presents an interesting theoretical and experimental challenge[1-4]. Imaging SAWs on isotropic glass spheres has previously been achieved by observing changes in optical reflectivity caused by the photoelastic effect[5], as well as in surface displacement by interferometry[6]. Acoustic wave propagation on crystal spheres, on the other hand, is not yet well understood because of its much greater complexity. Imaging acoustic waves on such spheres offers the possibility of new insights into crystal wave propagation.

In this work we present time-domain finite element simulations of surface acoustic waves on single-crystal spheres, and compare the results with spatio-temporal imaging experiments.

2. Simulation and experiment

We performed 3D numerical simulations of SAW propagation on single-crystal spheres of silicon, sapphire and quartz with different orientations and sizes. The excitation source was chosen to model experimental conditions for surface wave imaging at GHz frequencies, which consist of thermoelastic heating by picosecond laser pulses that generate a broadband acoustic spectrum up to 1 GHz. From the simulated time-resolved output we extract the out-of-plane surface displacements at each point on the sphere surface.

Figure 1 shows an example of a simulation of surface acoustic wave propagation on a silicon crystal sphere. For this simulation we modelled a 120 µm diameter sphere oriented with the excitation point coinciding with the [110] crystal axis. The figure shows a shapshot of the projection onto the *x*-*y* plane of the out-of-plane surface displacement 47 ns after the arrival of the excitation pulse on the reverse side of the sphere. It is apperent that the anisotropy of the crystal structure has a strong influence on the propagation pattern, in this case

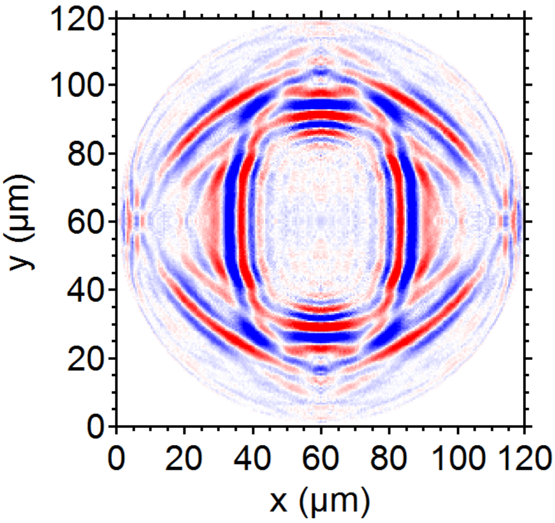

Fig. 1 Simulation of surface acoustic waves propagating on a 120 µm diameter silicon crystal sphere after excitation at a 2-fold symmetry point: projection onto the *x*-*y* plane at time t = 47 ns.

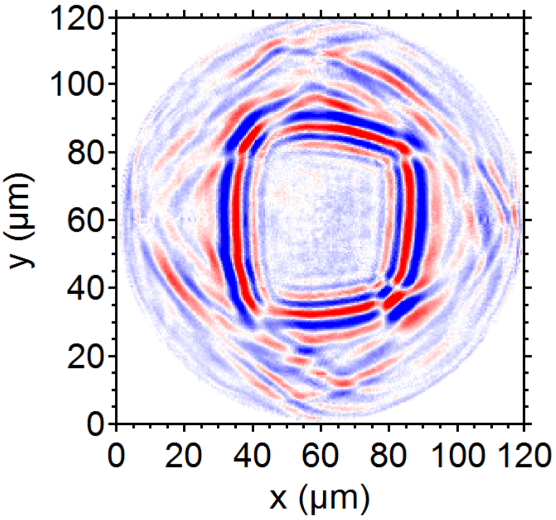

Fig. 2 Simulation of surface acoustic waves propagating on a 120 µm diameter silicon crystal sphere after excitation at an off-symmetry point: projection onto the *x*-*y* plane at time t = 47 ns.

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exhibiting 2-fold symmetry. Figure 2 shows the result of the excitation at an off-symmetry point, with the acoustic pattern also proving to be asymmetric.

Supporting experimental results of a 1 mm diameter silicon single-crystal silicon sphere using an optical pump-probe set-up are also presented. We compare the results using Fourier analysis, with which we are able to visualize the propagation at fixed frequencies and also to extract the acoustic surface-wave dispersion relation.

3. Conclusion

In this work we demonstrate real-time imaging of SAW propagation on crystalline spheres using numerical simulations and experiments. Results on different spheres with different structures and orientations show complex variations in the acoustic wave propagation, which reflect the underlying symmetry involved. The results should lead to a deeper understanding of the physics of SAW dispersion and propagation on curved crystalline surfaces.

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