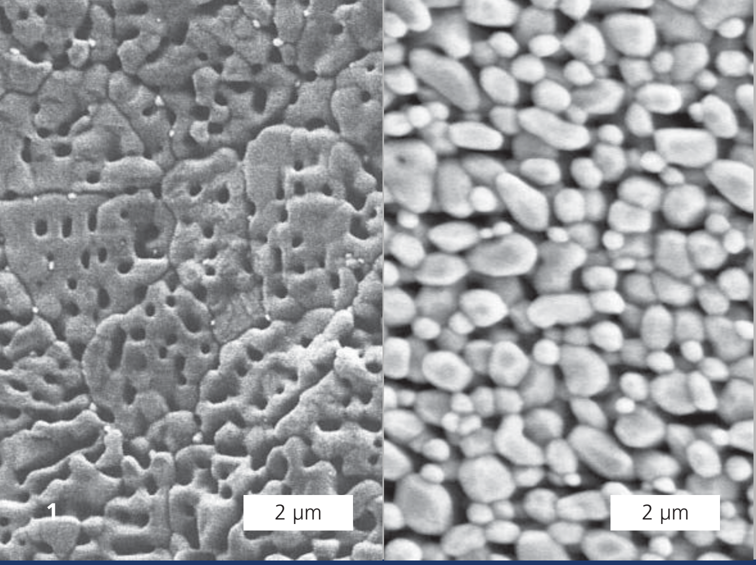

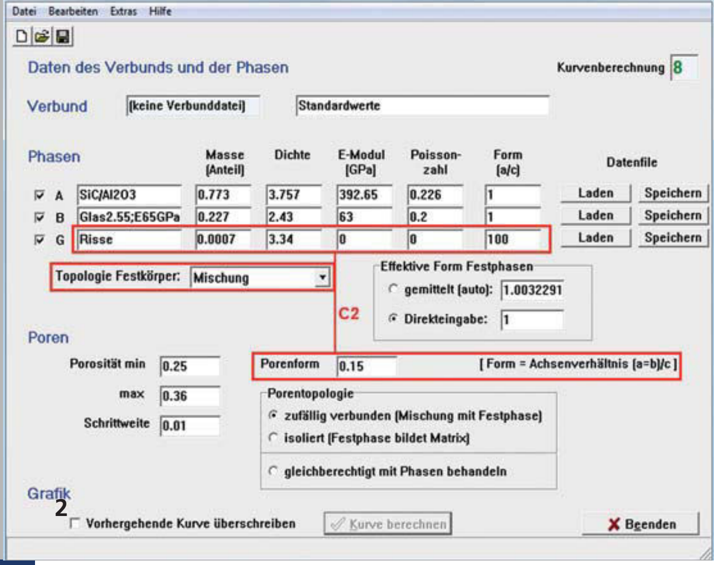

GRINDING TOOLS AND POROUS CERAMICS: STRENGTH CONTROL BY YOUNG'S MODULUS

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Compact grinding bodies as well as porous ceramics for filtration or catalysis need a high open porosity associated, however, with much higher mechanical loads of the tools. The safe control of their mechanical reliability is, therefore, essential for their successful use. In the manufacture of grinding wheels, the Young's modulus is regarded as a simply measurable tool of quality control. In research and development, however, it is commonly not known which theoretical modulus has to be attributed to a new composition or a modified sintering regime with resulting changes of the topology of the glassy (ceramic) binder and of the pores.

Any modeling calculation has to take into account a multitude of different theoretical approaches, which describe the Young's modulus depending on the pores' volume content, shape and topology. Such differences are illustrated in Figure 1 where the continuous matrix with isolated pores will, at equal porosity, exhibit a higher modulus and mechanical stability compared to the microstructure on the right with the partially sintered ceramic grains.

For microstructures of grinding tools (Figure 3 and 4), different manufacturing temperatures will change the viscosity of the glassy binder (introduced originally as a dry powder) with resulting consequences for the topology of the binder phase and of the shape of the pore channels. Of course, the calculation also has to integrate the total compositions with the moduli and Poisson numbers of the components, e.g. when diamond tools contain additional corundum grits or when the glassy binder is strengthened by very fine hard crystalline particles.

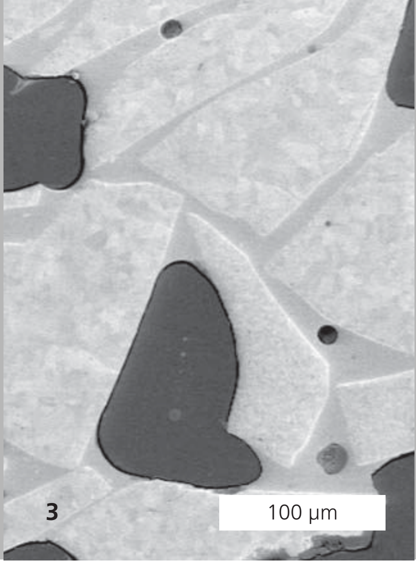
On behalf of Fraunhofer IKTS, a modeling program for windows was developed by Dr. W. Kreher at TU Dresden on the basis of complex theoretical investigations [1]. With IKTS data, e.g. for Al_2O_3, SiC, diamond and different glasses, the calculation gives Young's moduli and Poisson numbers for various hard material combinations. For compact grinding tools (Figure 4) or other porous components (Figure 5) with most different binder and pore configurations (resulting, e.g., from different compositions and firing regimes), the relation between porosity and Young's modulus can be calculated with a wide variety of input options (Figure 2):

- Different configurations of the glassy binder component
- Treatment of the glassy binder as a "matrix" or "mixture" of particles of the binder and of the hard ceramic
- Input of a shape factor for pores (with values < 1 for elongated channels) and selection of different pore topologies.

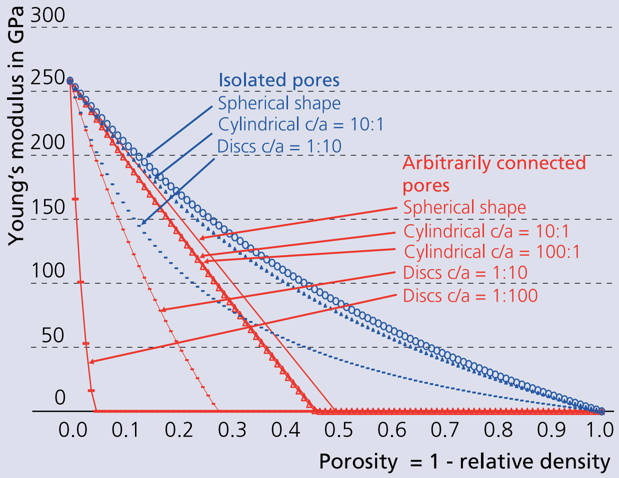
If necessary, supposed defects can additionally be considered in the description of flawed bodies and are entered as "Risse – Cracks" in the input example of Figure 2.

As an example, the first diagram shows the effect of different pore configurations and shapes on the modulus of grinding bodies made of 60 wt.-% corundum (Al_2O_3), 25 % cubic boron nitride (CBN) and 15 % glassy binder. The blue curves give the dependence on the porosity for a microstructure with isolated pores (topology of Figure 1, left) described by the effective field model, whereas the results for the case of connected pores (Figure 1, right; effective medium model) are plotted in red.

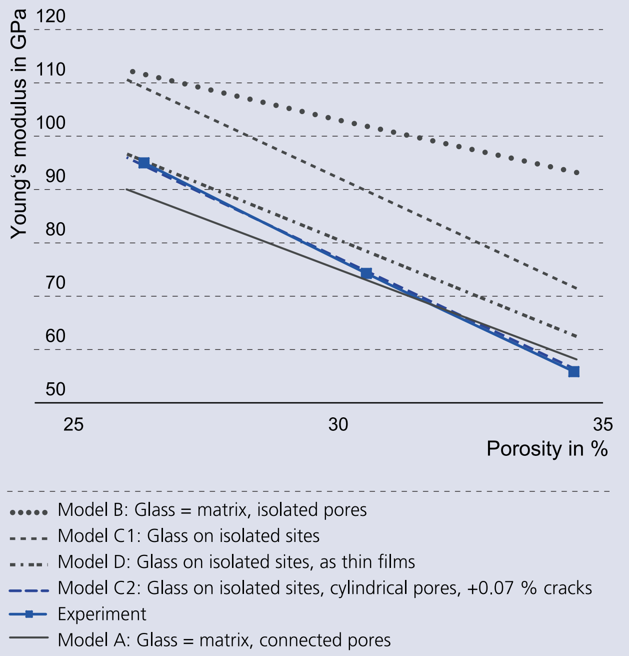
The second diagram demonstrates how the comparison of measured und calculated moduli of grinding bodies with 63 wt.-% corundum (Al_2O_3), 14 % silicon carbide (SiC) and 23 % glass indicates an insufficient sintering of these tools at 880 °C: An agreement of absolute values and of the slope is achieved for cylindrical pore channels if the glassy binder did not form a thin, homogeneous matrix yet and the grinding body contains a population of 0.07 vol.-% of cracks.



Influence of different pore structures on the dependency of the Young's modulus on the porosity using the example of a glass-bonded CBN-Al_2O_3 grinding body



Comparison of actual measured and modeled Young's moduli for different pore or defect structures using the example of a glass-bonded SiC-Al_2O_3 grinding body



Services offered

- Modulus/porosity modeling of complex grinding tools and of other ceramic components depending on composition and microstructural topology
- Development of grinding bodies and porous ceramics for use under mechanical loads

Reference

[1] W. Kreher, W. Pompe, Internal Stresses in Heterogeneous Solids, Akademie-Verlag, Berlin, 1989.

1 Porous Al_2O_3 microstructures with different pore topologies, described by approaches of an "effective field model" (left), "effective medium model" (right).

2 Input mask for the calculation of Young's modulus.

3 Complex microstructure of a grinding tool of polycrystalline Al_2O_3 grains, glassy binder (grey) and pores (dark).

4 Compact grinding wheel for metal work.

5 Low-defect porous Al_2O_3 tubes as substrates for filtration membranes, made by a casting process and sintering.

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