cillations, seen in the inset at Fig. 9. Since the small sampling rate (determined by the long integration time of the capacitance bridge) the high frequency predictions of the Fourier transform analysis is unreliable.

Magnetostriction measurements were also performed on a single crystal of $PtSn_4$ at 4.2 K as shown in Fig. 11 [11]. These experiments were compared with ab-initio simulations of the Fermi surface and showed excellent agreement with experiment, which confirms magnetostriction measurements as a powerful tool for measuring dHvA quantum oscillations.

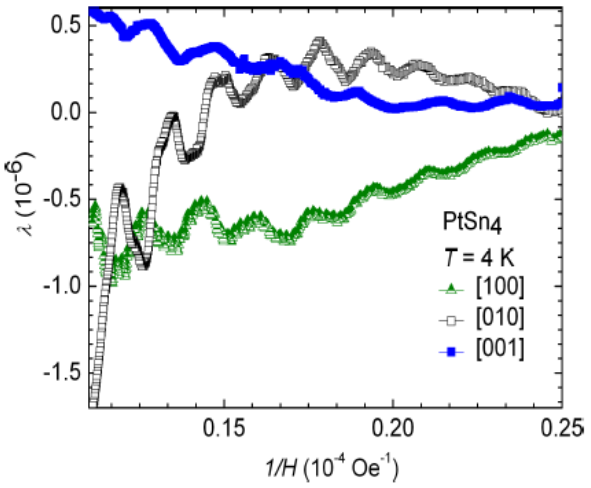

Fig. 11. Change in linear unit cell parameter ($\lambda = \Delta l / l$) of $PtSn_4$ with changing magnetic field along the three crystallographic directions - the small amplitude of $\lambda(1/H)$ is attributed to the diamagnetic nature of the sample [11].

4 CONCLUSIONS

Dynamic magnetostriction measurements on soft magnetic materials are presented. The effect of residual stress caused by plastic deformation on the $\lambda(H)$ curve is good visible and can be explained by a stress induced texture. A basic problem is here the stress induced rearrangement of the domains which affects the absolute value of the magnetostriction as calculated by $\lambda_{diff} = const \cdot (\lambda_{\parallel} - \lambda_{\perp})$.

The losses as determined from frequency dependent hysteresis measurements can be correlated with the hysteresis area as obtained from magnetostriction measurements. As proportionality factor an expression containing the Youngs modulus E respectively the internal stresses σ_i was obtained.

Quantum oscillations on a polycrystalline sample of Al are shown by measuring the magnetostriction with a high sensitivity in fields up to 9 T. The magnetoelastic oscillations agree well with classical dHvA results as well as with theoretical calculations. Similar oscillations were observed in a $PtSn_4$ single crystal. Also here the data agree with classical dHvA magnetization measurements as well as with theoretical calculations.

REFERENCES

[1] J. E. Goldman, *Magnetostriction of annealed and cold worked nickel rods*, Phys. Rev. **72**(6), 529-530 (1947).
[2] M. Zehetbauer, R. Grössinger, H. Krenn, M. Krystian, R. Pippan, P. Rogl, T. Waitz, R. Würschum, *Bulk Nanostructured Functional Materials by Severe Plastic Deformation*, Adv. Eng. Mat. **12**(8), 692-700 (2010).
[3] Stefan Hartl, *Magnetic properties of deformed Electrical Steel*, Master-thesis, TU Vienna (2014).
[4] Stephan Sorta, *Magnetostriktionsmessungen bei Raumtemperatur*, Master-thesis, TU Vienna (2014).
[5] E. W. Lee, *Magnetostriction and magnetomechanical effects*, Rep. Prog. Phys. **18**(1), 184-229 (1955).
[6] G. Bertotti, *Hysteresis in Magnetism: For Physicists, Materials Scientists, and Engineers*, Academic Press, San Diego (1998).
[7] M. Rotter, H. Müller, E. Gratz, M. Doerr, M. Loewenhaupt; *A miniature capacitance dilatometer for thermal expansion and magnetostriction*, Rev. Sci. Instrum. **69**(7), 2742-2746 (1998).
[8] G. K. White, J. G. Collins, *Thermal expansion of copper, silver, and gold at low temperatures*, J. Low Temp. Phys. **7**(1-2), 43-75 (1972).
[9] E. M. Gunnersen, *The de Haas - van Alphen Effect in Aluminium*, Philos. Trans. R. Soc. London, Ser. A **249**(965), 299-320 (1957).
[10] C. O. Larson, W. L. Gordon, *Low-Field de Haas - van Alphen Study of the Fermi Surface of Aluminum*, Phys. Rev. **156**(3), 703-715 (1967).
[11] M. Inamdar, M. Kriegisch, L. Shafeek, A. Sidorenko, H. Müller, A. Prokofiev, P. Blaha, S. Paschen, *Quantum oscillations in ultra pure PtSn4*, Solid State Phenom. **194,** 88-91 (2013).

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