

Thermal expansion of Si_3N_4 and Ge_3N_4

Roman Minikayev¹, Wojciech Paszkowicz^{1,4}, Paweł Piszora², Michael Knapp³, Carsten Baetz³

1. Polish Academy of Sciences, Institute of Physics, al. Lotników 32/46, Warszawa 02-668, Poland **2.** Adam Mickiewicz University, Faculty of Chemistry, Grunwaldzka 6, Poznań 60-780, Poland **3.** Technische Universität Darmstadt, Institute of Materials Science, Petersenstr. 23, Darmstadt 64287, Germany

e-mail: paszk@ifpan.edu.pl

Si_3N_4 and Ge_3N_4 belong to a family of nonoxide ceramics. They exhibit unique physico-chemical and mechanical properties making them suitable for various applications. Si_3N_4 exhibits superior thermomechanical and physicochemical properties such as oxidation and thermal shock resistance, mechanical fatigue, creep and wear resistance, high fracture toughness, it is chemically inert and hydrophobic. Ge_3N_4 is known to be thermally stable and resistant to oxidation, its photocatalytic behavior has been reported. Their applications include the use for surface protection [1] (both compounds), in engine components and turbochargers, bearings, metal cutting and shaping tools and hot metal handling [2], interlayer dielectrics for metal-insulator-semiconductors devices, metal-nitride-oxide-semiconductors and as passivation films or diffusion masks [3] (Si_3N_4), in photodiodes, amplifiers [1], metal-insulator-semiconductor field effect transistors (MIS FET) [4], waveguides [5] Li-ion batteries [6], and as photocatalysts [7] (Ge_3N_4).

In the present study, thermal expansion of Si_3N_4 and Ge_3N_4 polymorphs is experimentally determined and discussed on the basis of literature data. Two Si_3N_4 samples and one Ge_3N_4 sample (ALDRICH) were studied.

The study was performed under low- and high-temperature conditions by X-ray diffraction, at a synchrotron-radiation source. The diffraction studies were carried out at a powder diffractometer [8] at the B2 (Hasylab/DESY) bending-magnet beamline, using the Debye-Scherrer geometry. An imaging-plate detector was applied for the data collection. The Rietveld-refinement program Fullprof 2.k (v 2.7) [9] was used for the structural analysis. The quantitative analysis yielded the following proportions of α and β polymorphs in the samples: 92:8, 9:91 (samples of Si_3N_4) and 27:73 (sample of Ge_3N_4). The temperature variation of lattice parameters, atomic positions and thermal expansion of α and β nitride show smooth trends. It is concluded that despite the fact that each samples was built from two phases, a combination of applied experimental conditions with the careful analysis using the Rietveld method leads to acceptable values of thermal expansion in the broad temperature range studied.

References

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