MONO- AND DISACCHARIDES IN DEFLOCCULATION PROCESS OF NANOCERAMIC POWDERS

Mikolaj Szafran, Pawel Falkowski and Anna Danelska
Inorganic Technology and Ceramics Department, Faculty of Chemistry, Warsaw University of Technology,
3 Noakowskiego Str. 00-664 Warsaw, Poland
corresponding author: szafran@ch.pw.edu.pl

Introduction

Colloidal processing offers the potential to reliably produce ceramic bulk forms through accurate control of initial suspension structure and its evolution during fabrication [1]. This is especially essential for colloidal processing of nanoparticles where the initial suspension "structure" very often determines the microstructure and the final properties of sintered sample. That's why the studies on deflocculation of nanopowders have recently met with great interest. Previous researches showed that addition of monosaccharides is very effective in reducing the viscosity of suspensions of nanosized alumina particles [2,3,4]. Akinc et al.[2] reported that the addition of fructose to suspensions reduces viscosity by displacing adsorbed water molecules from the surface. This process increases the amount of free (bulk) water in suspensions and causes an effective particle radius to decrease. Therefore, water layers surrounding alumina particles do not interact with one another and hence do not increase the viscosity. Additionally, the mobility of water molecules also is increased.
Nowadays, the area of this interest grows and the next main structural ceramic material – zirconia is approached form this angle. The current study was focused on comparison between the role of saccharides in deflocculation process of nanosized alumina and zirconia oxide.

Experimental

Materials
Two types of nanopowder were investigated: (1) nanosized alumina powder with an average particle size of 45 nm (with particle size ranging from 10 to 100 nm), density of 3.53 g/cm^3 and a specific surface area of 36,2 m^2/g (S_{BET}) was purchased from Nanophase Technologies Corp., Burr Ridge, IL.; (2) nanosized zirconia powder stabilized by 3 mol% Y_2O_3 with an average particle size of 44 nm was obtained from Inframat Advanced Materials, Farmington, USA. The specific surface (S_{BET}) and density were 24,4 m^2/g and 5,56 g/cm^3 respectively.
As dispersing agents and stabilizators the D-fructose, D-glucose, L-sorboze and sucrose were used. D-fructose, D-Glucose, sucrose were purchased from POCH S.A. (Poland). L-Sorbose was purchased from FLUKA. The chemical structures of dispersant are given in Fig.1 The organic dispersants were laboratory reagent-grades used without further purification

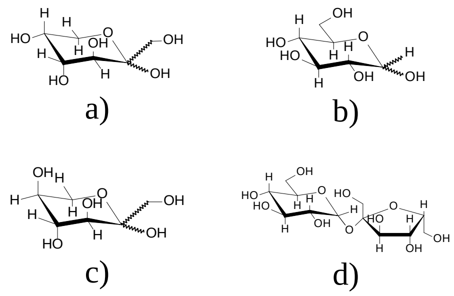

Fig.1 Chemical structures of saccharides: a) D-fructose, b) D-glucose, c) L-sorbose, d) sucrose

Aqueous suspensions with monosaccharide additive were prepared in redistilled water at room temperature. The concentration of monosaccharide was varied from 1 to 18 wt% (based on the weight of alumina powder). Rheological properties were measured using a Brookfield DV+II- Pro rheometer (Brookfield Engineering Laboratories Inc. Massachusetts, USA). The shear rate increased from 0.1 to 100 s^{-1} and back to 0.1 s^{-1}.
Electrophoretic measurements were carried out with a Zetasizer 3000 (Malvern Instruments). Dilute suspensions with the 10^{-3} mol/dm^3 concentration of NaCl electrolyte in the solution were ultrasonicated for 5 min before the analysis. Results were given as a function of the pH for different initial saccharide concentrations.

Results and discussion

Research shows (Fig. 1) that the addition of saccharide which differ from one another only in location of substituent groups in space affects neither pH value of the isoelectric point nor the zeta potential of nanometric alumina suspension. Prepared suspensions had pH below 6.5 so the electrokinetic potential is above 40mV. Hence, it can be stated that our suspensions with nanosized alumina were stable.

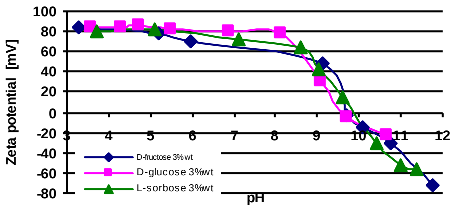

Fig. 1 Zeta potential measurements of nanosized alumina suspension with addition of 3 wt.% of monosaccharides

Li et al. [2] showed that increasing the fructose concentration in nanosized alumina suspension decreases steadily the viscosity. In the similar way the viscosity of suspension with addition of L-Sorbose and D-glucose decreases with increasing saccharide concentration. In case of nanosized zirconia the different effect was found. Fig 2 shows that the value of the viscosity of 34.6 vol.% n-ZrO_2 suspensions was increased after addition of saccharide. Higher fructose or glucose concentrations, up to 10wt%, do not decreased the viscosity below the viscosity of suspension without any additives.

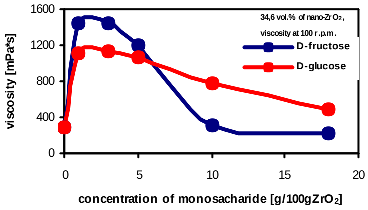

Fig. 2 Influence of monosaccharides concentration on viscosity of n-ZrO_2 suspension at shear rate $33s^{-1}$

In water solutions the monosaccharides undergo the mutarotation process and an equilibrium state between appropriate anomeric forms is established. In order to check the influence of mutarotation on rheological properties of monosaccharides two types of suspension with the same concentration of sugar were produced. In the first type of suspension, monosaccharide was added as crystals directly to the solvent. Immediately after sugar dissolving (10-30 second) the nanosized powder was added. In the second case, the monosaccharide solution of the strictly defined concentration was prepared in the beginning. Next, this solution was subjected to conditioning for 12 hours at room temperature. Then the nanosiezed metal oxide powder was added to the sugar solution. In both cases the solid content of metal oxide was the same. In case of alumina, the suspensions in which sugars were added as a solution have lower viscosity [5] while there is no effect on nanosized ZrO_2 suspension. The viscosity curves of nanosized ZrO_2 where monosaccharide was added before and after mutarotation overlap each other what is shown in Fig 3.

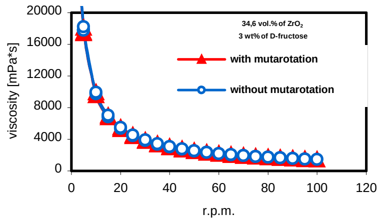

Fig. 3 Influence of 3wt% fructose concentration on viscosity of n-ZrO_2 suspension at shear rate 33 s^{-1}, monosaccharide were added before and after mutarotation

Summary

In contrast to alumina suspensions the addition of saccharide increases the viscosity of nanometric ZrO_2 suspension. The method of monosaccharides addition significantly influences rheological properties of nanometric alumina suspensions while there is no effect on nanosized ZrO_2 suspension

Acknowledgments

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