Institute of Dentistry

Novel Diopside Glass-Ceramics for Dental Applications

Jamila Almuhamadi*, Natalia Karpukhina, Mike Cattell
j.m.a.almuhamadi@qmul.ac.uk
Queen Mary University/UK, Al-Zawiya Medical University/Libya

Introduction

A human natural teeth may be lost due to progression of periodontal diseases, trauma or as a result of dental caries, (Fig 1). Glass-ceramic materials have been used to replace missing teeth and un-aesthetic teeth enamel since they have the potential to reproduce the depth of translucency, colour and texture of natural teeth. Glass-ceramics used to provide dental restorations must have a high modulus of elasticity, flexural strength and toughness.

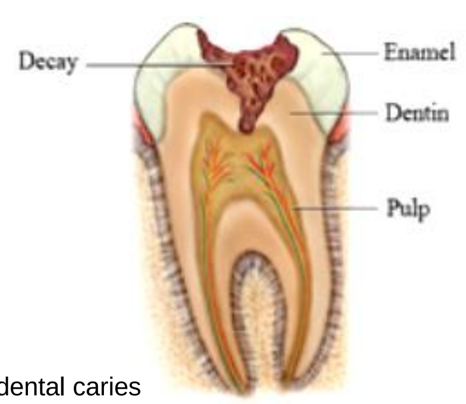

Fig 1: Lost of tooth enamel due to dental caries

The problem

Clinical reports on zirconia (Y-TZP) based crowns and fixed partial dentures have shown a high rate of short-term failures which are related to the chipping/fracture of veneering ceramics (Fig 2). This chipping is considered a serious problem in dentistry for all ceramic restorations, and a factor is when the veneering material has a thermal expansion coefficient (TEC) higher than that of zirconia substrate ($10X10^{-6}$/K).

Aim: to produce a novel strong and thermally compatible diopside glass-ceramics for zirconia (Y-TZP) restorations.

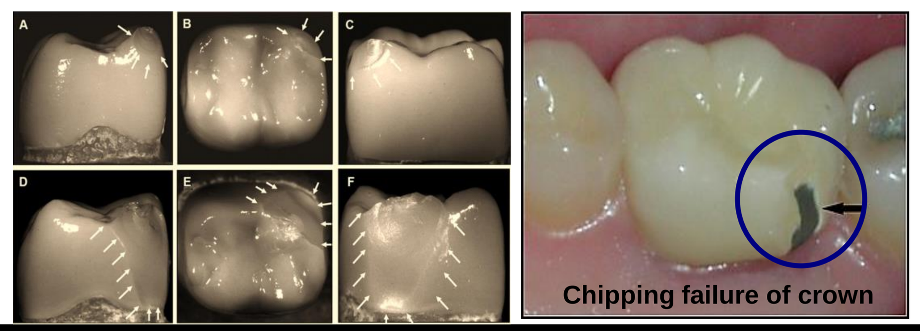

Fig 2 : Veneered Y-TZP crowns exhibiting typical veneer chipping failure mode

Methodology

A series of glass compositions based on $CaMgSi_2O_6$-$NaAlSi_2O_6$ system were designed using Appen Factors (Table 1).

Table 1: Glass compositions in mol%

Glass	SiO_2	Al_2O_3	CaO	Na_2O	MgO
100Di-0Jd	50.00	0.00	25.00	0.00	25.00
85Di-15Jd	51.95	1.95	22.08	1.95	22.08
75Di-25Jd	53.33	3.33	20.00	3.33	20.00
50Di-50Jd	57.14	7.14	14.29	7.14	14.29
25Di-75Jd	61.54	11.54	7.69	11.54	7.69
0Di-100Jd	66.67	16.67	0.00	16.67	0.00

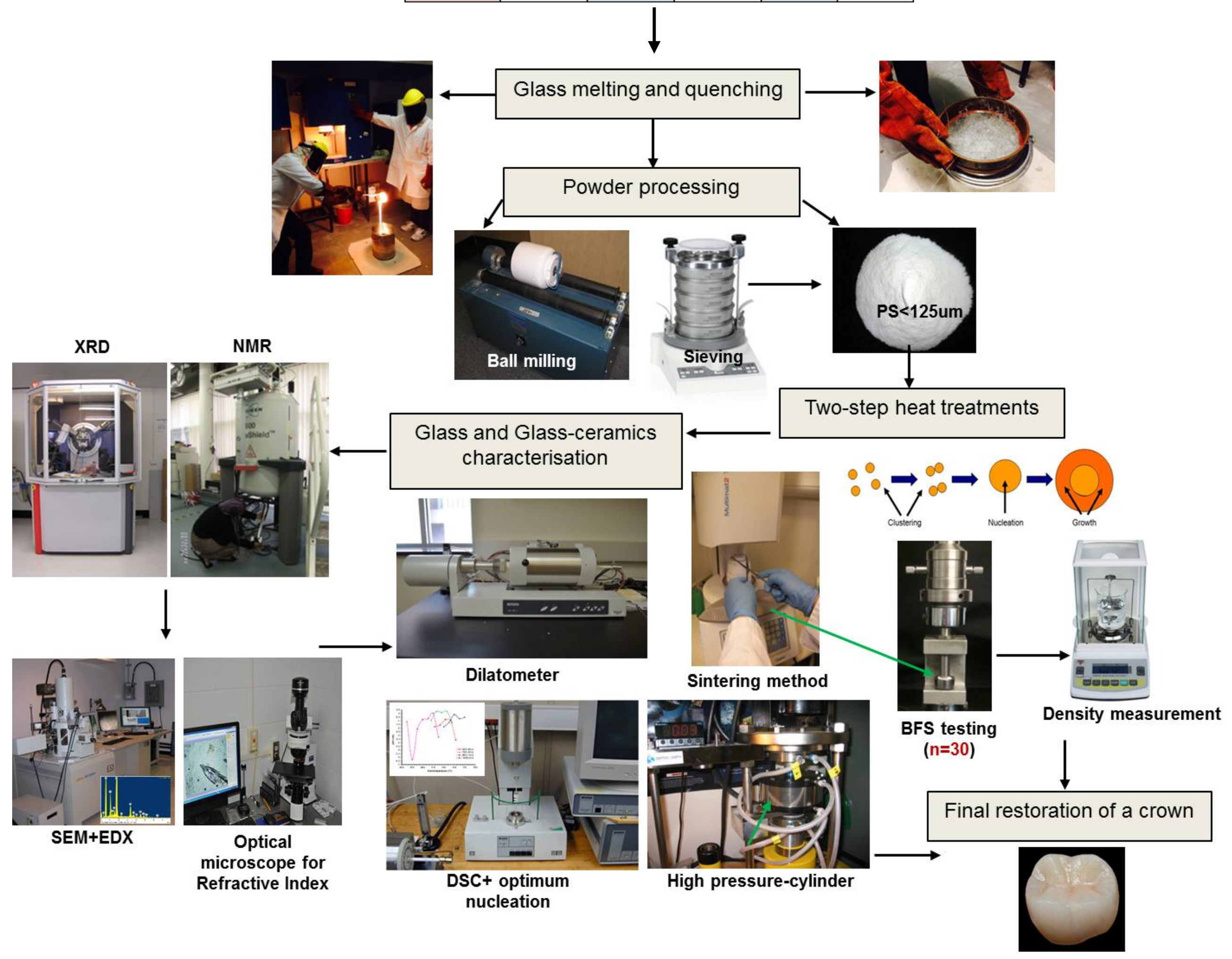

Fig 3: Diagram of experimental glass and glass-ceramics synthesis

Results

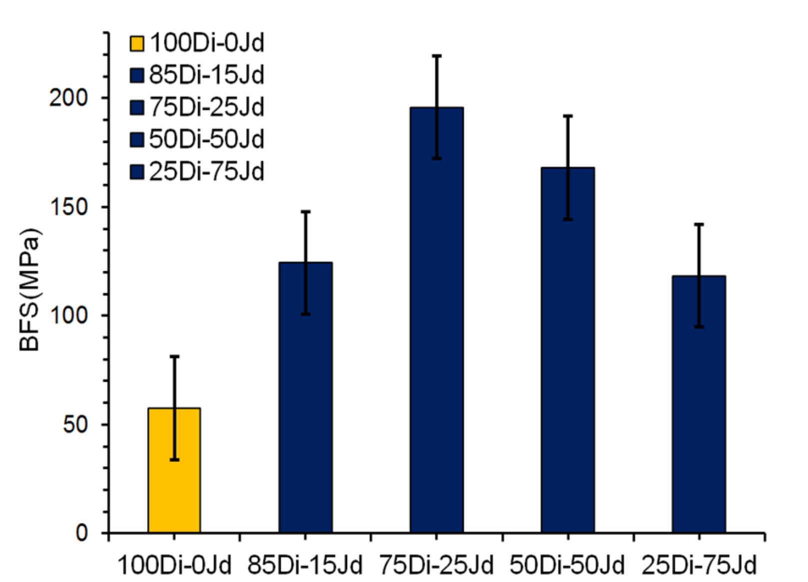

Fig 4: BFS results of sintered glass-ceramics showing increases in the BFS with the formation of diopside solid solution.

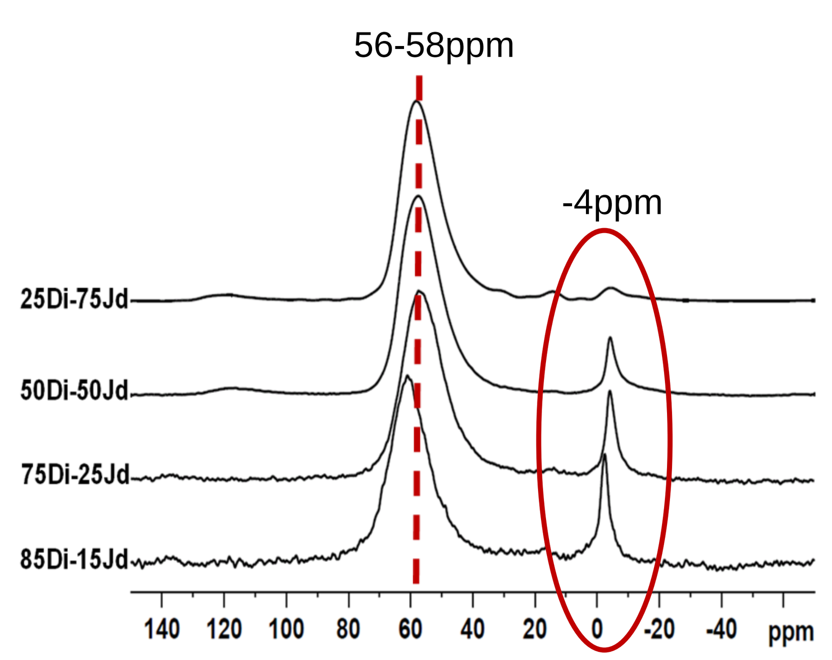

Fig 5: [27]Al NMR results of glass-ceramics showing a formation of diopside solid solution at -4ppm.

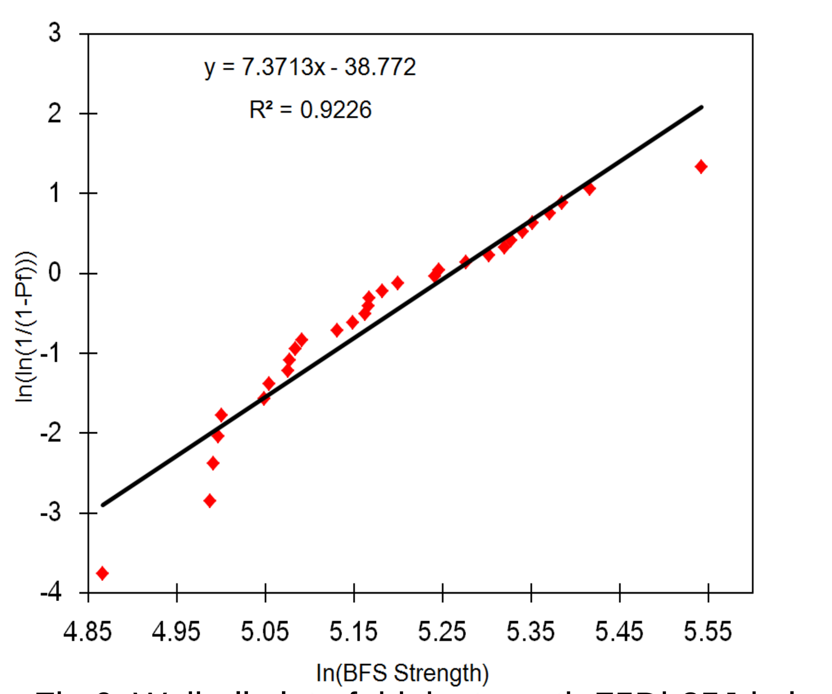

Fig 6: Weibull plot of high strength 75Di-25Jd glass-ceramic.

Table 2: BFS results of experimental glass-ceramics

Glass-ceramics	Median BFS MPa (Q1, Q3)	Mean BFS MPa (SD)
100Di-0Jd	58.04[a] (53.33, 61.22)	57.80 (7.26)
85Di-15Jd	125.14[b] (105.17, 134.98)	119.62 (20.42)
75Di-25Jd	175.33[c] (160.05, 204.33)	180.68 (28.62)
50Di-50Jd	164.45[c] (145.22, 182.37)	168.11(32.82)
25Di-75Jd	117.84[b] (100.10, 143.38)	118.40 (29.44)

Different superscript letter indicate significant difference between groups
Q1, Q3 : (25%, 75%)

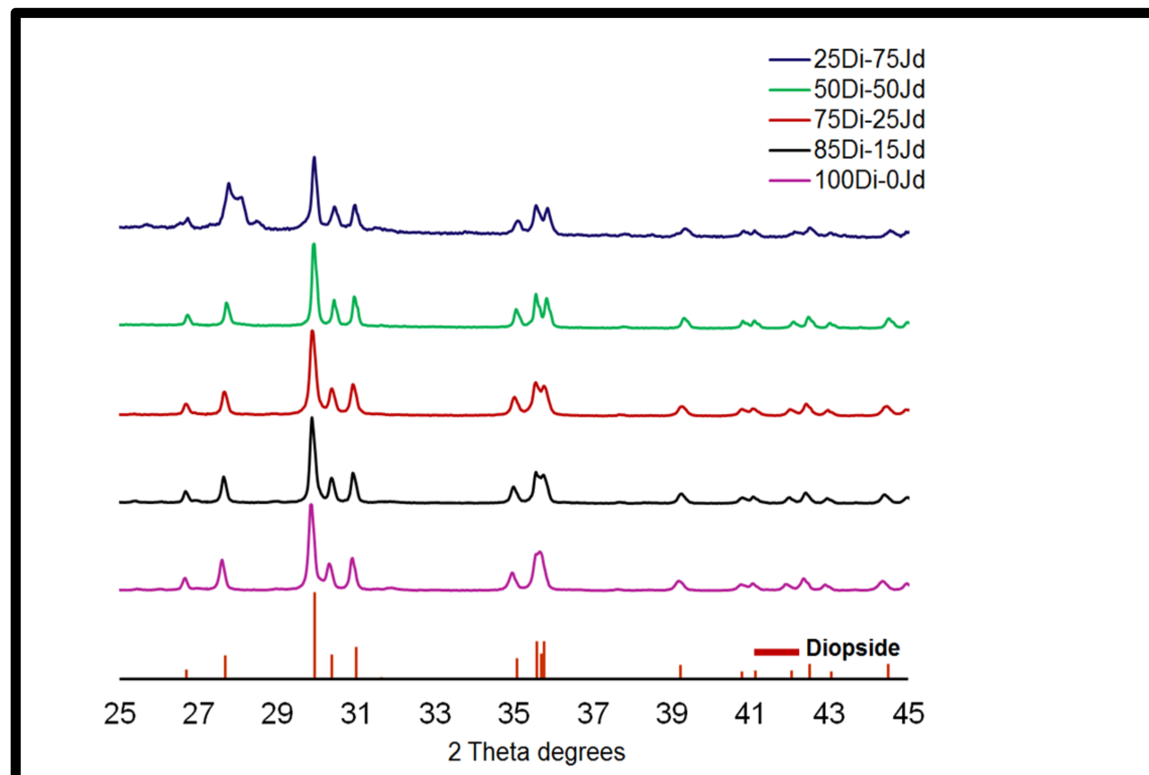

Fig 7: XRD results of glass-ceramics showing diopside as the major crystalline phase.

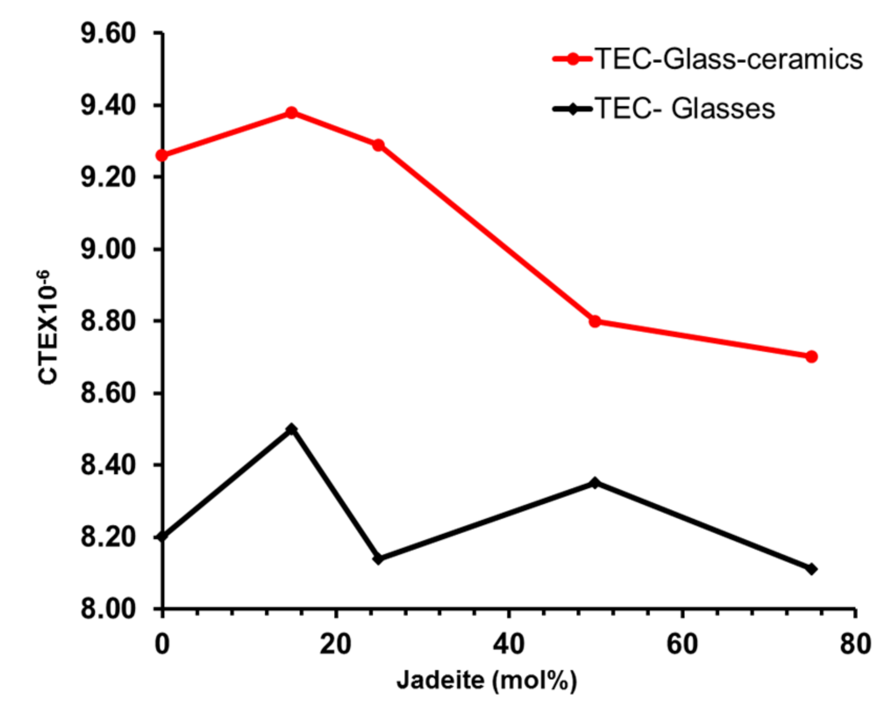

Fig 8: TEC results of glasses/glass-ceramics showing increases of TEC due to the formation of diopside solid solution.

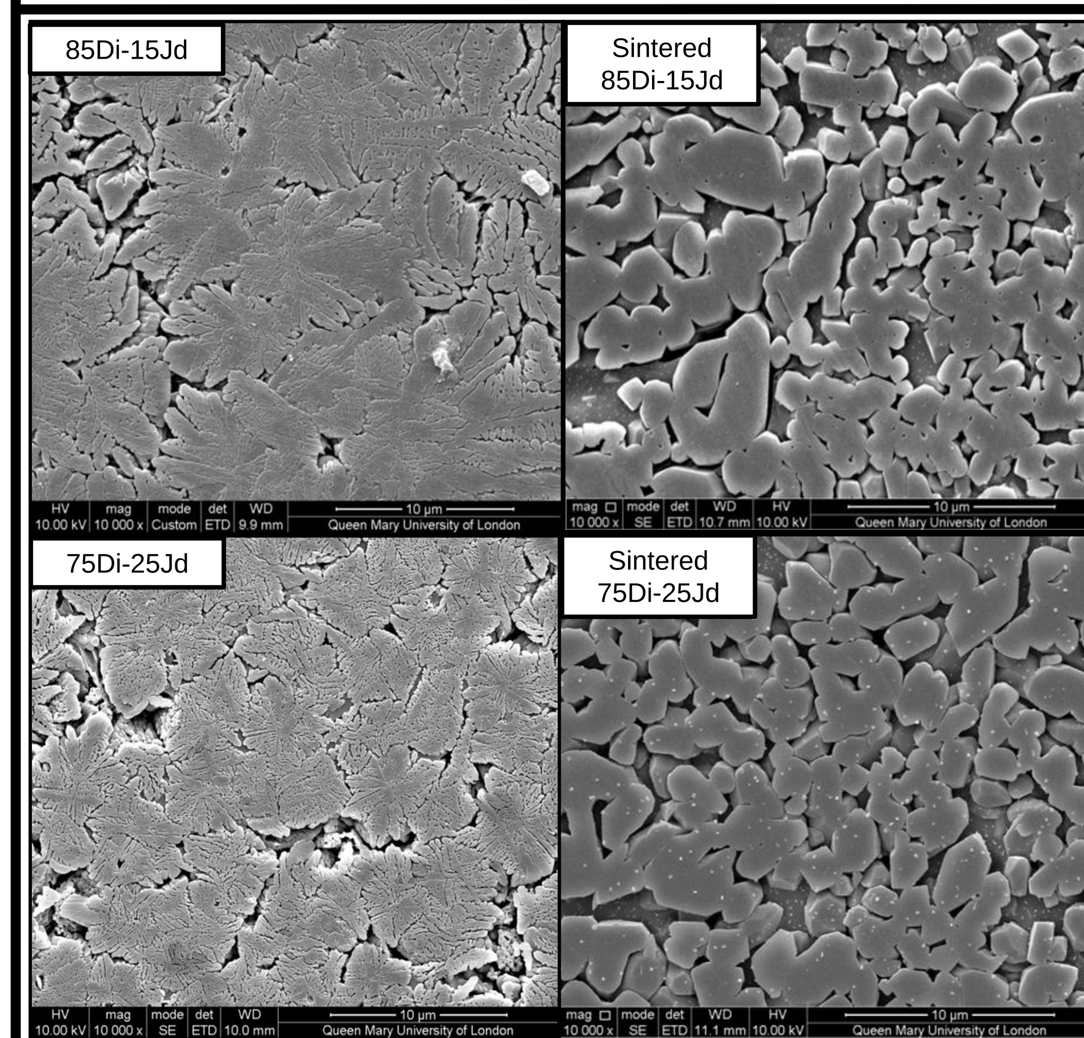

Fig 9: SEM photomicrographs of diopside glass-ceramics after two-step heat treatments showing a presence of rosette-like diopside crystals with absence of matrix micro-cracking. After sintering , diopside crystal coalescence and growth were noticed.

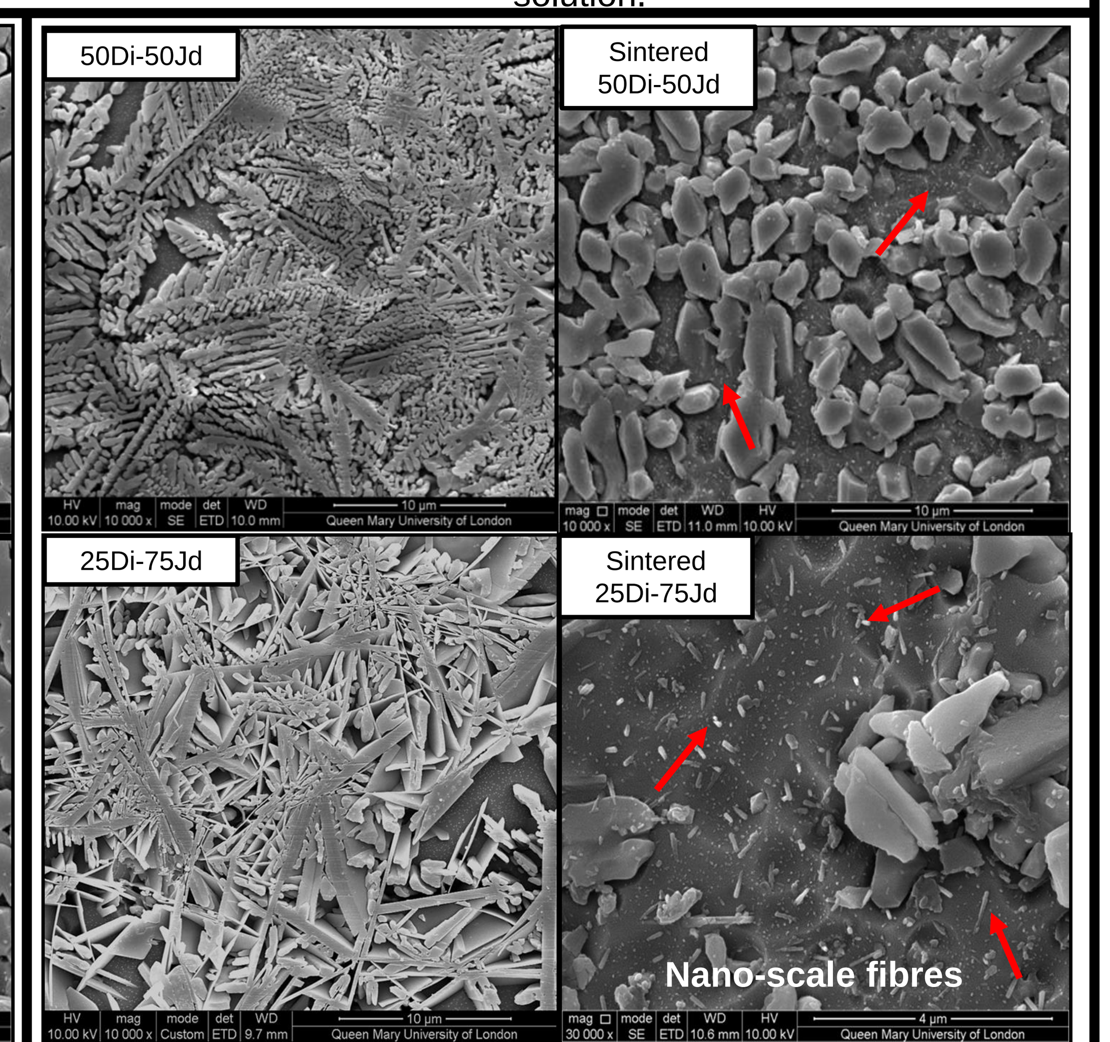

Fig 10: SEM photomicrographs of diopside glass-ceramics after two-step heat treatments showing a presence of dendritic and platelet-like diopside crystals with absence of matrix micro-cracking. After sintering, nano-scale diopside fibres were visible.

Conclusions

- High strength diopside glass-ceramics with TECs compatible with zirconia (Y-TZP) ceramics were successfully produced.
- These glass-ceramics are useful as a veneering material for Y-TZP ceramics and for all-ceramic diopside restorations (inlays, onlays, crowns and bridges).
- The produced nano-scale diopside fibres may suggest it is use as a low wear enamel material.

This project is funded by the Libyan Ministry of Higher Education