Detection of coherent acoustic phonons in thin gold films by surface plasmon resonance

Noll F[(1,2)*], Krauß N[(2)], Gusev V[(3)], Dekorsy T[(2,4)], Hettich M[(1,2)]

(1) Research Center For Non-Destructive Testing GmbH (RECENDT), Altenberger Straße 69, Linz, Austria
(2) Department of Physics, University of Konstanz, 78464 Konstanz, Germany
(3) Laboratoire d'Acoustique de l'Université du Mans (LAUM), UMR 6613, Institut d'Acoustique - Graduate
(4) German Aerospace Center, Institute of Technical Physics, Pfaffenwaldring 38-40, 70569 Stuttgart, Germany

*Corresponding author's email: felix.noll@recendt.at

Background – Elastic properties of thin metal films have been investigated in detail by optical pump-probe methods that detect changes in the reflectivity of the material due to mechanical strain. However, for measurements based on photoelastically induced changes in reflectivity, the small signals often pose a significant challenge. Detection in surface plasmon resonance (SPR), which is highly sensitive to changes in the metal dielectric function, has been used to substantially increase the signal to noise ratio [1]. This method further allows for the separation of the real and imaginary part of the temporal dynamics in the materials permittivity [2]. Here, we use a combination of asynchronous optical sampling and detection in SPR geometry to further investigate the potential applications in picosecond ultrasonics.

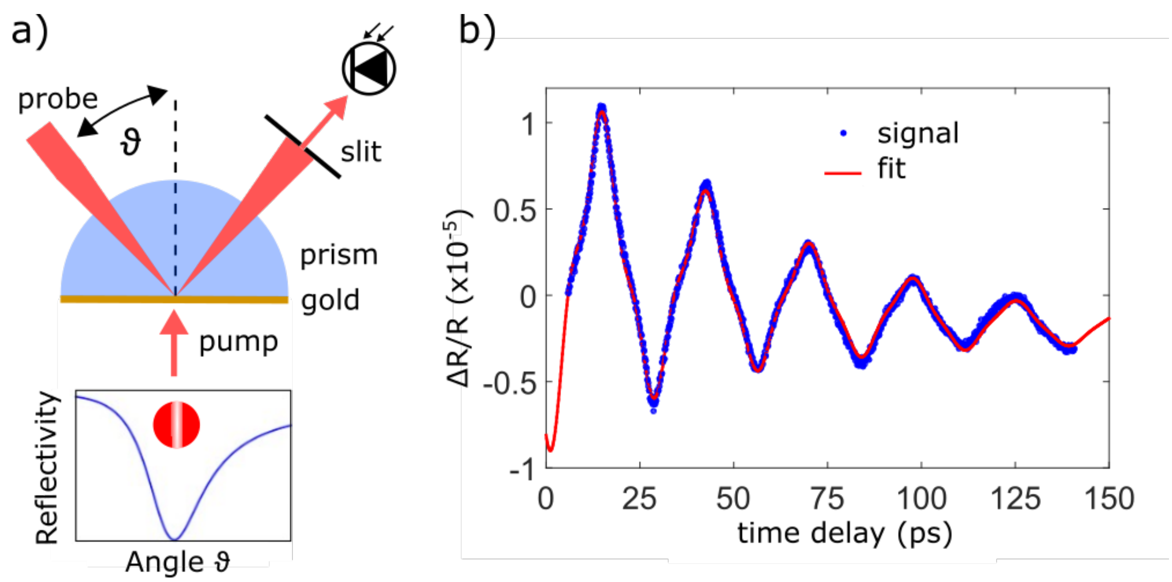

Fig. 1. a) Setup with SPR resonance curve and beam cross section b) Time domain signal of coherent longitudinal phonons

Methods – The principle of the measurements is depicted in Fig. 1. Thin gold films in the range of 30 to 50 nm are evaporated on a glass prism. The coherent acoustic phonon dynamics are optically excited from the air side and detected in Kretschmann configuration, i.e., from the glass side under SPR conditions. A slit is used to select an angle interval for detection. Coherent acoustic phonons in the gold film lead to changes in the plasmon resonance. By measuring at different positions of the SPR curve, i.e., at different angles, the dependence of the plasmon resonance on the real and imaginary part of the permittivity can be used to separate the respective contributions.

Results – We observe Eigenmodes of the thickness oscillation up to the 7^{th} harmonic. Through comparison of the lifetime of the first and third harmonic we can eliminate the influence of the dominant damping mechanism of transmission to the substrate and access the material intrinsic damping. Further, angle resolved measurements show a high sensitivity of the signal amplitude to changes in the real part of the dielectric function, indicating that the coherent acoustic phonons have only negligible influence on the imaginary part of the dielectric permittivity.

Conclusions – A highly sensitive approach to the detection of acoustic phonons in thin metal films is demonstrated. We find increased damping for higher order thickness modes which indicates the influence of intrinsic damping mechanisms. Further, we find the coherent acoustic phonons to mostly alter the real part of the dielectric permittivity with no detectable influence on the imaginary part. With improvements, this method could yield absolute values of the change in dielectric permittivity through mechanical strain.

References

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