The cryogenic thermal expansion and tensile properties of nanofiber-ZrW_2O_8/EP nanocomposites

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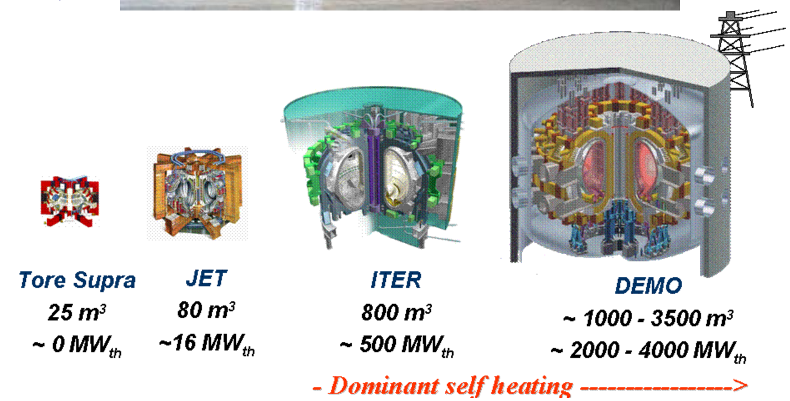
Contents

Introduction

advantages

epoxy resin

- **low density**
- **high elastic modulus**
- **electrical insulation properties**
- **heat and chemical resistance**
- **strong bond ability**

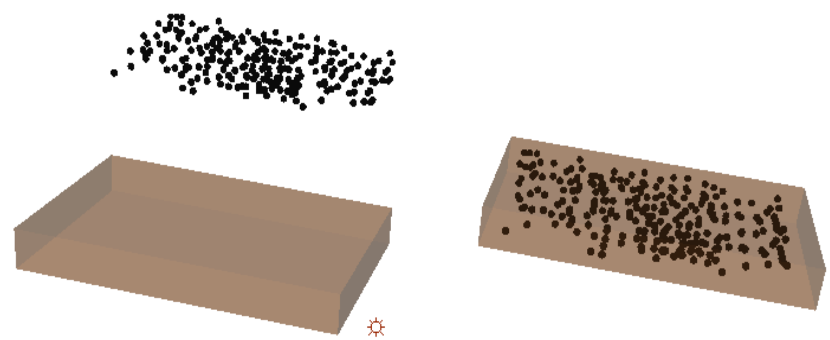


disadvantages

large CTE
40-80×10^{-6}/K

low thermal conductivity
RT : 0.15-0.25 W (m·K)$^{-1}$
77 K: 0.05-0.1W (m·K)$^{-1}$

➢ ***Adding filler materials to a polymer.***



Employing a rigid filler with a negative thermal expansion behavior can effectively reduce the CTE of the polymer composite.

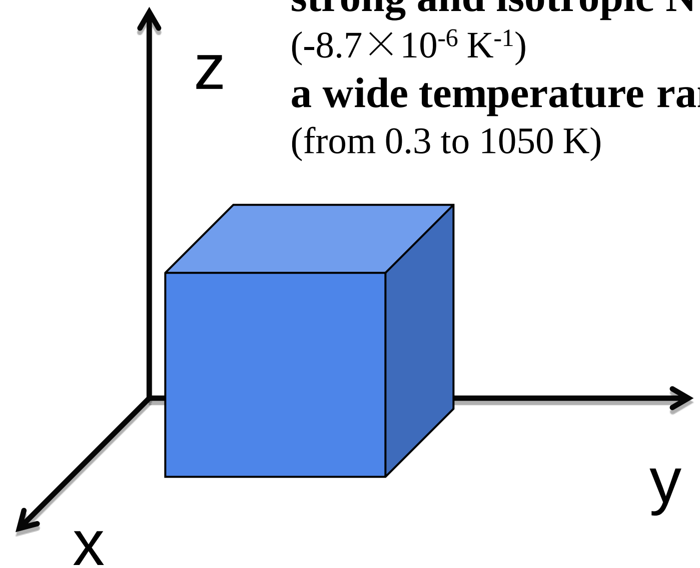
ZrW_2O_8

strong and isotropic NTE

(-8.7×10^{-6} K^{-1})

a wide temperature range

(from 0.3 to 1050 K)



$ZrOCl_2 \cdot 8H_2O$ + $Na_2WO_4 \cdot 2H_2O$ $\xrightarrow[\text{130 ℃ 24 h in Parr bomb}]{\text{HCl/1-butanol}}$ $ZrW_2O_7(OH)_2 \cdot 2H_2O$ $\xrightarrow[\text{500 ℃ 2 h}]{\text{sintered}}$ ZrW_2O_8

Preparation of ZrW_2O_8

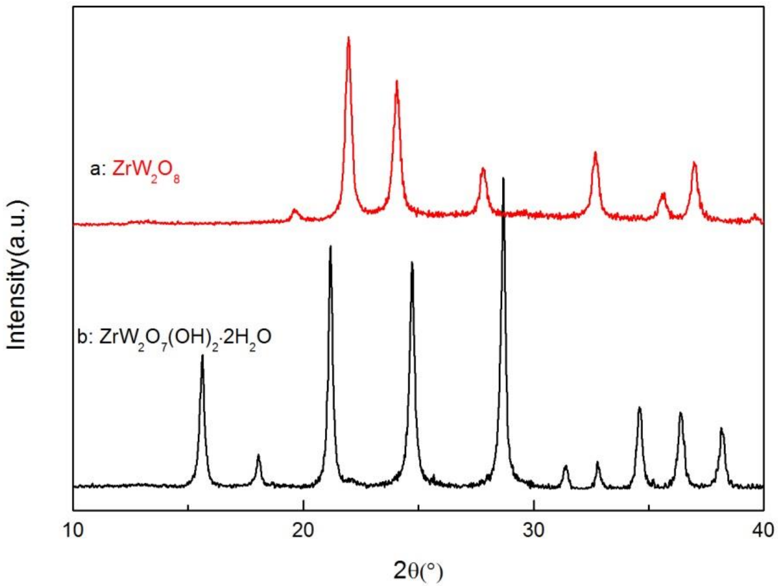
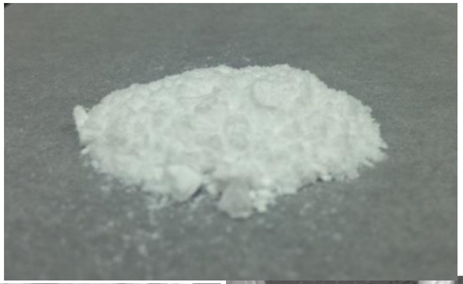
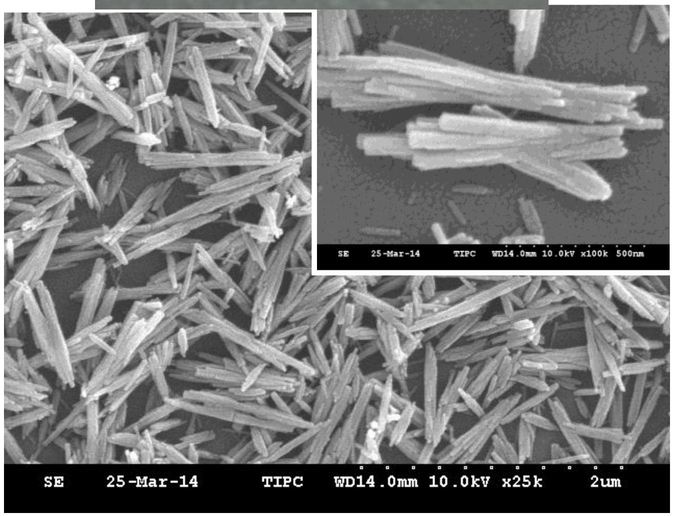


Fig.1. XRD patterns of $ZrW_2O_7(OH)_2.2H_2O$ and ZrW_2O_8.

$$ZrW_2O_7(OH)_2{\cdot}2H_2O \xrightarrow{500\ ^{o}C\ 2\ h} ZrW_2O_8$$

- **All peaks of $ZrW_2O_7(OH)_2{\cdot}2H_2O$ disappeared after sintering treatment;**
- **$ZrW_2O_7(OH)_2{\cdot}2H_2O$ translated into ZrW_2O_8 completely.**



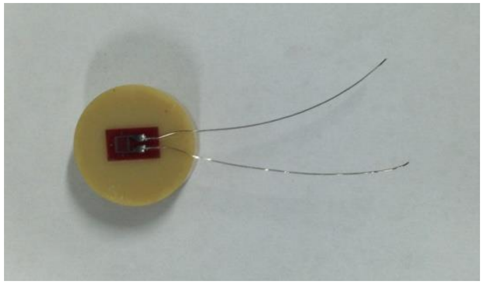


particles
20-40 nm wide,
600-800 nm long.

bundles
50–100 nm wide,
600-1000 nm long.

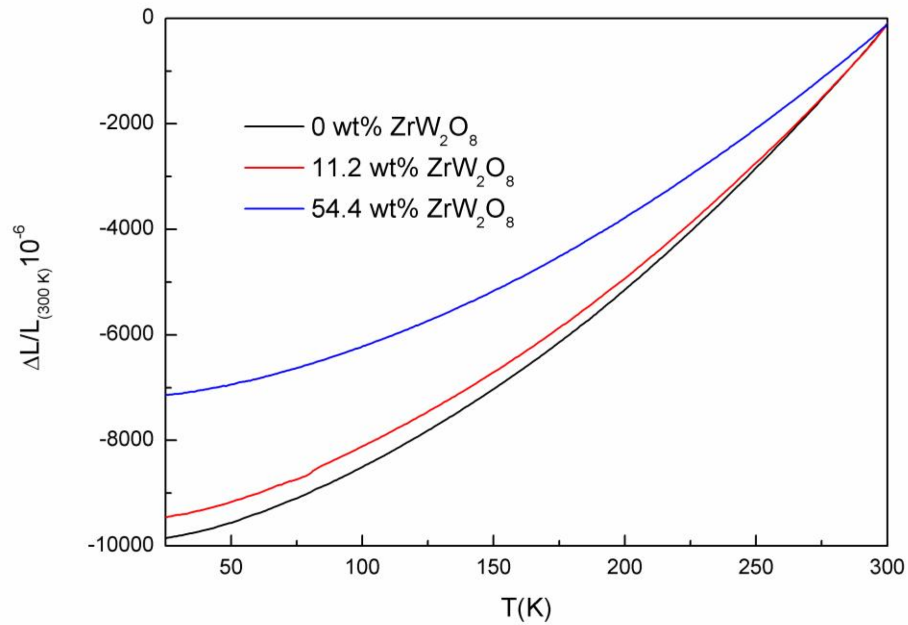
- **The agglomerates were fairly monodisperse and small enough to make them good candidates for incorporation into polymer composites.**

CTE of ZrW_2O_8/EP nanocomposites



- The nanocomposites with ZrW_2O_8 material show lower thermal expansion than that of neat epoxy resin;
- The linear thermal expansion of nanocomposite decreases with the increase weight content of ZrW_2O_8 nanofiber;
- The average CTE of the nanocomposite with 54.4 wt % NTE material is 27.5% lower than that of neat epoxy resin.

The ZrW_2O_8 reduces the CTE of the epoxy resin.

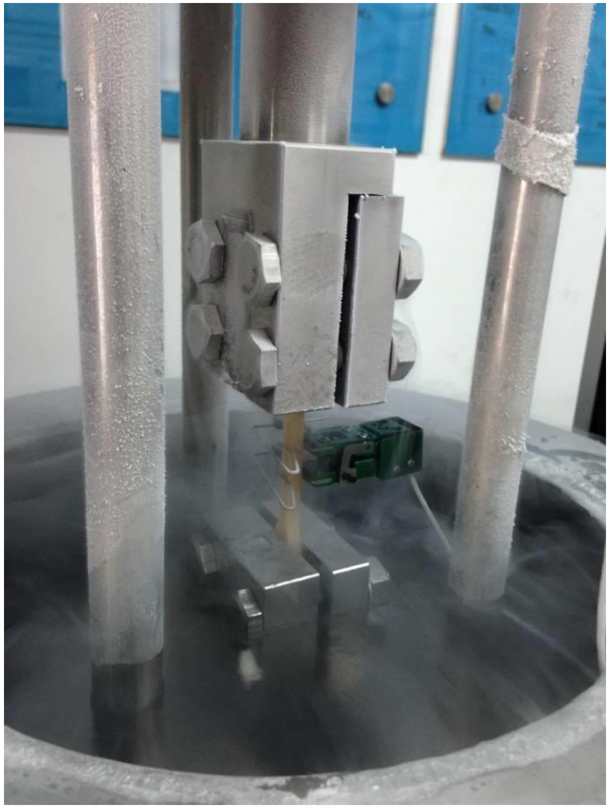


The linear thermal expansions as a function of temperature for the composites.

Table 1.The average CTE from 77 to 300 K for all samples.

wt % of NTE material	0	11.2	54.4
Average CET from 77 to 300 K ($\times 10^{-6}\ K^{-1}$)	35.787	34.364	25.952
Lower than CTE of neat epoxy resin (%)	——	4.0	27.5

Tencile test of ZrW_2O_8/EP



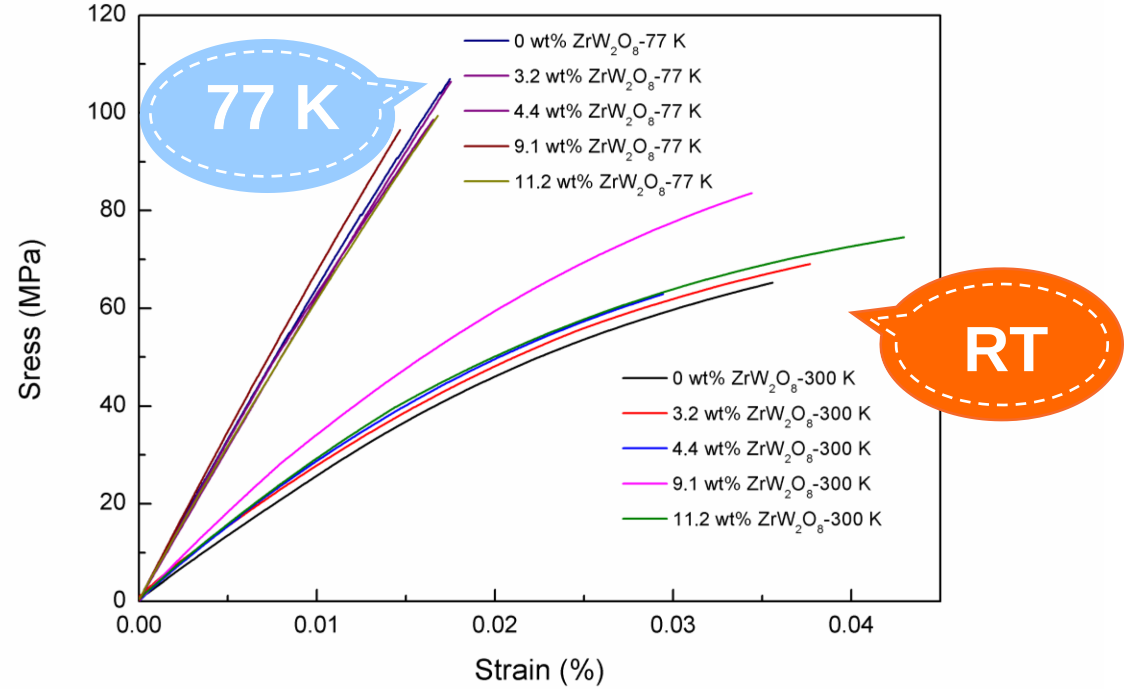


Fig.4. The stress-strain curves of ZrW_2O_8/EP nanocomposites.

- **At RT, the stress–strain curves show large plastic deformation prior to failure of the specimen, and the nanocomposites show a ductile behavior;**
- **When the temperature decreased to 77 K, the nanocomposites show a brittle behavior and increased strength.**

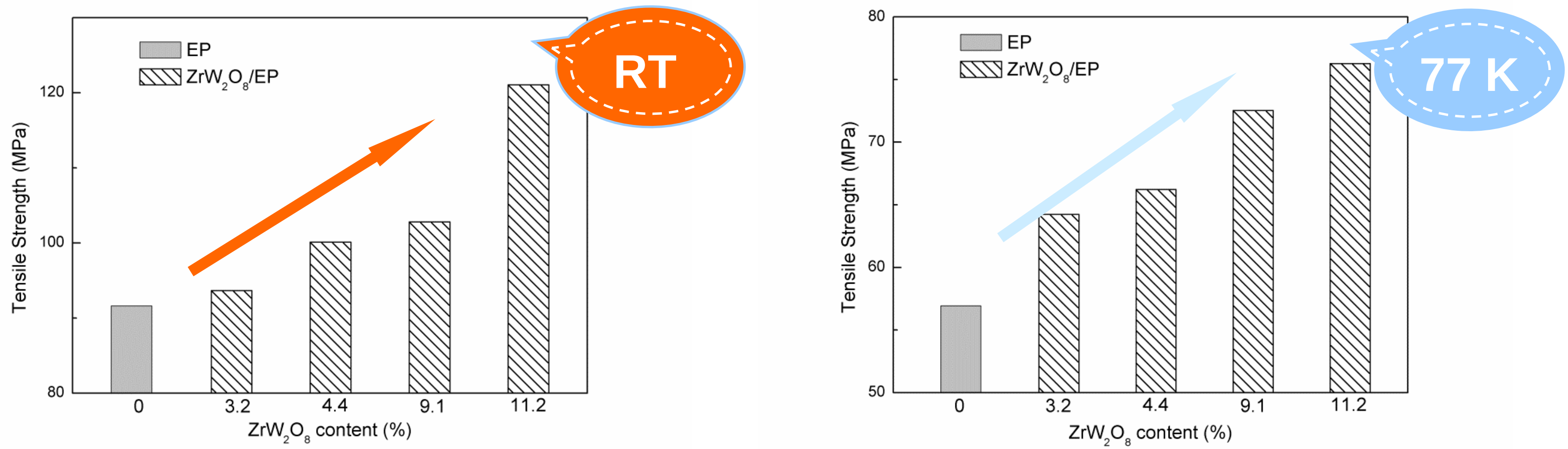


Fig.5. Tensile strength of ZrW_2O_8/EP nanocomposites: (a) at RT and (b) at 77 K.

wt % of NTE material	0	3.2	4.4	9.1	11.2
Tensile stength (MPa)	56.94	64.23	66.21	72.53	76.27
Higher than that of EP(%)	__	12.8	16.3	27.7	34.0

wt % of NTE material	0	3.2	4.4	9.1	11.2
Tensile stength (MPa)	91.63	93.67	100.11	102.79	121.06
Higher than that of EP(%)	__	2.2	9.3	12.2	32.1

- **The tensile strength at 77 K is much higher than that at RT;**
- **At RT and 77 K, the tensile strength increases when the weight fraction of ZrW_2O_8 nanofiber increases.**

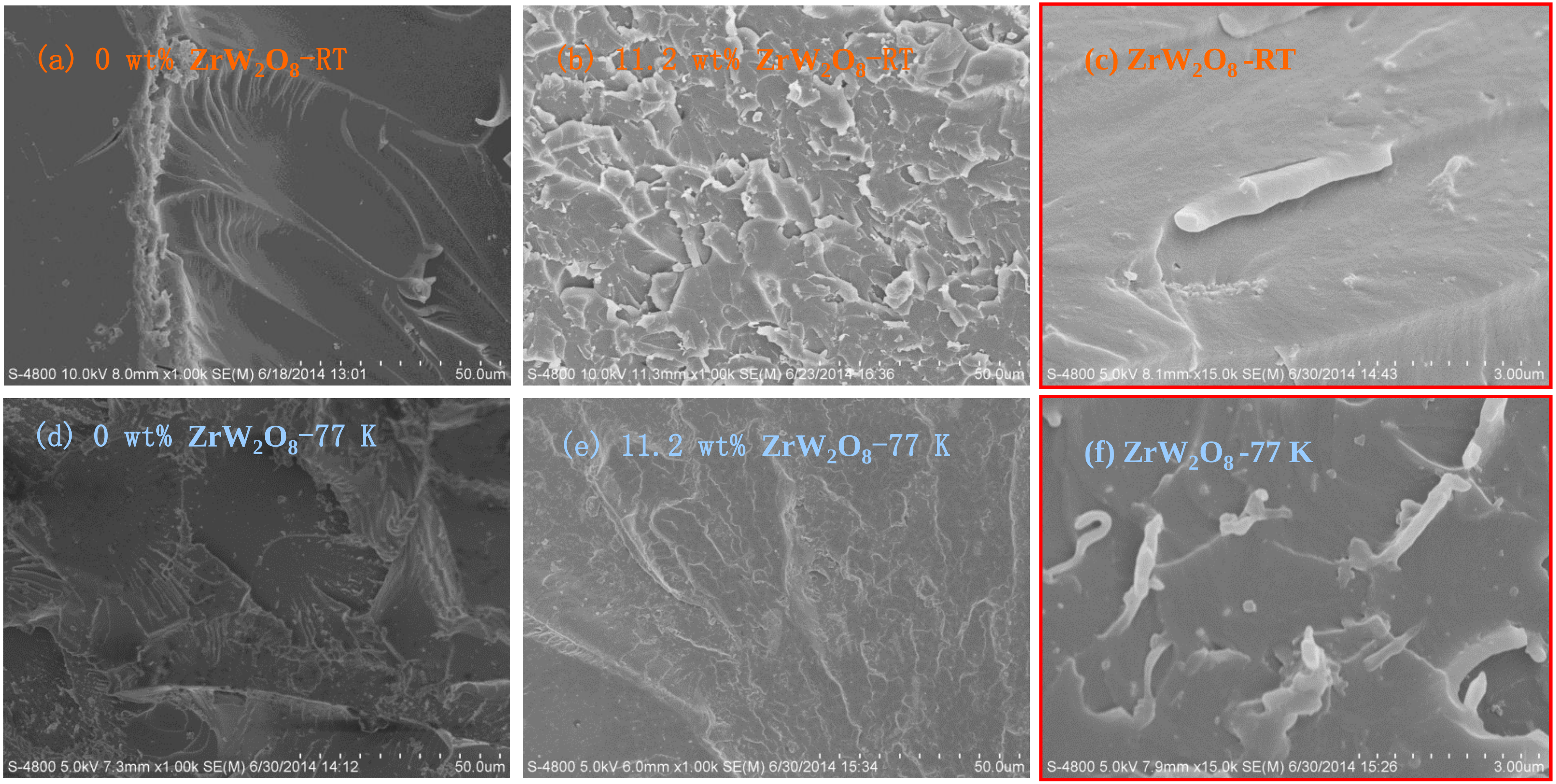


Fig. 6. SEM images of fracture surface.

- **Certain mount of the matrix was attached on the surface of the pulled out ZrW_2O_8 (c、f), illustrating the strong interfacial bonding between ZrW_2O_8 and the matrix.**
- **Compared with the pure matrix, the fracture surface of nanocomposites shows significant increase in roughness, demonstrating the toughening effect of ZrW_2O_8 in matrix.**
- **The fracture surface at 77 K is rougher than that at RT.**

Conclusions

- Nanofiber-ZrW_2O_8/EP nanocomposites were prepared and it is observed that the CTEs of the nanocomposites can be tailored significantly;

- The nanocomposites containing ZrW_2O_8 exhibits improved tensile strength than the neat epoxy resin.

Thanks