Development of Electrically Conductive ZrO2-CaO-Fe2O3-V2O5 Glass and Glass-Ceramics as a New Cathode Active Material for Na-ion Batteries with High Performance

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Figure Captions

Fig. 1 The block diagram of the DC four-probe method applied for electrical conductivity measurement of the vanadate glasses.

Fig. 2 DTA curves of samples (A) *x*ZFV with '*x*' of (a) 0, (b) 10, (c) 20 and (d) 30, and (B) *y*ZCFV with '*y*' of (a) 0, (b) 5, (c) 10, (d) 15 and (e) 20.

Fig. 3 (A) Electrical conductivity (σ) and (B) activation energy for electron hopping (W_H) obtained from DC conductivity measurement of samples *x*ZFV (a) before and (b) after heat-treatment at 500 ^oC for 100 min.

Fig. 4 (A) Electrical conductivity (σ) and (B) activation energy for electron hopping (W_H) of samples *y*ZCFV measured (a) before and (b) after heat-treatment at 500 ^oC for 100 min.

Fig. 5 XRD patterns of *x*ZFV glass with '*x*' of (a) 0, (b) 10, (c) 20, and (d) 30.

Fig. 6 XRD patterns of samples (A) 20ZFV and (B) 0ZCFV (a) before and (b) after heat treatment at 500 ^oC for 100 min.

Fig.7 SEM images of samples (A) 20ZFV and (B) 0CZFV (a) before and (b) after heat treatment at 500 ^oC for 100 min.

Fig. 8 (A) Normalized V *K*-edge XANES spectra of *x*ZFV glasses with '*x*' of (a) 0, (b) 10, (c) 20 and (d) 30 before heat treatment shown together with those of reagent chemicals of V_2O_5, VO_2 and V_2O_3. Fig. 8 (B) is a focused version of Fig.8 (A) surrounding of the pre-edge peaks.

Fig. 9 (A) Normalized V *K*-edge XANES spectra of samples 20ZFV(blue) and 0ZCFV (red) before ((a), (c)) and after the heat treatment((b), (d)) shown together with those of reagent chemicals of V_2O_5, VO_2 and V_2O_3. Fig. 9 (B) is a focused version of Fig.9 (A) surrounding of the pre-edge peaks.

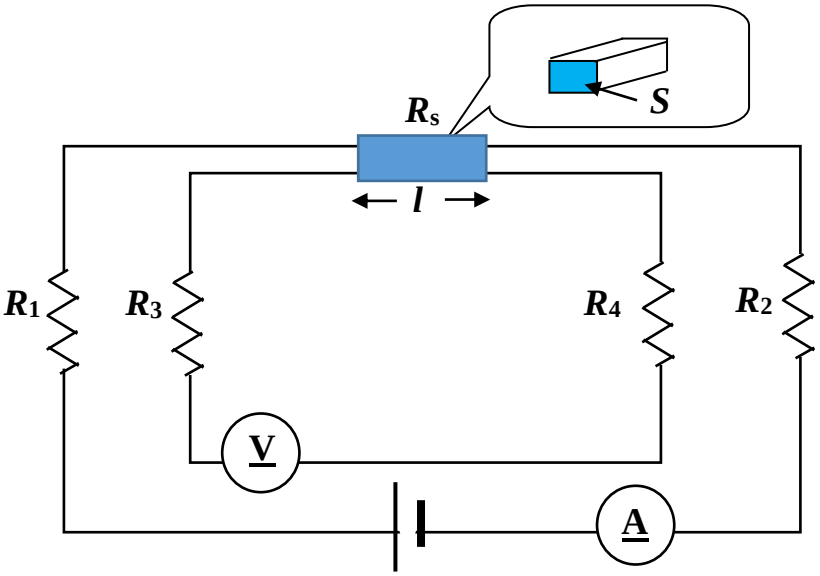
Fig. 10 ^{57}Fe- Mössbauer spectra of *x*ZFV glasses with '*x*' of (a) 0, (b) 10, (c) 20 and (d) 30 (A) before and (B) after heat treatment at 500 ^{o}C for 100 min.

Fig. 11 ^{57}Fe-Mössbauer spectra of *x*ZCFV glasses with '*x*' of (a) 0, (b) 5, (c) 10 and (d) 15 (A) before and (B) after heat treatment at 500 ^{o}C for 100 min.

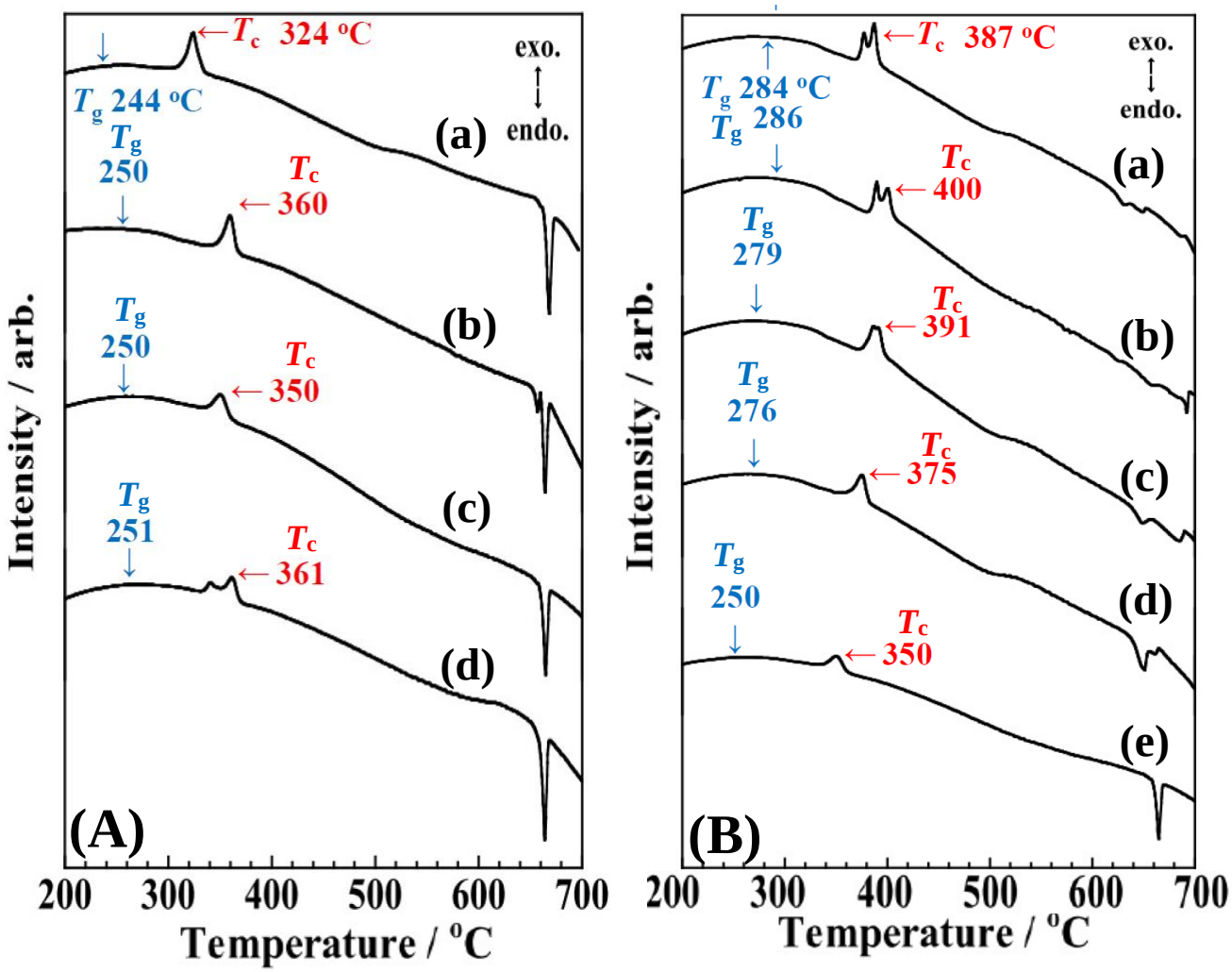
Fig. 12 Tauc plot for samples (a) 20ZFV and (b) 0ZCFV of (A) before and (B) after heat treatment at 500 ^{o}C for 100 min and that of V_2O_5 ((B)-(c)). Dotted lines are fitting lines for determining E_g values.

Fig. 13 Charge(red) and discharge (blue) capacities of samples (a) 20ZFV and (b) 0CZFV (A) before and (B) after heat treatment at 500 ^{o}C for 100 min.

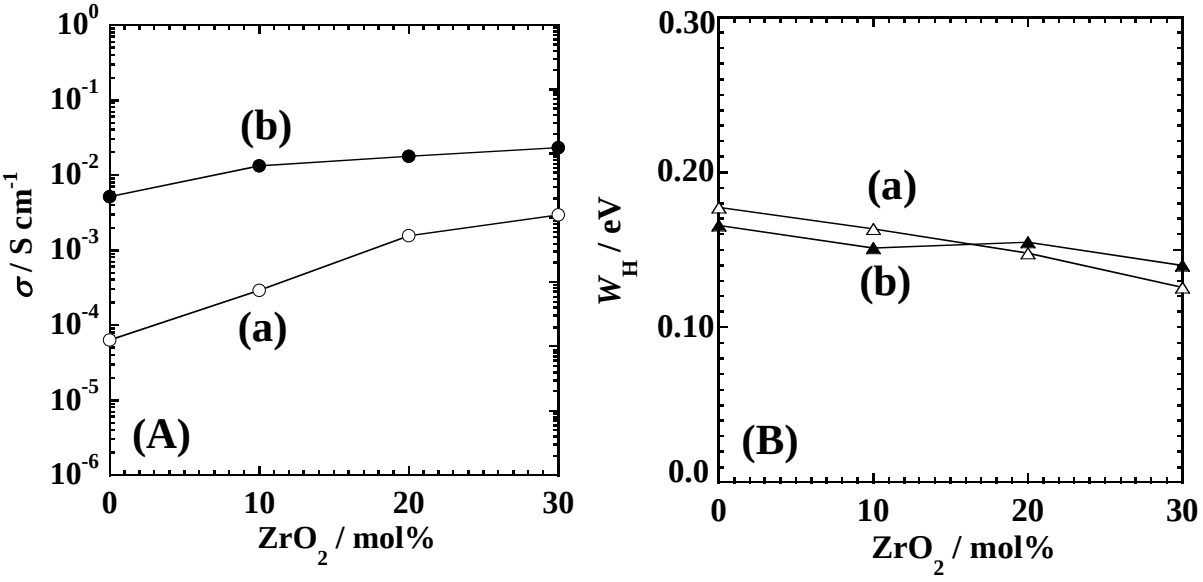
Fig.14 Capacities of charge (circles) and discharge (triangles) processes repeatedly recorded up to 30 times for samples 20ZFV (blue) and 0CZFV (red) before (open symbols) and after heat treatment at 500 ^{o}C for 100 min (closed symbols).



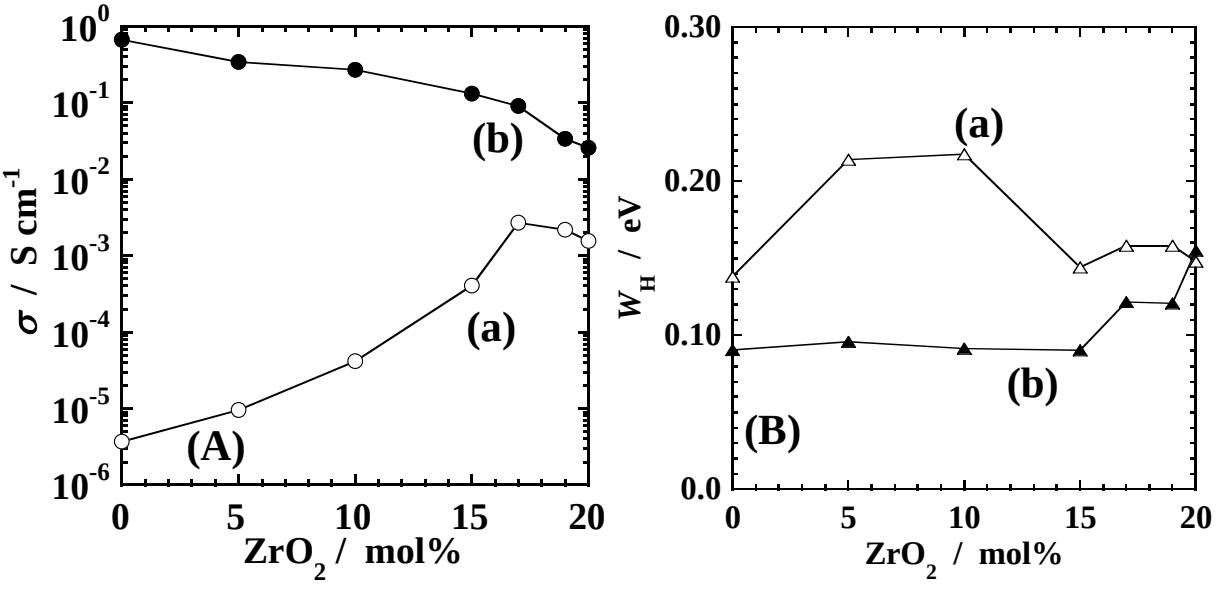
Khan *et al.*, Fig. 1



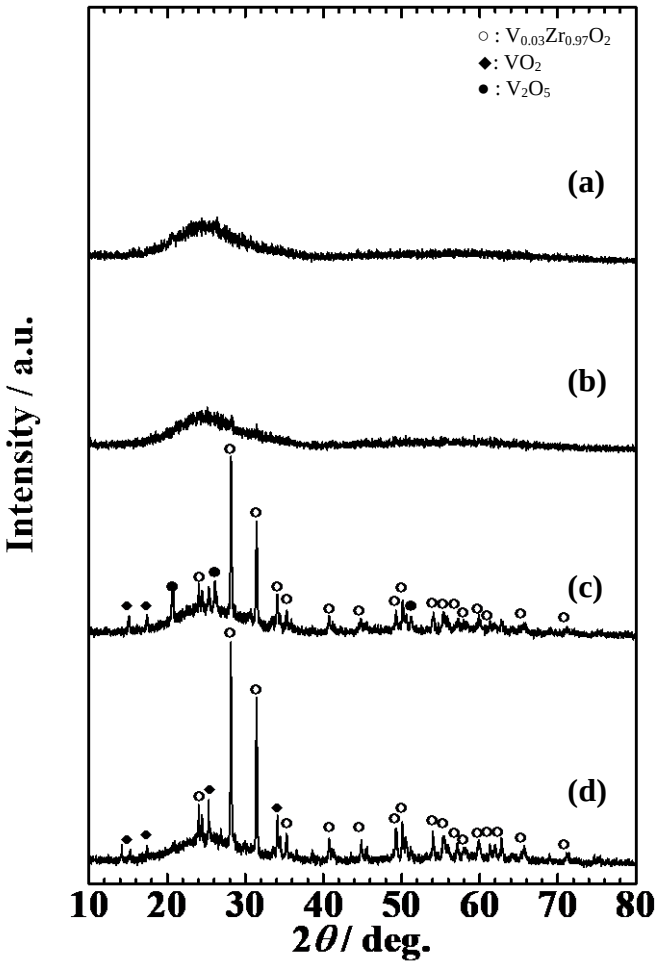
Khan *et al.*, Fig. 2



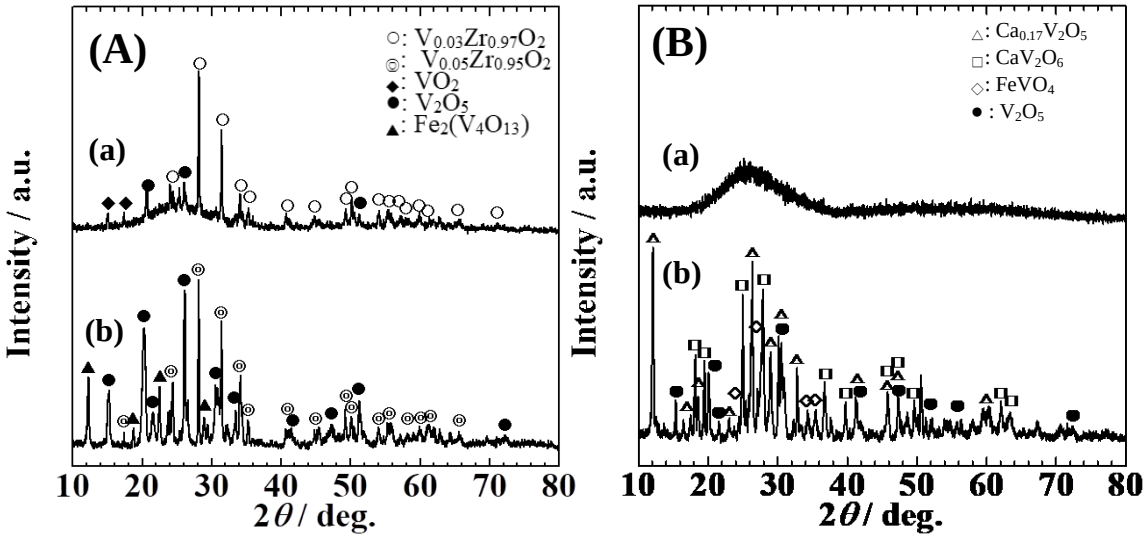
Khan *et al.*, Fig. 3



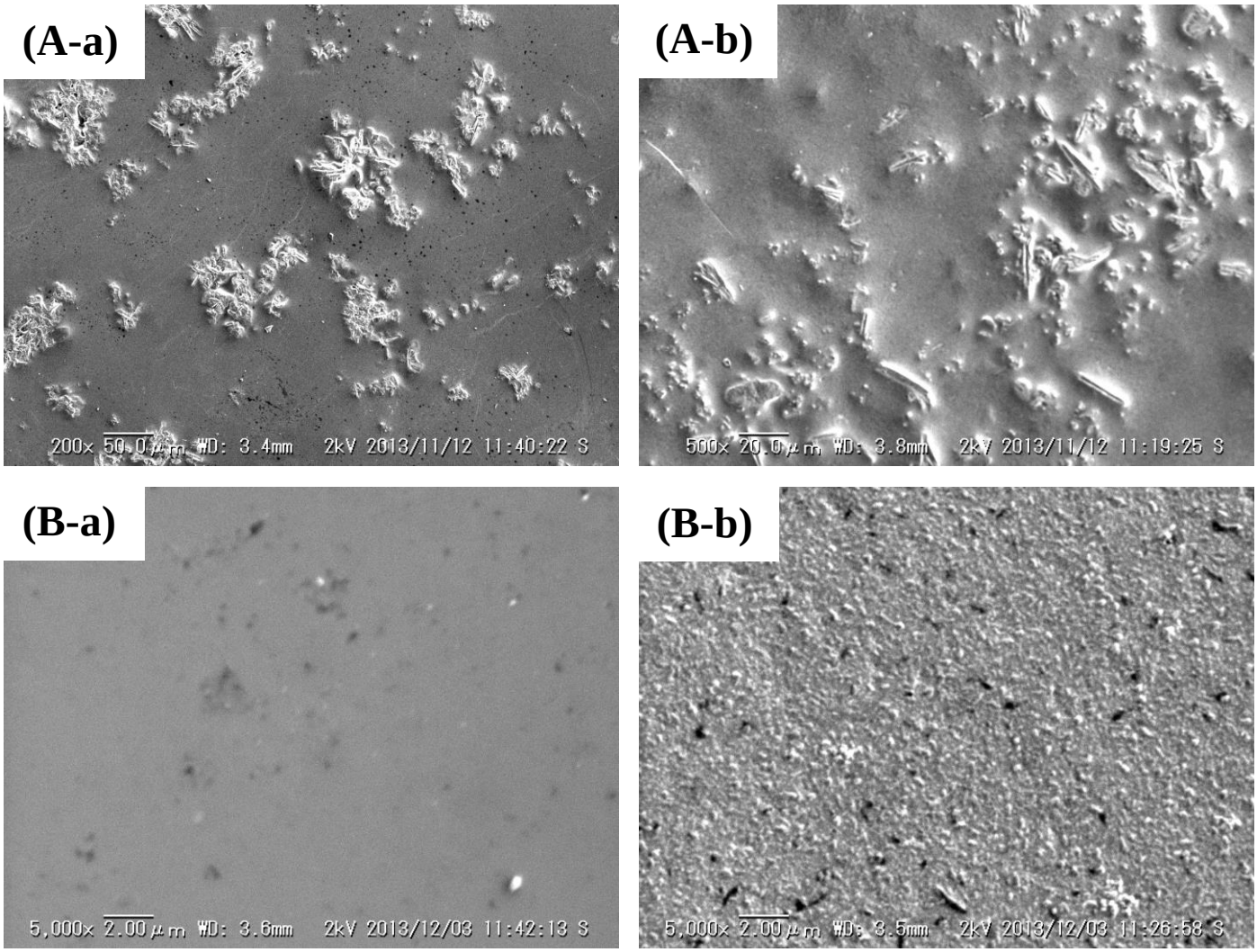
Khan *et al.*, Fig. 4



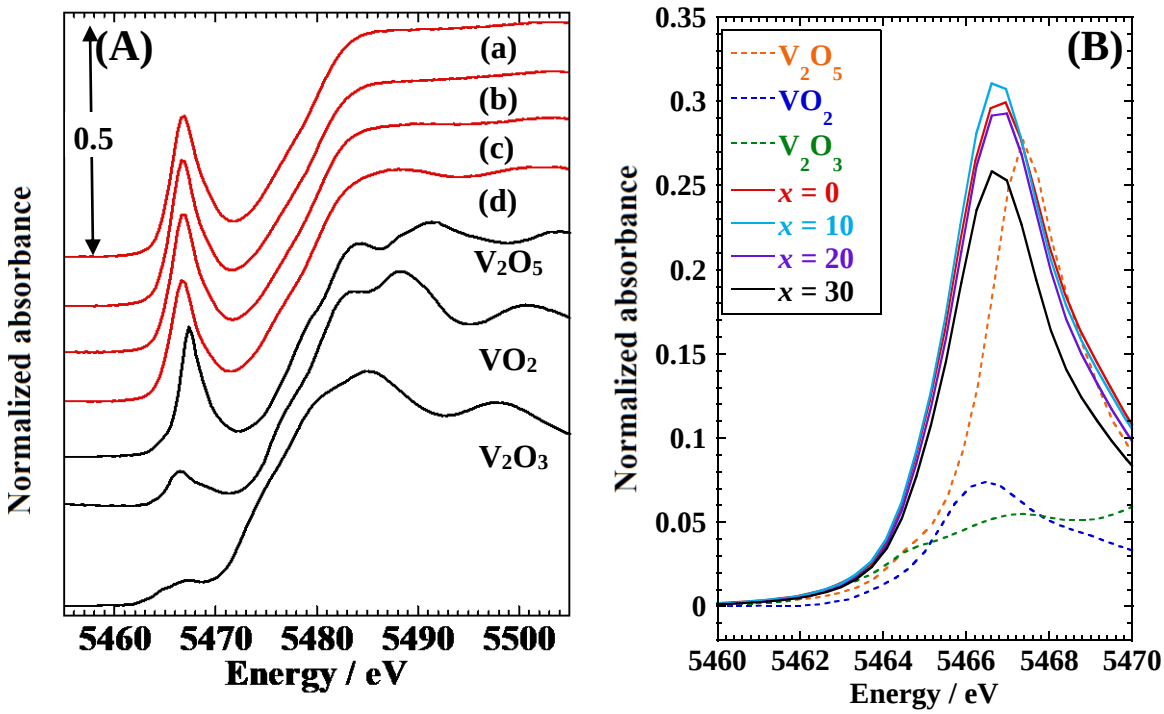
Khan *et al.*, Fig. 5



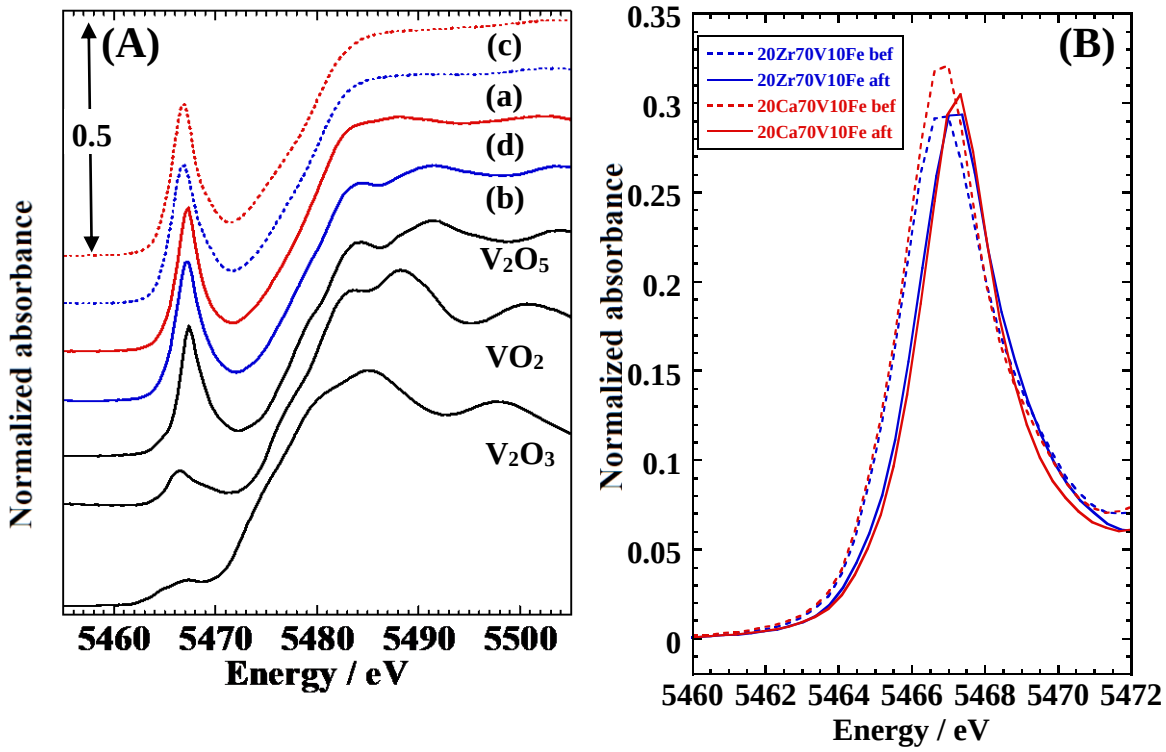
Khan *et al.*, Fig. 6



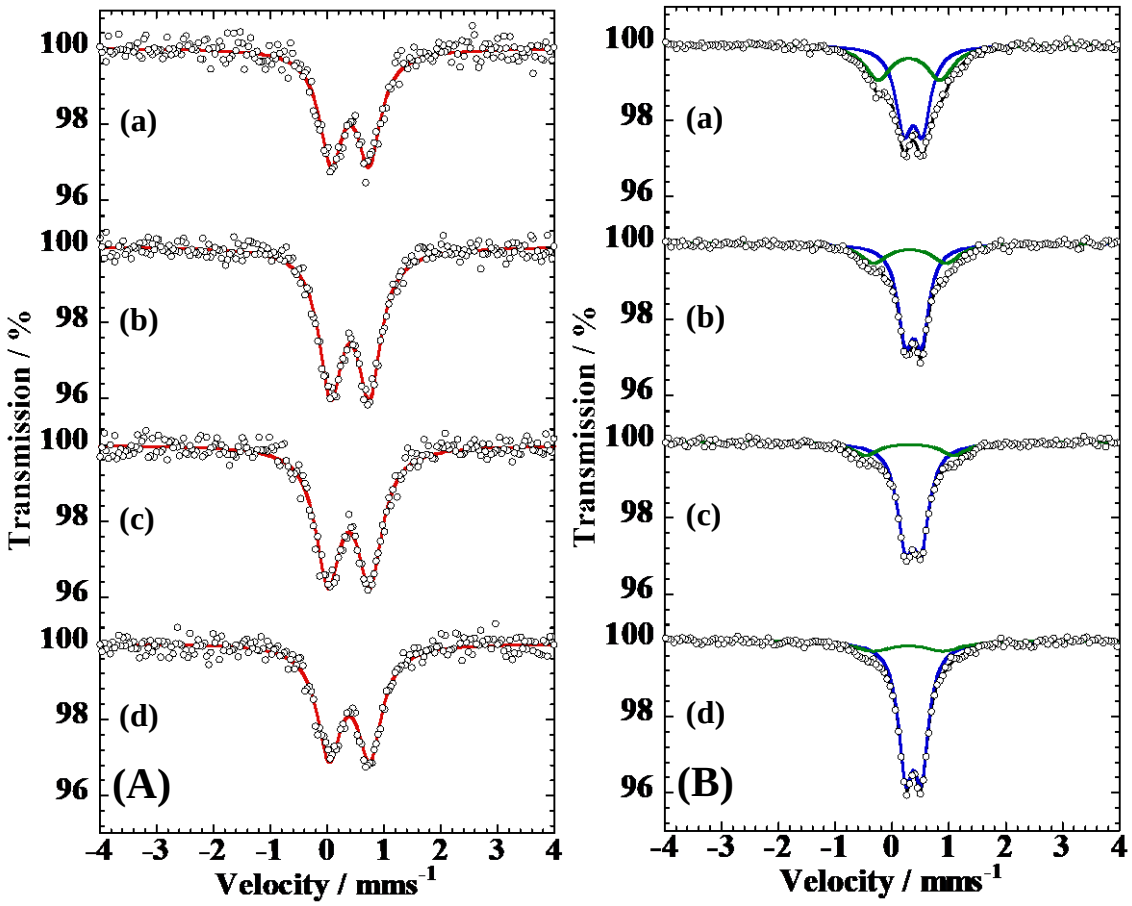
Khan *et al.*, Fig. 7



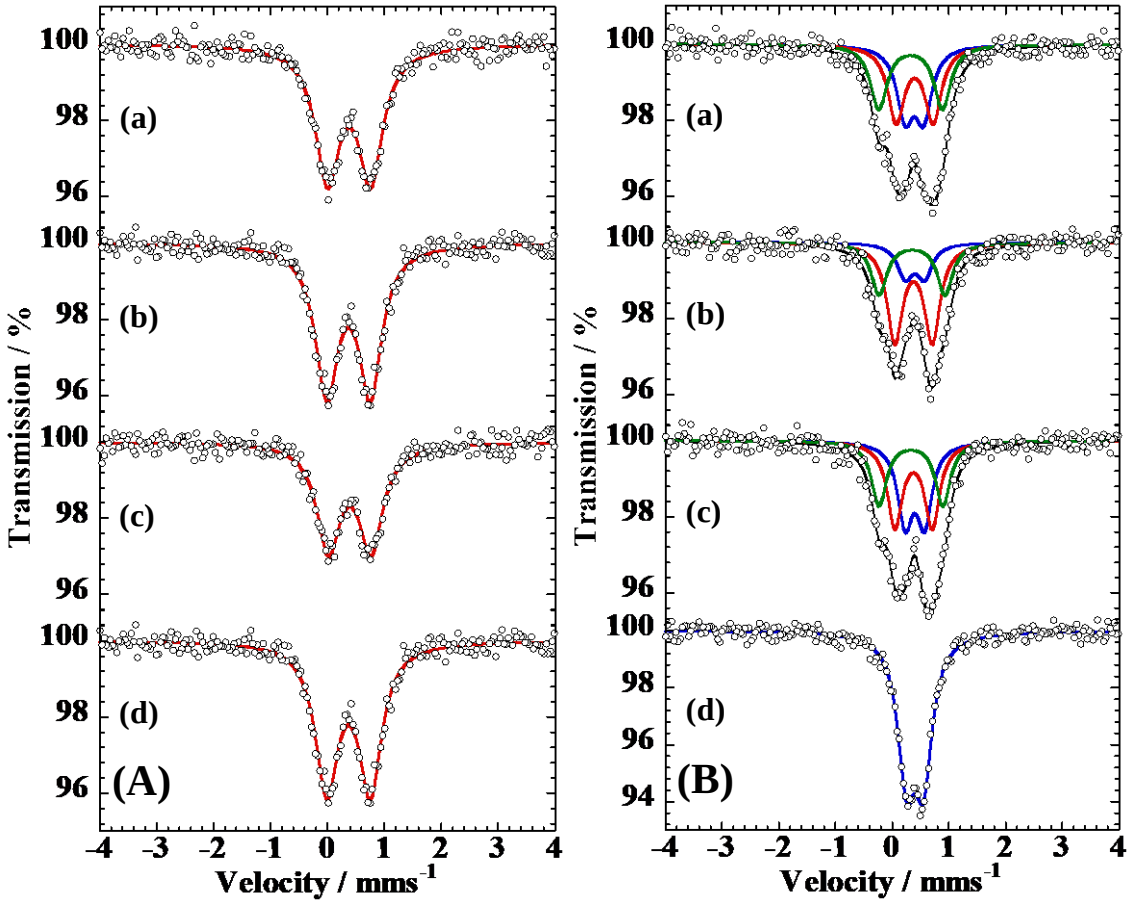
Khan *et al.*, Fig. 8



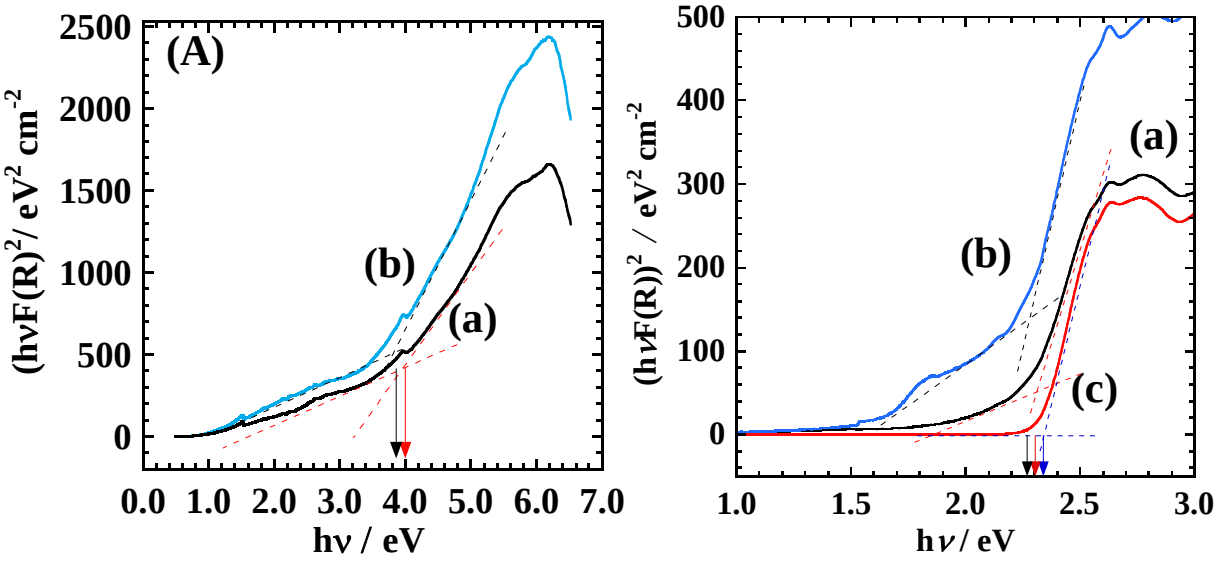
Khan *et al.*, Fig. 9



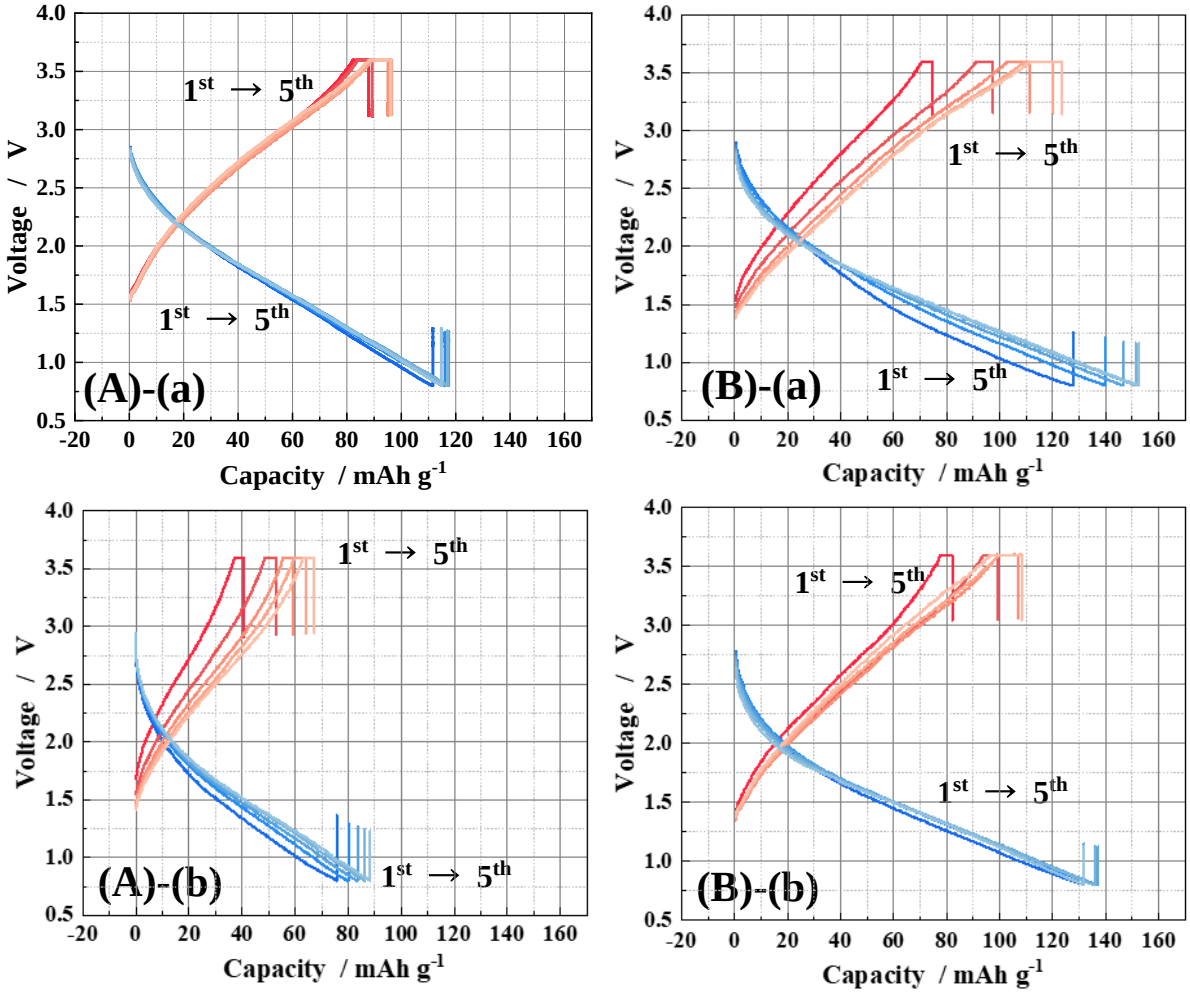
Khan *et al.*, Fig. 10



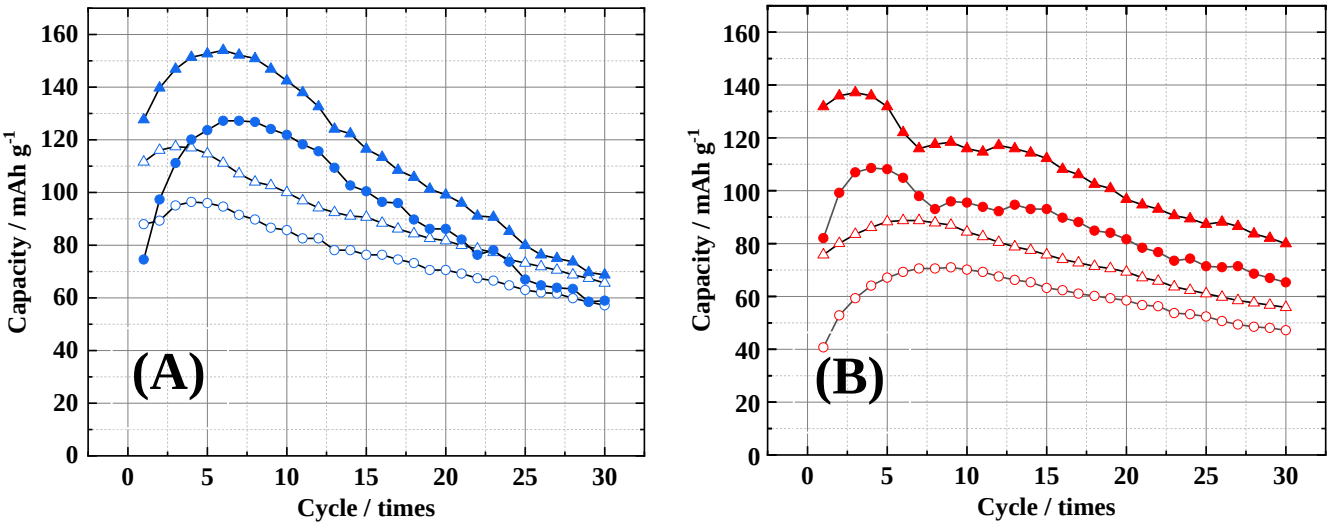
Khan *et al.*, Fig. 11



Khan *et al.*, Fig. 12



Khan *et al.*, Fig. 13



Khan *et al.*, Fig. 14