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PROCESSING OF SPHERICAL BIOACTIVE GLASS PARTICLES

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INTRODUCTION

Bioactive glasses have been used about 25 years as filling in living tissue, but mainly in crushed form (Hench 1990). Some advantages may, however, be achieved if the particles were spherical. For instance, Day & Day (1993) have reported that spherical glass particles can be fluidized and injected into tumors. Also the pore size as well as porosity of packings can be resonable accurately controlled if the particle shape and size distribution is known. This is also true if the glass is sintered to rigid, but porous, bodies for, say, prosthetic applications.

One possibility to produce spherical particles from irregularly shaped glass powder is to melt glass particles in a thermal reactor. In this study, the flame spraying system is used as a thermal reactor. The powder is fed through the flame spraying nozzle into an acetylene/oxygen flame where the particles melt and after cooling resolidify to spherical glass particles. The bioactivity of the glass seems however to be maintained in the process.

EXPERIMENTAL SYSTEM

The flame spraying method is conventionally used to cover metallic articles with metallic, plastic or ceramic coatings. The coating material is usually in powder form and the powder size distribution is typically 5–100 µm. Narrow size distribution helps to maintain continuous powder feed (Pawlowski 1995). In the spraying process the powder is first fed into the spray gun and then sprayed with a carrier gas in the flame, where it melts and accelerates. Molten particles hit the substrate, spread and form the coating.

In this study the flame spray system is used as a thermal reactor to rounding crushed, irregularly shaped bioactive glass particles. The particles are not impacted on a surface, but instead collected into a container.

Glass particles were fed into the flame using a so called locally fluidizing feeder, which is capable of feeding irregular particles at a controlled rate. The locally fluidizing feeder, originally reported by e.g. Annamalai et al. (1992), was modified for glass particle feed at Tampere University of Technology (Tikkanen et al. 1994). The feeder is capable of feeding irregular glass particles up to 300 g/min (Tikkanen et al. 1994). The modification includes the use of pure oxygen as a carrier gas for the particles. The flow rate of carrier gas was 8 l/min. This modification, when taken into account in the flow rates of burning gas, maximizes the flame temperature. Normally nitrogen or pressurized air would have been used as carrier gas.

The spray gun used in this study was GastoDyn DS 8000 and the fuel gases acetylene and oxygen were mixed in the ratio of 2:3. The flame which has a velocity 80–100 m/s (Pawlowski 1995) accelerates the droplets which get a typical speed of 50–100 m/s (Smith 1992). The flame with a temperature of 3000–3500 °C has enough energy to melt the glass and form spherical droplets. The droplets were sprayed through a pipe where they slowed up and cooled.

BIOACTIVE GLASS USED IN THIS STUDY

The glass used in this study is bioactive, which means that bone is chemically bonded to it when implanted. The composition of the glass has been reported as 13-93 (Brink et al. 1995). Also soft tissue forms a chemical bond with this glass. The glass has a large working range, which is a rare property for bioactive glasses. The durability is comparatable to that of ordinary table ware. This bioactive glass is easily blown and pressed, and the manufacturing of fibre products is also possible. The glass was prepared by melting raw materials at 1360 °C, then cast, annealed and crushed.

RESULTS AND DISCUSSION

In this study, spherical particles were successfully produced from an irregularly shaped powder of bioactive glass by flame spraying process. It was noticed that size distribution, feed rate and flame temperature affect the results. The best results were obtained when the particle size was less than 125 μm, feed rate some grams per second and the flame consisted of acetylene/oxygen. Also larger feed rates and a hydrogen/oxygen flame were tried, but in these cases the flame did not supply enough heat to make the particles spherical.

Large particles require more energy for complete melting than the conventional flame spray process can supply. Particles in the right size range (<125 μm) seemed to melt completely and resolidify in the form which minimizes the surface energy, that is in a spherical form.

CONCLUSIONS

The use of a thermal reactor is a practical way to produce spherical particles from irregular shaped glass powder. Flame spraying is a cheap and easy way to construct the thermal reactor. Flame spray gun is suitable for the production of spherical particles if small enough powder feed rates and large enough fuel gas flow rates are used.

Flame spraying of the bioactive glass 13-93 to achieve spherical particles is possible, and no compositional changes were detected at the surface of the particles as investigated by electron spectroscopy for chemical analysis (ESCA). The bioactivity is therefore expected to be maintained. Testing of these spherical particles *in vitro* are going on, and experiments *in vivo* are planned.

REFERENCES

Annamalai, K., Ruiz, M., Vo, N., and Anand, V.: "Locally Fluidizing Feeder for Powder Transport", Powder Technology, vol 73 (1992), pp. 181-190.

Day, D.E. and Day, T.E.: Introduction to Bioceramics (edited by Hench L.L. and Wilson, J.), World Scientific Publishing, Singabore (1993), pp. 305-317.

Brink M., Karlsson K.H. and Yli-Urpo A.: "Novel Bioactive Glasses and Their Use", Finnish patent application No. 950147 (1995).

Hench, L.L.: Bioactive glasses and glass-ceramics: A perspective, Handbook of Bioactive glasses and glass-ceramics (edited by Yamamuro, T., Hench, L.L. and Wilson, J.), CRC Press, USA (1990), pp. 7-23.

Pawlowski, L.: The Science and Engineering of Thermal Spray Coatings, John Wiley & Sons, New York (1995), 414 p.

Smith, R.W.: Equipment and Theory, A Lesson from Thermal Spray Technology (edited by Willis, B.), Materials Engineering Institute, ASM International, (1992), 66 p.

Tikkanen, J., Eerola, M., Rajala, M.: "Coating glass by flame spraying", Journal of Non-Crystalline Solids, vol 178 (1994), pp. 220-226.