Reactive field assisted sintering of YAG ceramics

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Introduction

YAG and its production via FAST/SPS

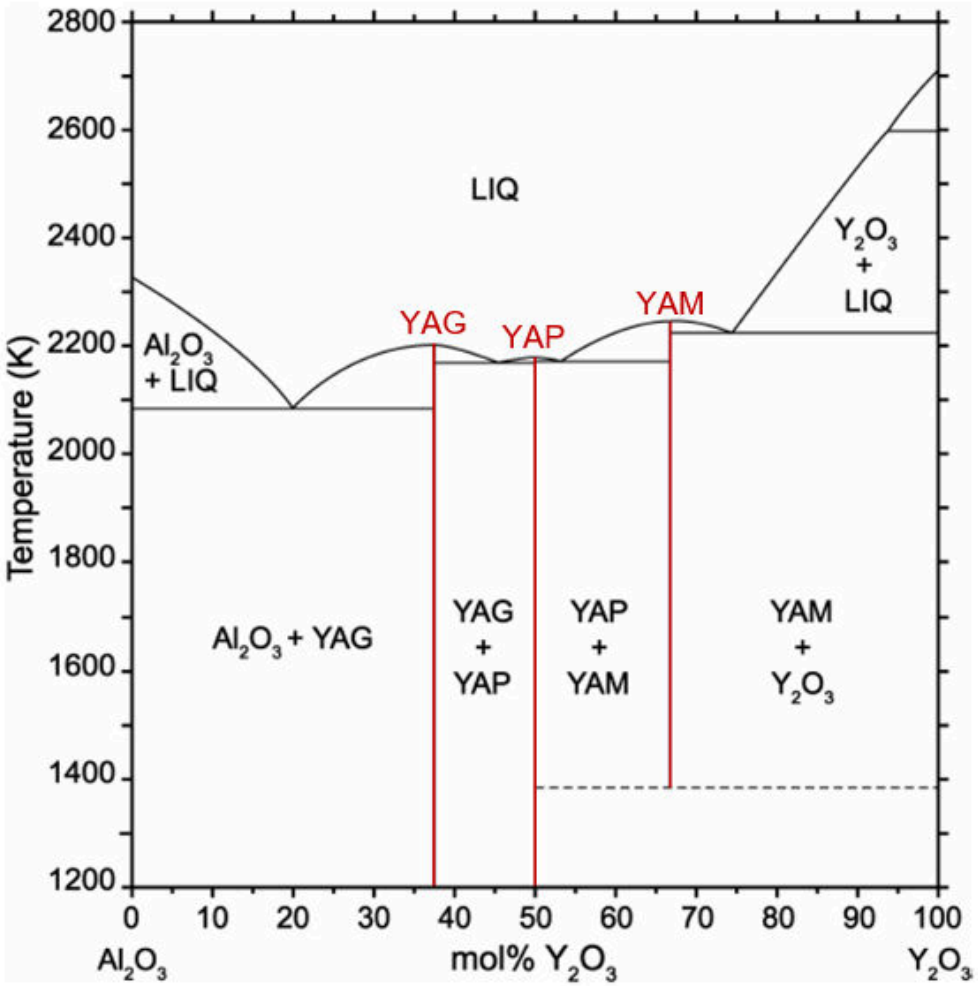
Yttrium aluminum garnet (YAG):

- Chemical formula: $Y_3Al_5O_{12}$
- Line compound in Al_2O_3-Y_2O_3 system
- High thermal, mechanical and chemical resistance

Production of YAG:

- Conventionally with solid-state-reactions
- Field assisted sintering technology / Spark plasma sintering (FAST/SPS) advantageous
  - ↳ Advantages: Lower sintering temperatures, shorter processing times, high heating rates

Al_2O_3-Y_2O_3 system



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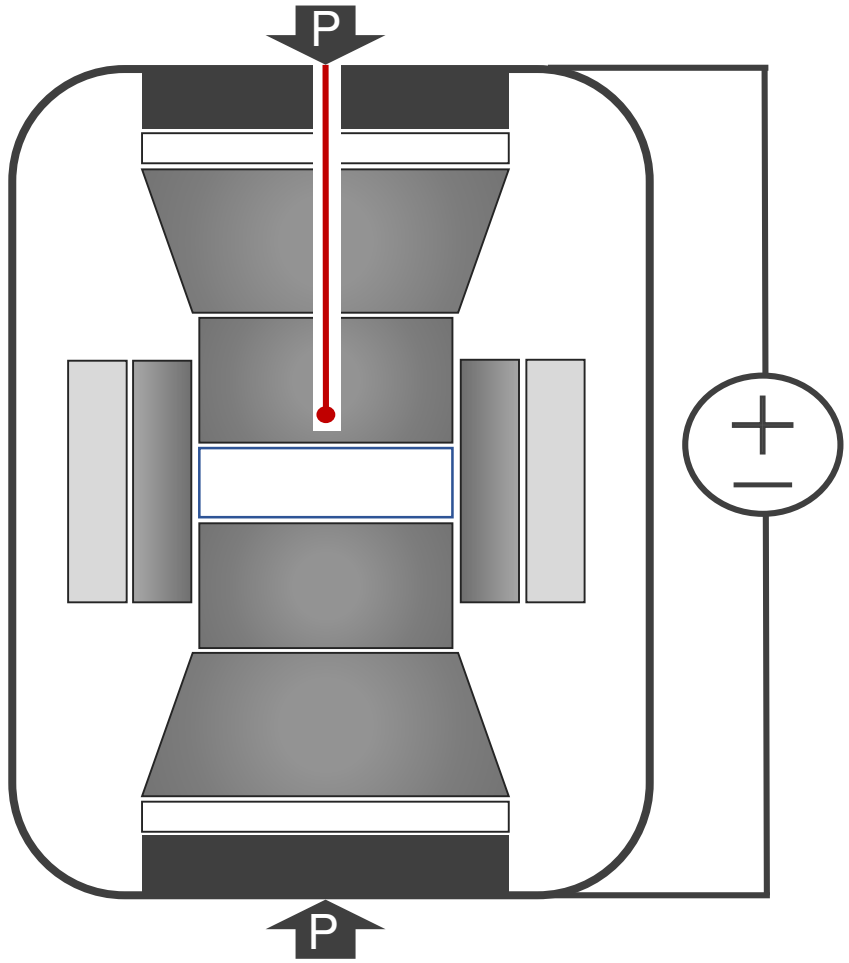
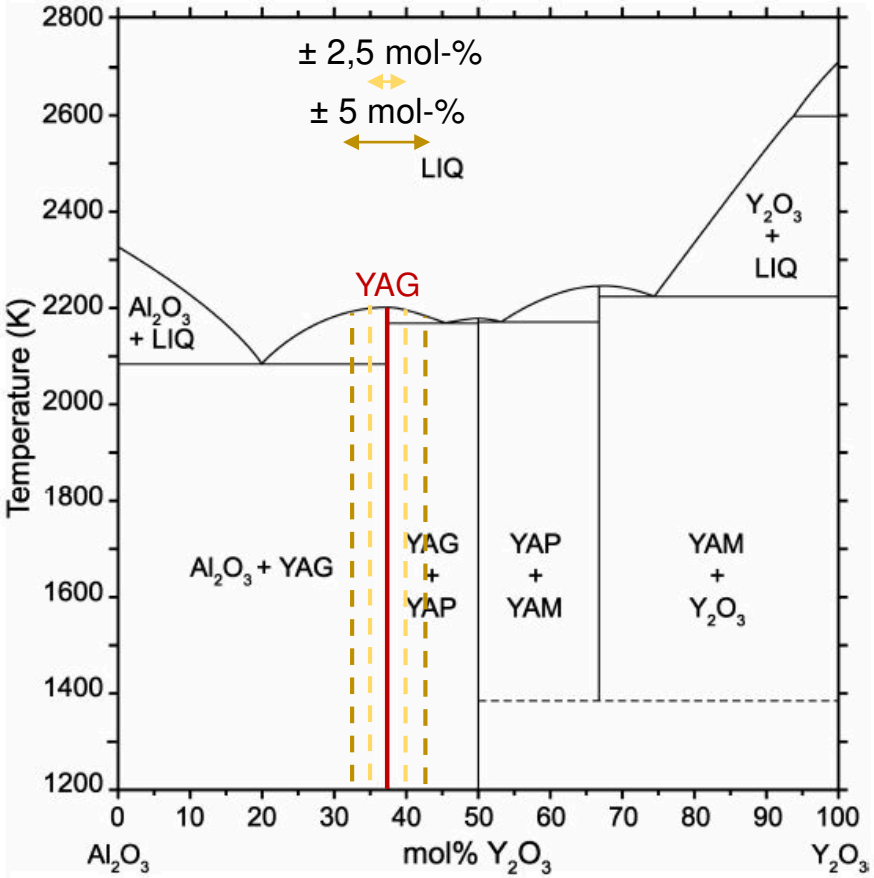
Schematic of FAST/SPS apparatus (P ≙ pressure)



Adapted from: O. Guillon, J. Gonzalez-Julian, B. Dargatz, T. Kessel, G. Schierning, J. Räthel und M. Herrmann, „Field-Assisted Sintering Technology/Spark Plasma Sintering: Mechanisms, Materials, and Technology Developments," Advanced Engineering Materials, vol. 16, no. 7, pp. 830-849, 2014

Motivation and objectives



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Motivation:

- Difficult to avoid formation of secondary phases during processing of YAG

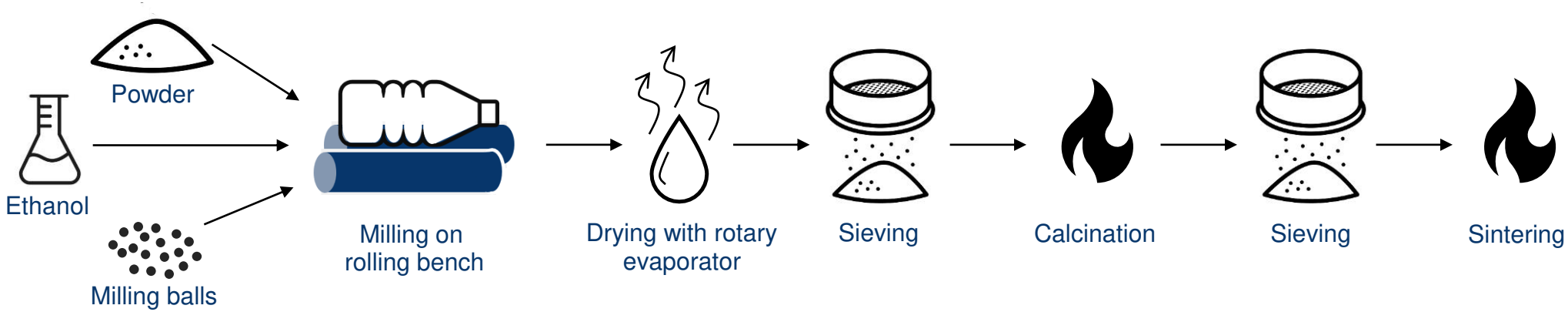
  ↳ How do they influence the material?

Main objectives:

- Prepare stoichiometric and non-stoichiometric YAG samples via FAST/SPS
- Investigation of phase formation: Influence on the microstructure

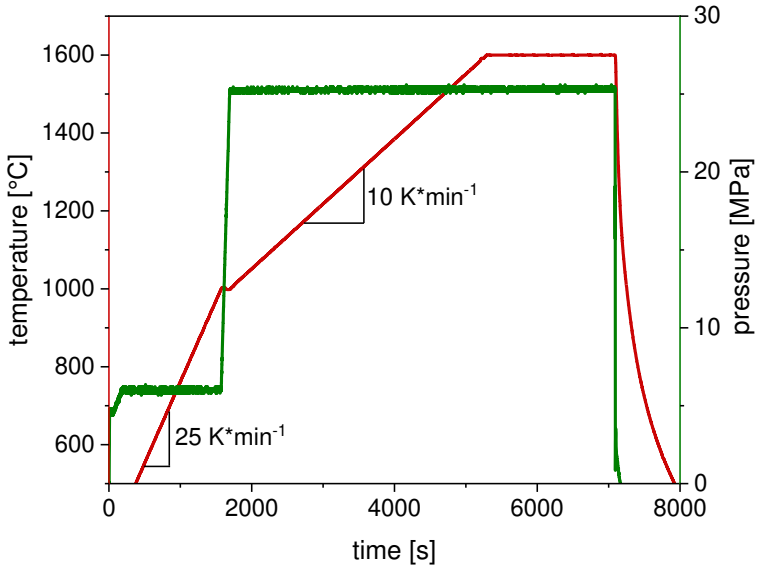
Methodology

Powder processing



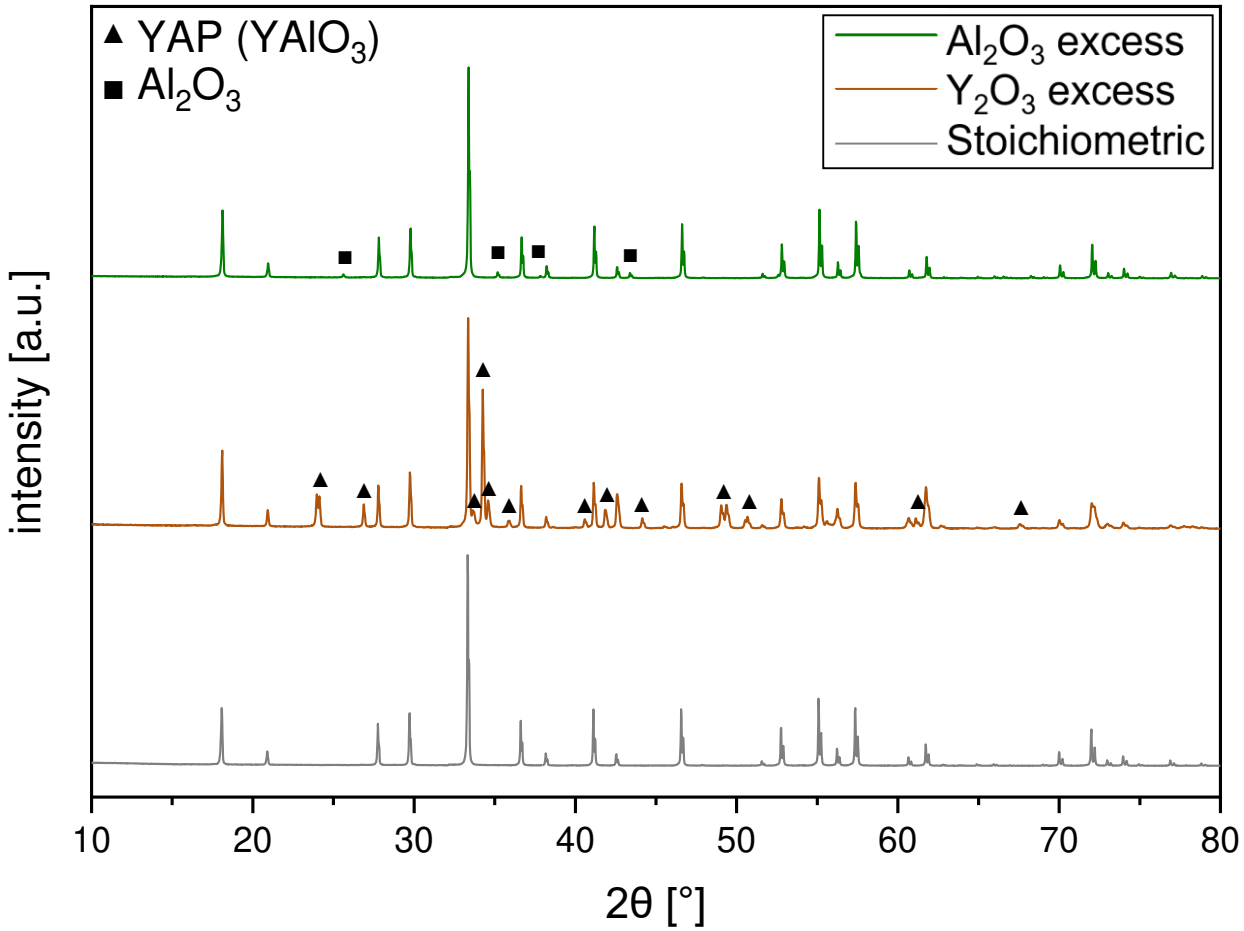
FAST/SPS parameters

- Room temperature to 1000 °C (5 MPa)
- 1000 °C to 1600 °C (25 MPa)
- Dwell at 1600 °C (30 min, 25 MPa)
- Cooling to RT by turning off the system



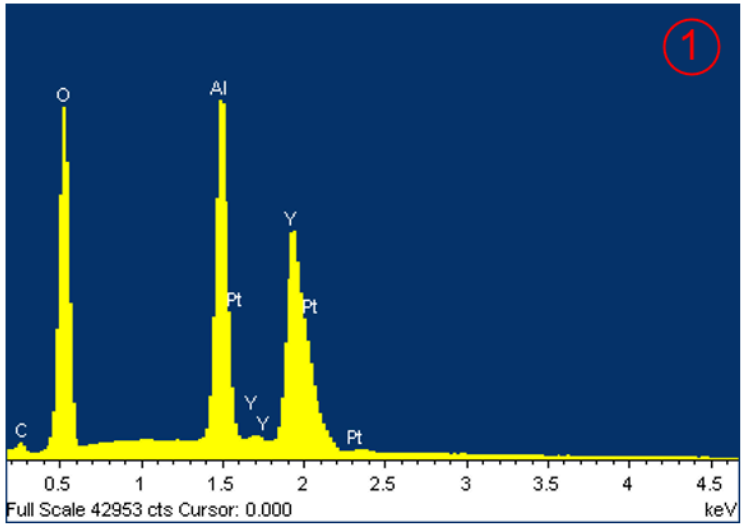
XRD-Analysis

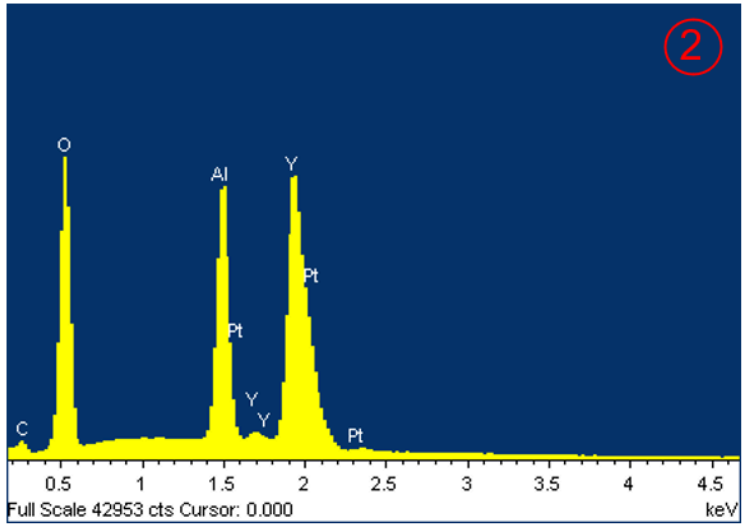
Sintered samples (1600 °C, 25 MPa, dwell: 30 min)



SEM-EDS of the sintered samples

Y_2O_3 excess (+ 5 mol-%)

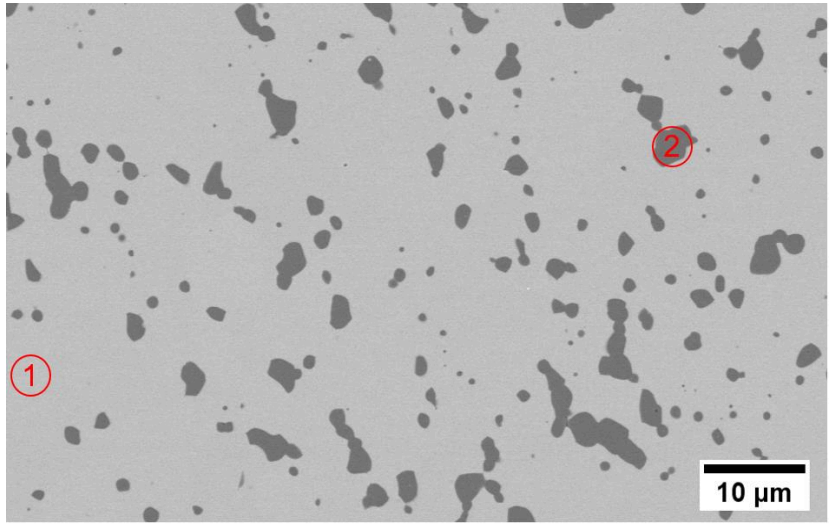


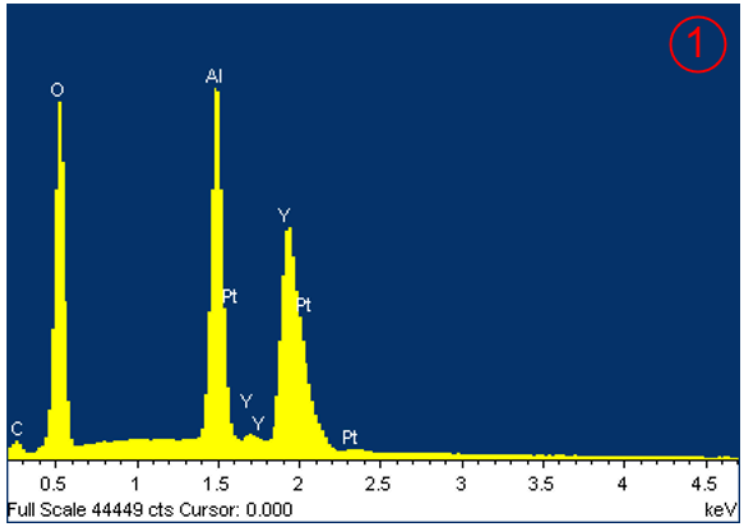


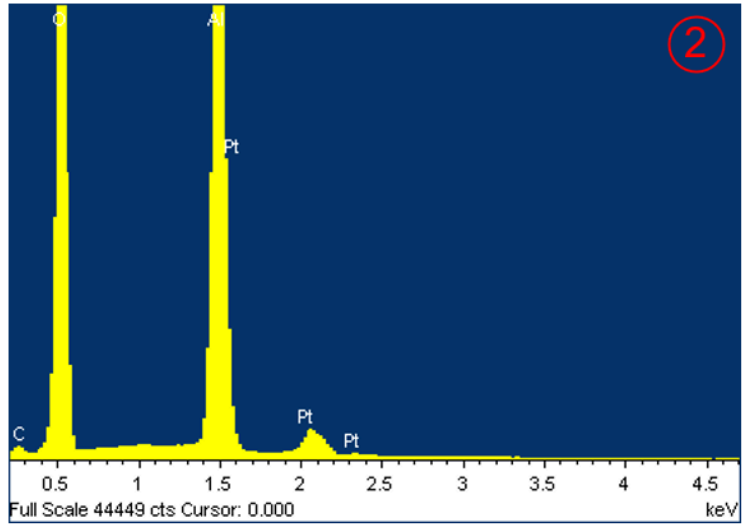
- According to XRD results, the secondary phase is YAP ($YAlO_3$)
- Spectrum (2): Lower Al intensity and higher Y intensity compared to YAG matrix spectrum (1)
- Calculated content of YAP-Phase from SEM images: 37 % (Rietveld: 41 %)

SEM-EDS of the sintered samples

Al_2O_3 excess (+ 5 mol-%)







- According to XRD results, the secondary phase is Al_2O_3
- Spectrum (2): Higher Al/O intensity compared to YAG matrix spectrum (1), Y was not detected
- Calculated content of Al_2O_3-Phase from SEM images: 14 % (Rietveld: 10 %)

Conclusion

- FAST/SPS enables the production of dense samples with only isolated pores in the microstructure
- Higher secondary phase content obtained with Y_2O_3 excess than with the same deviation from the stoichiometric ratio in Al_2O_3 rich direction
- Secondary phases: Y_2O_3 excess leads to formation of YAP ($YAlO_3$), Al_2O_3 excess leads to formation of Al_2O_3

Outlook

- **Change in FAST/SPS parameters**: Investigate the influence on the microstructure and formation of secondary phases in samples with deviation from the stoichiometric YAG ratio
- **Nanoindentation**: Investigate the hardness of the secondary phase