# Fundamental investigation of the technological research on the reaction sintering of MgAlON at 1500 °C from $Al_2O_3$, MgO and AlN

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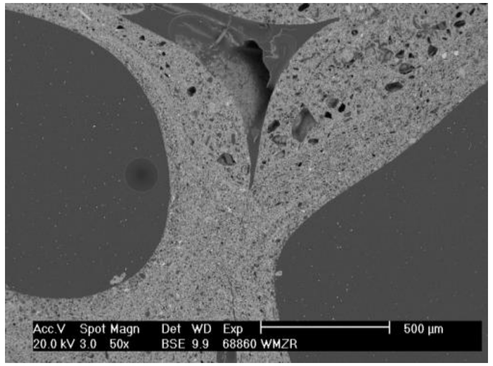


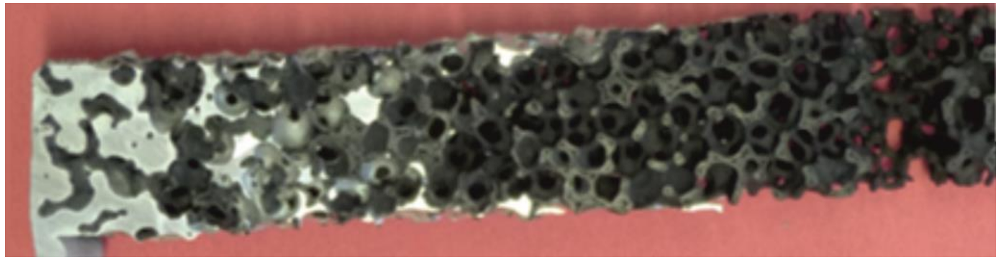

2nd International Virtual Conference on Materials Science & Engineering, September 23-24, 2022

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*MDPI "Crystals"*
*Special Issue "High-Tech Metals – Overview, Microstructure, Properties and Recyclability"*

# 1. Aim of the Fundamental Investigation of MgAlON

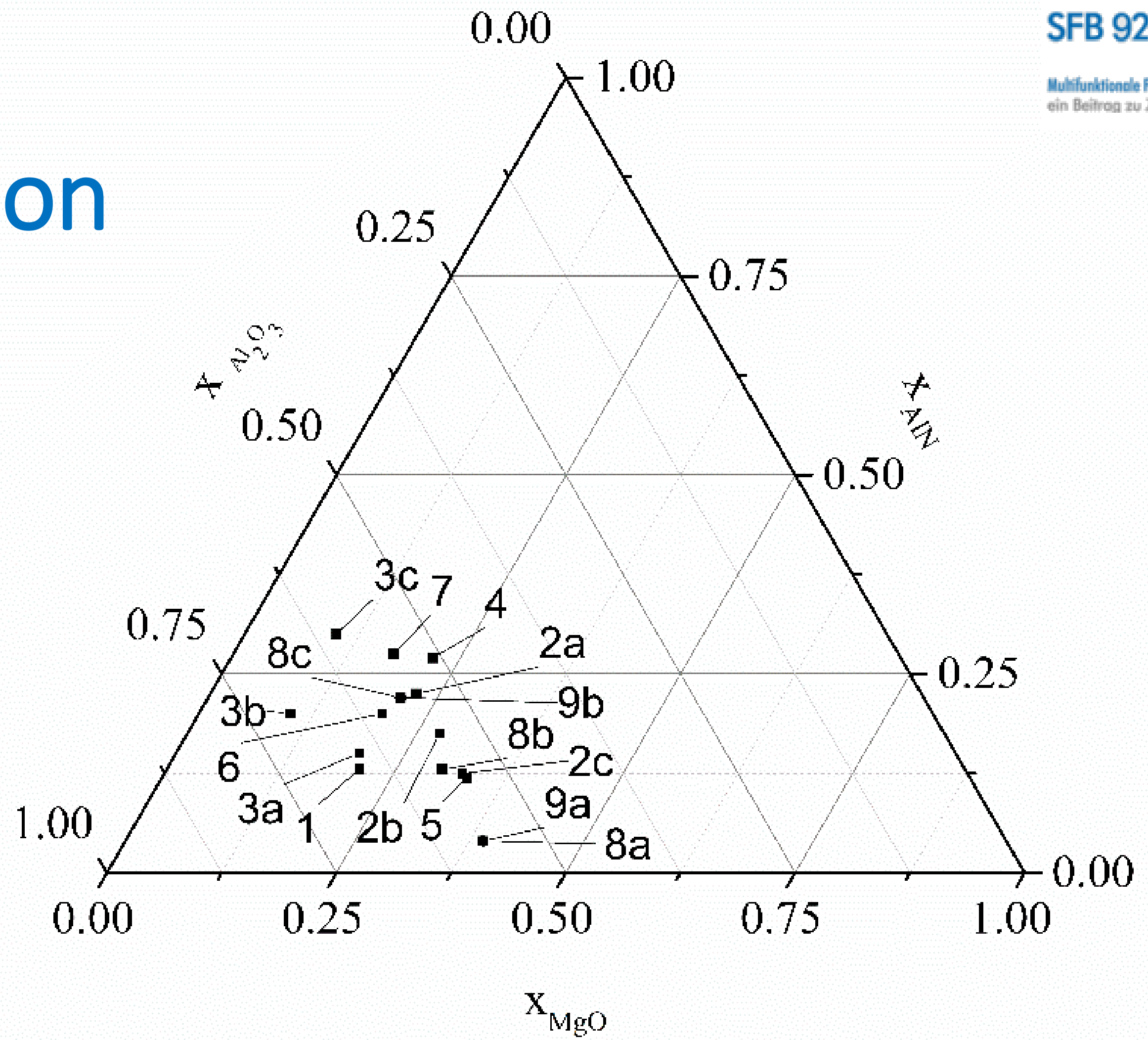
Ceramic Foam Filters => Purification of metal melts,
especially for Magnesium as a light-weight material

Coating Material for Ceramic Foam Filters = MgAlON

Investigation of the technological synthesis of MgAlON at 1500°C in nitrogen atmosphere

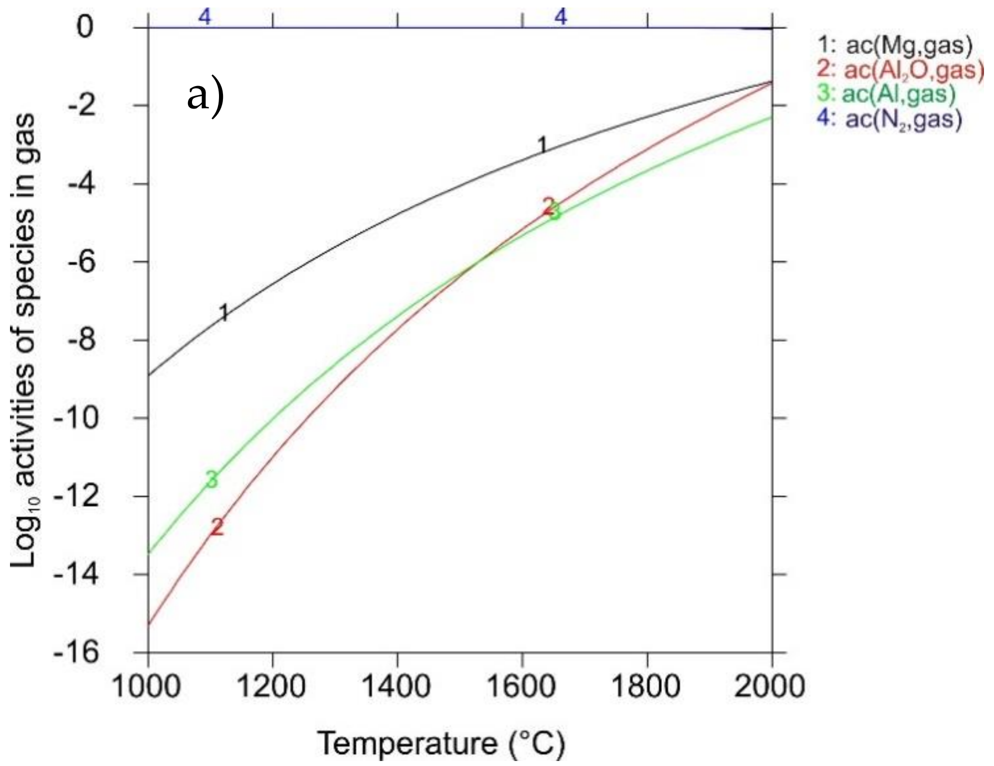
# 2. Starting Composition

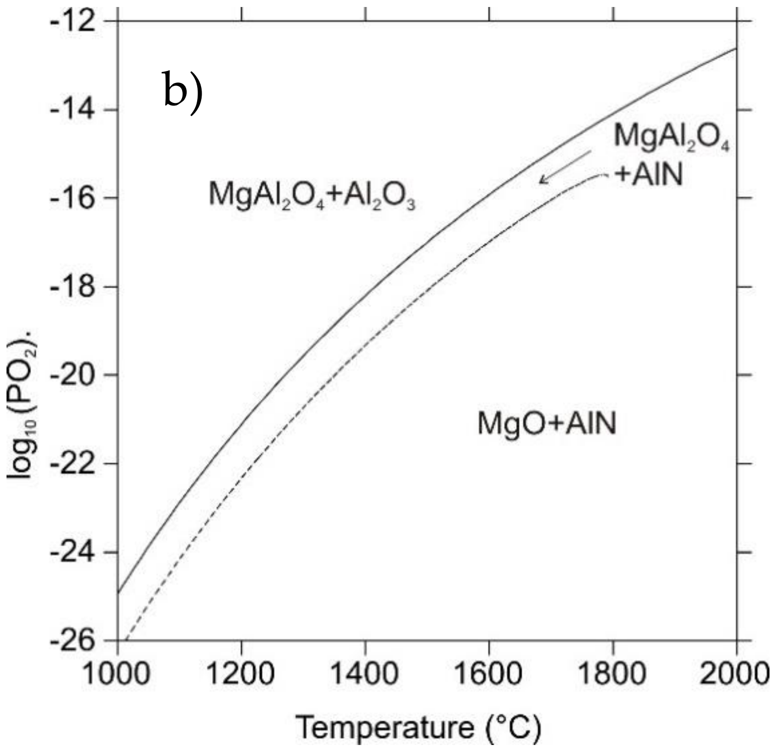
- Samples in the ternary system $Al_2O_3$ - MgO - AlN




Schramm, A., Thümmler, M. Fabrichnaya, O., Brehm, S., Kraus, J., Kortus, J., Rafaja, D., Scharf, C., Aneziris, C. G.: Reaction Sintering of MgAlON at 1500 °C from $Al_2O_3$, MgO and AlN and Its Wettability by AlSi7Mg, Crystals 2022, 12, 654. https://doi.org/10.3390/cryst12050654

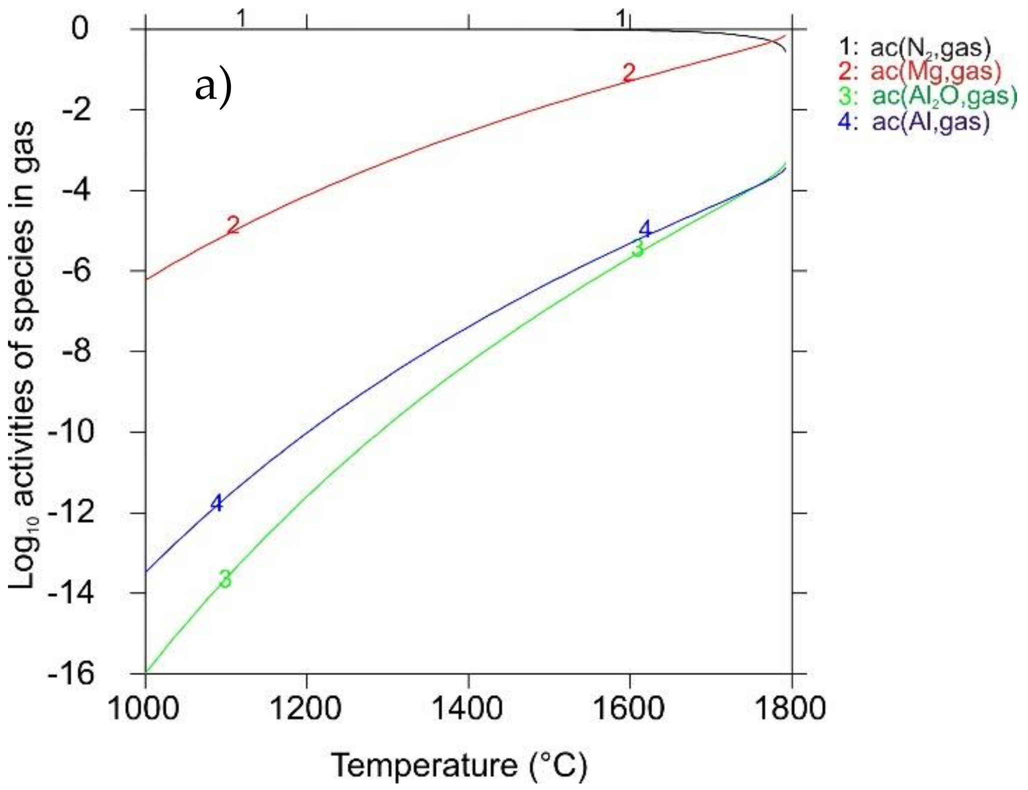
# 3. Theoretical and thermodynamic consideration

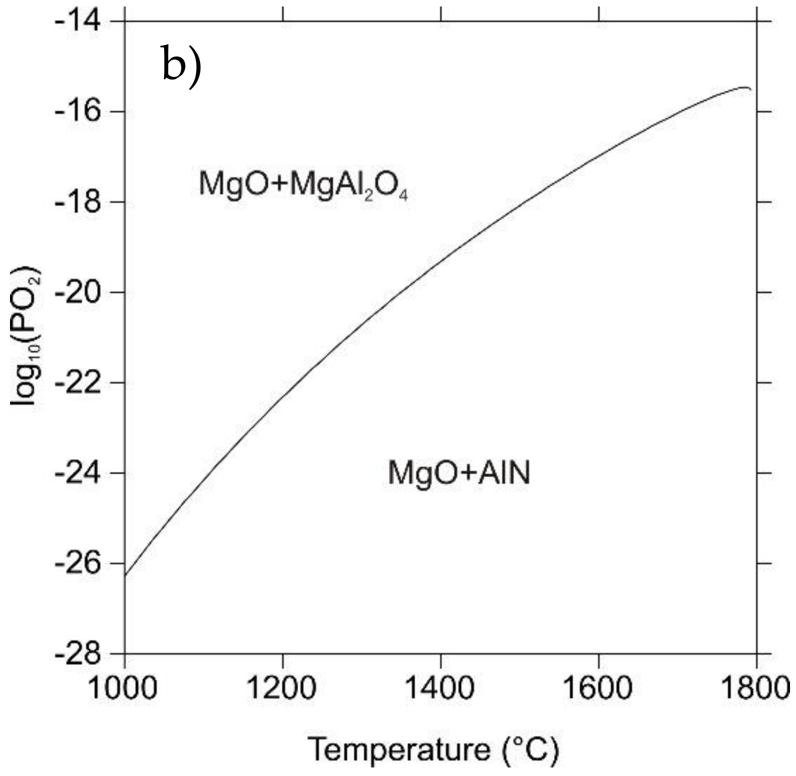



Equilibrium of $MgAl_2O_4$ with $Al_2O_3$ and AlN in presence of gas as a function of temperature:
(a) activities of gas species;
(b) partial pressure of oxygen, the dashed line shows the stability limit of $MgAl_2O_4$.

# 3. Theoretical and thermodynamic consideration




Equilibrium of $MgAl_2O_4$ with MgO and AlN in presence of gas as a function of temperature: (a) activities of gas species; (b) partial pressure of oxygen.

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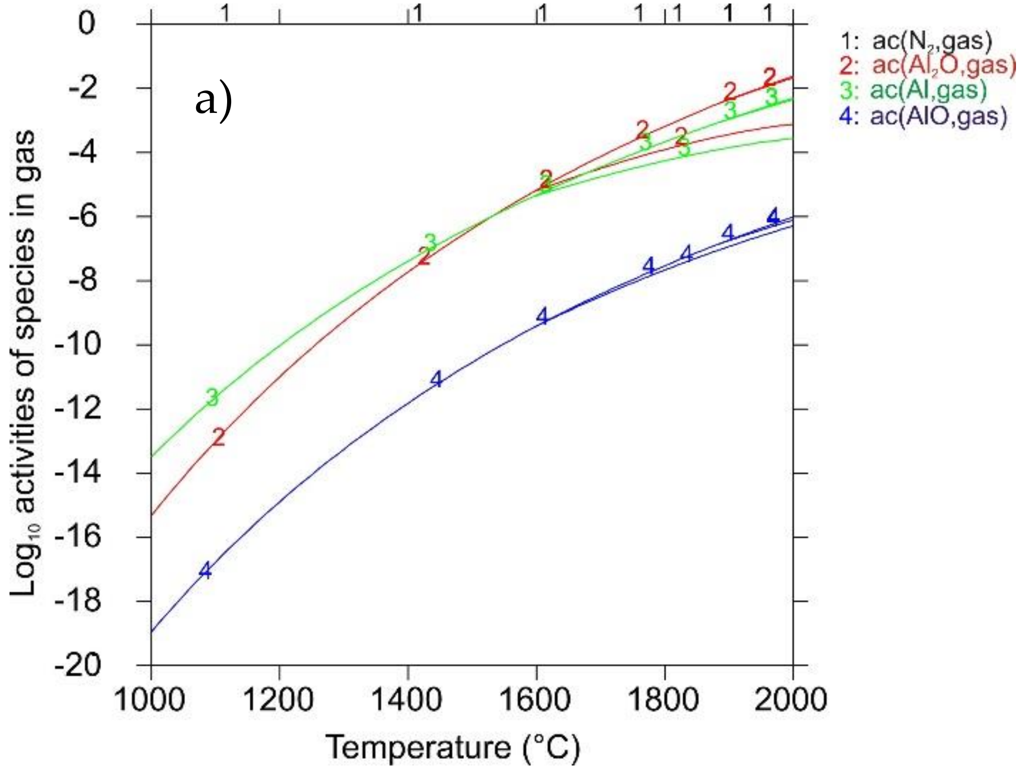
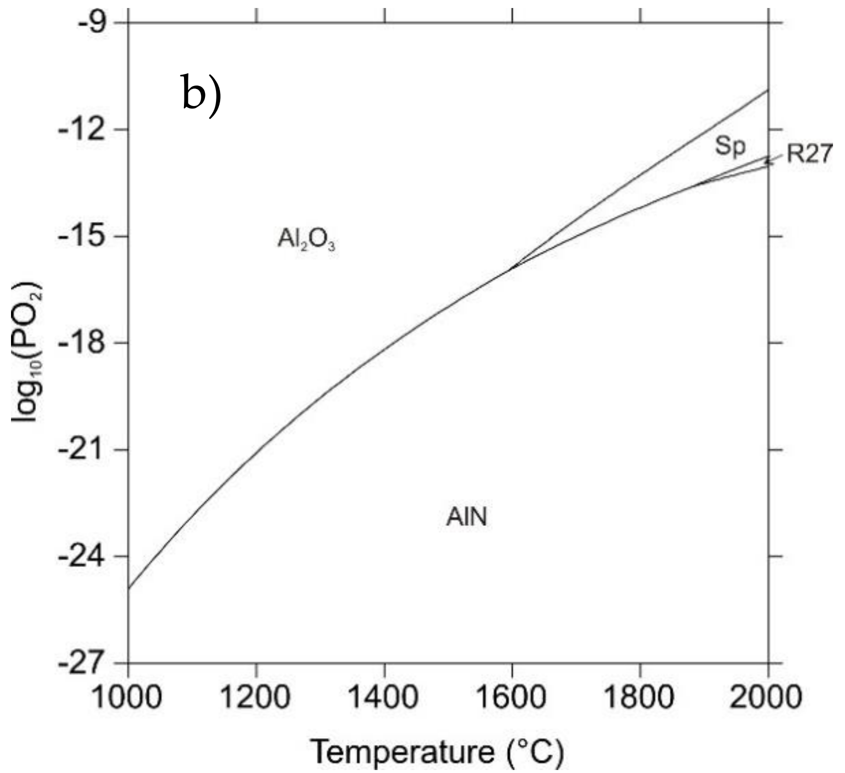


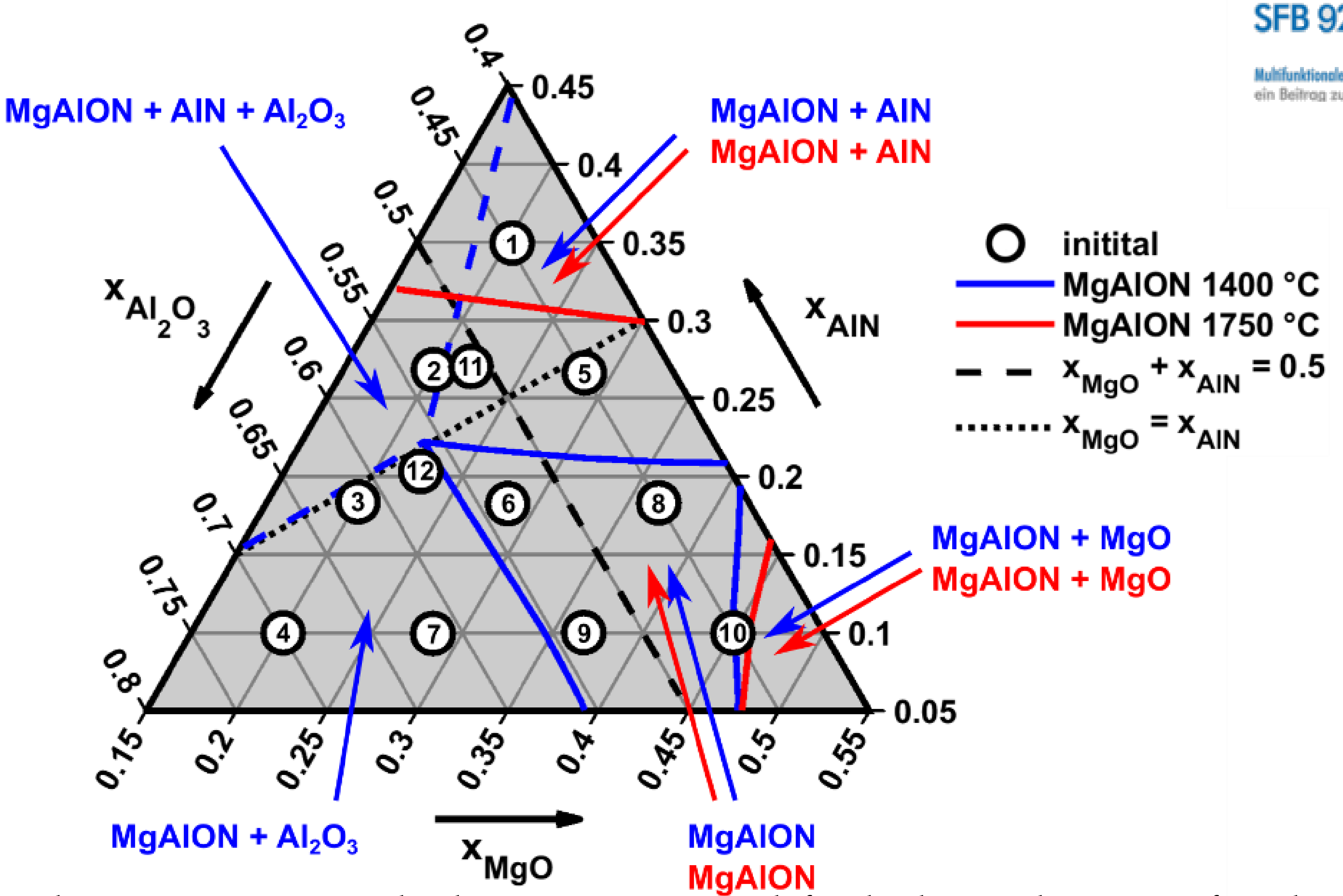




Phase equilibria in the $Al_2O_3$-AlN system $Al_2O_3$+AlN, $Al_2O_3$+Spinel AlON, Spinel AlON+AlN, R27+Spinel AlON and R27+AlN in presence of gas: (a) temperature dependence of the activities of gas species; (b)temperature dependence of the partial pressure of oxygen.

# 3. Theoretical and thermodynamic consideration

Standard Gibbs energies of reaction $\Delta_r G^\circ$ at 1500 °C and 1 bar, calculated using PBE-DFT.

| Reaction No. | Chemical Equation | $\Delta_r G^\circ_{DFT}$ (kJ mol$^{-1}$) | $\Delta_r G^\circ_{ref}$ (kJ mol$^{-1}$) |
|---|---|---|---|
| 1 | $MgO_{(s)} \rightarrow Mg_{(g)} + ½ O_{2\,(g)}$ | 325.4 | 366.3 |
| 2 | $MgAl_2O_{4(s)} \rightarrow Al_2O_{3(s)} + Mg_{(g)} + ½ O_{2(g)}$ | 351.6 | 408.3 |
| 3 | $Al_2O_{3(s)} + 4\,AlN_{(s)} \rightarrow 3\,Al_2O_{(g)} + 2\,N_{2(g)}$ | 681.9 | 793.4 |
| 4 | $MgAl_2O_{4(s)} + 4\,AlN_{(s)} \rightarrow 3\,Al_2O_{(g)} + Mg_{(g)} + ½ O_{2(g)} + 2\,N_{2(g)}$ | 1033.4 | 1201.7 |
| 5 | $AlN_{(s)} \rightarrow Al_{(g)} + ½ N_{2(g)}$ | 247.0 | 230.8 |
| 6 | $2\,Al_{(g)} + ½ O_{2(g)} \rightarrow Al_2O_{(g)}$ | –529.3 | –485.5 |




Compositions of the initial powder mixtures used, shown in a simplified phase diagram for the ternary system MgO-AlN-$Al_2O_3$. The homogeneity ranges of MgAlON and the adjacent multiphase regions for 1400 °C and 1750 °C were estimated according to the phase diagrams proposed by Willems [Preparation and Properties of Translucent Gamma-Aluminium Oxynitride. PhD Thesis, Department of Chemical Engineering and Chemistry, Technische Universiteit Eindhoven, The Netherlands, 1992].

# 4. Summary



- Pressureless reactive sintering of $Al_2O_3$-AlN-MgO mixtures at a sintering temperature of 1500 °C with a duration of 3 hours does not result in a near-equilibrium state and yields an average conversion degree to MgAlON of only 76 wt%.
- Reactive sintering of the same mixtures at 1500 °C for 6 hours results in a near-equilibrium state, reaching an average conversion degree to MgAlON of 91.9 wt%.
- The highest conversion degrees of 99 wt% of MgAlON were reached in the MgO-rich corner of the quasi-ternary MgO-AlN-$Al_2O_3$ system with $Al_2O_3$:AlN ratios of around 20:6.
- At 1500 °C, MgAlON forms from $MgAl_2O_4$, which is a direct reaction product of MgO and $Al_2O_3$, and the subsequent, simultaneous dissolution of $Al_2O_3$ and AlN in the spinel structure. During this process, MgO is fully consumed after the first 3 hours; the loss of magnesium due to evaporation or parasitic reactions is insignificant.
- The relative amount of nitrogen in the MgAlON phase of the samples with the lowest and highest conversion degree after 6 hours of reactive sintering was measured to be 1.5 wt% for both samples.

# 5. Conclusion

Reaction sintering of MgAlON delivers suitable coated ceramic foam filter material for the refining of light metal melts (Mg)

# 6. Acknowledgement

The authors would like to thank the German Research Foundation (DFG) for supporting these investigations in terms of the Collaborative Research Centre 920 “Multi-Functional Filters for Metal Melt Filtration – A Contribution towards Zero Defect Materials”, Subproject C06 (Project-ID: 169148856).

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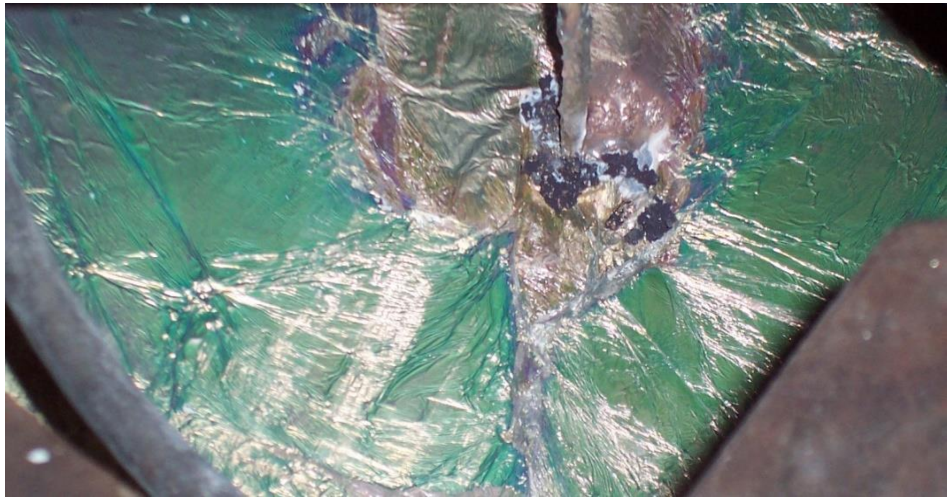

*Keywords:*
•high-tech metals
•microstructure
•properties
•material characterization
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