

Fluorcanasite/Frankamenite Based Glass-Ceramics for Bone Tissue Repair

S. Bandyopadhyay-Ghosh^{1,2}, A. Johnson², I. M. Reaney¹, K. Hurrell-Gillingham², I. M. Brook²
and P. V. Hatton²

¹*Department of Engineering Materials, Sir Robert Hadfield Building, Mappin Street, University of Sheffield, Sheffield, S1 3JD, UK.* ²*Centre for Biomaterials and Tissue Engineering, School of Clinical Dentistry, Claremont Crescent, University of Sheffield, S10 2TA, UK*

INTRODUCTION: Fluorcanasites/Frankamenites are quadruple chain silicate, have a highly crystalline microstructure of interpenetrating laths that give rise to high flexural strength (>300 MPa) and fracture toughness (>5 MPa m^{1/2})[1]. Miller *et al.* [2] demonstrated that the addition of excess CaO and P₂O₅ to the stoichiometric (Ca₅Na₄K₂Si₁₂O₃₀F₄) composition induced the early formation of an apatite layer in simulated body fluid. However, no quantitative data regarding their biocompatibility has been published to date, and knowledge of structure-property relationships in these materials remains limited. The aim of this research was therefore to further characterise these modified fluorcanasite glass-ceramics, to evaluate their castability, to compare their *in vitro* biocompatibility with parent glasses. Properties of the fluorcanasite glass and glass-ceramics including ion release, pH were also studied and the data related to biocompatibility.

METHODS: Three glass compositions were considered. Glass 1 had the stoichiometric fluorcanasite composition, Glass 2 had an increased calcium concentration and Glass 3 contained P₂O₅. These glasses were heat-treated using a two stage heat-treatment process at 520°C/2h and 780°C/2h. The parent glasses and the glass-ceramics were characterised using X-Ray Fluorescence Spectrometry (XRF), Differential Thermal Analysis (DTA), X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). The castability was evaluated with a spiral test piece using lost wax casting route. *In vitro* biocompatibility was investigated using rat osteosarcoma cells (ROS 17/2.8, Merck Inc., USA). The materials were evaluated in both their glassy and crystalline states. Samples and cells were incubated at 37°C in a 5% CO₂ atmosphere for 72 h. SEM was used to observe cell morphology. Quantitative MTT assay was also carried out. Ion release from discs (12 mm diameter × 2 mm thickness) was determined using inductively couple plasma-mass spectrometry (ICP-MS) and the change of pH in de-ionised distilled water was measured using a calibrated pH meter.

RESULTS: XRF data showed a close similarity between the pre-melt and post-melt molar compositions. The DTA curves of glasses showed exothermic peaks that were assigned to the crystallisation of various phases, identified by XRD. Essentially Glass 1, 2 and 3 crystallised to form frankamenite (Glass 1), frankamenite, fluorcanasite, xonotlite (Glass 2) and frankamenite, fluorcanasite, xonotlite, and fluorapatite (Glass 3). The microstructures obtained from fractured surfaces of the glass-ceramics consist of interlocking crystals of the strengthening chain silicate phase. These modified fluorcanasite glasses had excellent relative castability. SEM images from samples which had been tested for biocompatibility showed that cells had colonized the surfaces of fluorcanasite glass-ceramics to form a confluent sheet to a greater degree than their parent glasses. Quantitative MTT assay results were in good agreement with the qualitative SEM observations. The ion release and pH data suggested a close relationship between solubility (in particular sodium release) and biocompatibility.

DISCUSSION & CONCLUSIONS: Fluorcanasite and Frankamenite are the major crystalline phases in these glass-ceramics. Excellent relative castability of these modified fluorcanasite glasses confirming that they may be useful for the fabrication of custom prostheses via the lost wax casting. Incorporation of excess CaO (Glass 2) and P₂O₅ (Glass 3) in stoichiometric glass composition (Glass 1) improved *in vitro* biocompatibility. Controlled heat-treatment improved *in vitro* biocompatibility of modified fluorcanasite glass-ceramics compared to their parent glasses. Reduced solubility and related pH effects appeared to be the principal mechanisms responsible for improvement in *in vitro* biocompatibility.

REFERENCE: ¹G. H. Beall (1991) *J Non-Cryst Solids*, **129**:163-173. ²C. A. Miller, T. Kokubo, I. M. Reaney, P. V. Hatton and P. F. James (2002) *J Biomed Mater Res*, **59**: 473-480.