Title: Critical Assessment on Temperature Measurement and its Consequence to Observed Sintering Kinetics

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Text: Industrial application of microwaves has been demonstrated by different R&D groups all over the world to be beneficial for thermal processing of various materials, difficult to heat uniformly with standard heating techniques because of large volume and/or low thermal conductivity. The benefits are such as instantaneous volumetric and fast heating, reduced processing time and a reduction of process temperatures, leading to increased productivity, energy and cost savings. Since almost all processes are controlled by temperature and time it is easiest to compare microwave and conventional processing by comparing these parameters. But this has to be done carefully especially if high temperatures have to be applied such as for sintering of ceramics. If comparative investigations with different heating methods are performed in different systems, a careful calibration of the temperature measurement technique should be done to exclude systematic errors. Even more important is the fact that temperature gradients may be present. If so, then the measured temperature for process control, which gives temperature information of a very local area of the sample surface only, can deviate tremendously from the effective average sample temperature. It is well known that conventional heating results in a surface more hot than the volume and volumetric microwave heating may result in opposite temperature gradients. To perform more reliable comparative investigations, taking all these sources of errors into account, the millimeter-wave installation at the Forschungszentrum Karlsruhe which has been used for sintering of various functional and structural ceramics, was equipped with a modular heating system. This system allows conventional heating, mm-wave heating as well as mm-wave assisted heating up to temperatures of 1650 °C. Since the same temperature sensor is used for all heating techniques, systematic errors during comparative studies can be excluded. This system can be used in combination with a special dilatometer set-up so that information on sintering kinetics of ceramic samples as a function of temperature can be obtained as well. The influence of heating method and heating rates on temperature gradients can be investigated by the application of additional thermocouples. Comprehensive studies of all this information clearly demonstrate how critical the temperature parameter has to be observed if one wants to prove non-thermal microwave effects. Recent results obtained with the described dilatometer instrument will be presented and discussed.

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