Accepted as oral presentation at the 11th International Conference on Solid-State Sensors and Actuators, June 10-14, 2001, Munich, Germany

# THE TEMPERATURE-STABLE PIEZOELECTRIC MATERIAL $GaPO_4$ AND ITS SENSOR APPLICATIONS

Topic: Materials and Technology

P.M. Worsch, P.W. Krempl, C. Reiter, H. Thanner and W. Wallnöfer
AVL List GmbH, Hans List Platz 1, A-8020 Graz, Austria

An overview of the physical properties of gallium orthophosphate, $GaPO_4$, and their relevance for present and future technical applications is given. The high sensitivity and high thermal stability of this piezoelectric crystal make it a very attractive choice for a wide range of uncooled high temperature applications up to temperatures above 900 °C.

$GaPO_4$ belongs to the same point group as quartz, therefore the lack of pyroelectricity guarantees that temperature changes do not cause interference to the sensor signal. Moreover there exists no quartz-like α-β phase transition, so it does not change its high piezoelectric sensitivity under high stress. The crystal lattice is stable and the piezoelectric coefficient remains at a high level up to a reconstructive phase transition at 970 °C [1].

Up to 700 °C, the piezoelectric constant $d_{11}$ shows no measurable deviation from its room temperature value which is about twice that of quartz (Fig.1). Since also the insulation resistance is similar to that of quartz, this allows precise measurements with uncooled pressure transducers for combustion engines [2], gas turbines and injection molding machines, as well as accelerometers, force sensors and ultrasonic transducers at high temperatures.

For the new generation of crystal microbalances [3] and other sensors based on thickness shear resonators such as viscometers, biosensors and gas sensors, a good temperature compensation is necessary. We show that $GaPO_4$ meets these requirements, since for any operating temperature in the stability range a temperature-compensated cut can be given (Fig.2) including an orientation with very flat cubic behaviour in the range 350 °C - 650 °C. These cuts have a higher coupling than quartz [4],[5] as well as a higher sensitivity due to the lower damping in fluids.

For surface acoustic wave applications the high coupling and the very low temperature dependence of frequency or delay time, which make $GaPO_4$ attractive for filter applications [6] also allow the development of sensors with lower insertion loss and excellent temperature stability up to very high temperatures.

Submitting author: Peter M. Worsch, AVL List GmbH, Hans List Platz 1, A-8020 Graz, phone:+43 (0)316 787 533, fax:+43 (0)316 787 591, peter.worsch@avl.com

## REFERENCES

[1] P.W. Krempl, F. Krispel, W. Wallnöfer, "Industrial development and prospects of $GaPO_4$", Ann. Chim. Sci. Mat. 22 (1997) 623-626.

[2] www.gapo4.com

[3] H. Thanner, P.W. Krempl and P.M. Worsch, "$GaPO_4$ high temperature crystal microbalance with zero temperature coefficient", this meeting.

[4] J. Detaint, B. Capelle, O. Cambon and E. Philippot, "Properties of AT cut gallium phosphate resonators", 2000 Frequency Control Symposium, Kansas City, MO, USA, June 7-9 (2000)

[5] C. Reiter, H. Thanner, W. Wallnöfer, P.W. Krempl, "Material Properties of $GaPO_4$ and their relevance for applications", EWPM Montpellier (2000); to be published

[6] M. Solal, "Material aspects of SAW filter design for future mobile radio applications", EWPM Montpellier (2000); to be published

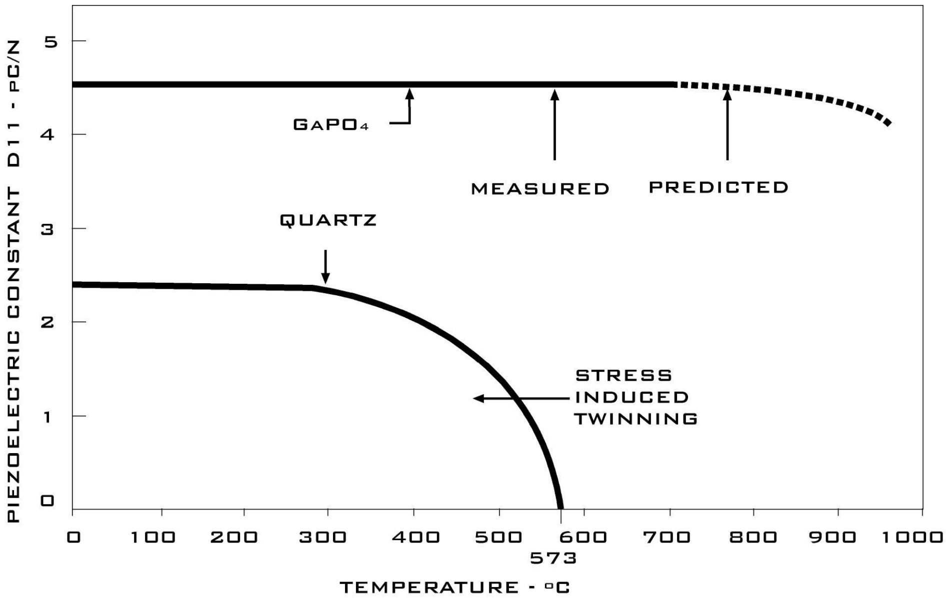


Figure 1: Comparison of the temperature dependence of the piezoelectric constant $d_{11}$ in $GaPO_4$ and in quartz

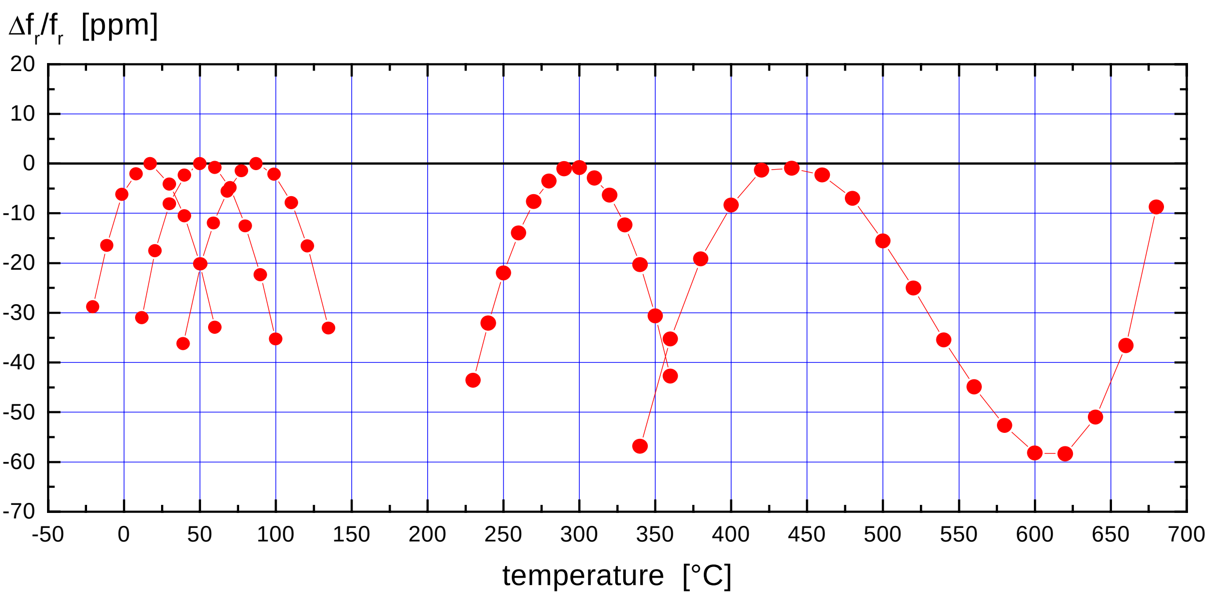


Figure 2: Temperature compensation in $GaPO_4$ thickness shear resonators