VIRTUAL SEMINAR
Thursday, 2.12.2021 at 13:00

MPŠ Seminar 3

FREEZE CASTING OF HIERARCHICALLY STRUCTURED HIGHLY POROUS γ-Al_2O_3 MONOLITHS

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Highly porous ceramic γ–Al_2O_3 monoliths are important in many applications, e.g. catalysis, thermal insulation and adsorption, yet they still have plenty of unrecognized potential. There is a lot of incentive to employ simple and green fabrication processes for the preparation of such porous ceramic materials; however, many challenges, especially the loss of mechanical strength and rigidity due to the increase of porosity, remain unresolved.

The presented research was set to establish an unconventional but genuine fabrication approach of hierarchically macro-mesoporous alumina (HMMA) monoliths prepared from hierarchically-assembled AlN-powder-hydrolysis-derived γ–Al_2O_3 (MA) powder of high surface area (~180 m^2/g) and mesoporosity (0.47 mL/g).

An attempt to prepare stable aqueous suspensions containing MA powder was made. The effects of dispersant (sodium polyacrylate), divalent cations (Mg^{2+}, Ca^{2+}) and cellulose nanofibers (CNF) addition on the suspension's electrokinetic, rheological and sedimentation properties were studied in detail. Aqueous suspensions containing MA particles dispersed with sodium polyacrylate (NaPAA) showed proneness to undesired sedimentation and segregation and were as such not suitable for further green body consolidation. On the other hand, addition of divalent cations or cellulose nanofibers (CNF) triggered the formation of interparticle association networks in the suspensions. While the former only partially prevented sedimentation, in the latter case, long-term stability lasting more than 12 weeks was achieved.

As-prepared suspensions were then consolidated into structurally stable and highly-porous MA ceramic monoliths with hierarchically distributed porosity. For this purpose, freeze-casting was employed as a simple but powerful technique commonly used for fabrication of highly porous, columnar monolithic materials. By unidirectional freezing of aqueous suspension containing NaPAA-dispersed MA powder and CNF hierarchically macro-mesoporous alumina monoliths were successfully prepared. Freeze-cast monoliths possessed relatively high surface areas (91–134 m^2/g) and high hierarchical porosity (93.1–99.2 %). Owing to the columnar porosity HMMA monoliths also exhibited high permeability (k_1=2.39–4.31×10^{-12} m^2 and k_2=2.23–9.15×10^{-7} m) and low, anisotropic thermal conductivity ranging from 0.039 W/m·K to 0.071 W/m·K that depended on the pore orientation. Despite their high porosity, monoliths still displayed remarkable Young's modulus and high compressive strengths (up to 52.0 kPa).

The results advocate using freeze-casting of stable aqueous suspensions containing MA particles as an appropriate technique for fabrication of hierarchical and highly porous but remarkably rigid HMMA monoliths rarely seen in highly porous green bodies.

Kindly invited.