Regulating the upconversion luminescence properties of Tm^{3+}/Yb^{3+}-codoped $ZrScW_2PO_{12}$ microparticles with negative thermal expansion effect through thermal stimulation for optical thermometry

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Calculation of CCT values of $ZrScW_2PO_{12}:Tm^{3+}/xYb^{3+}$ microparticles

The correlated color temperature (CCT) values of final products as a function of doping content were investigated through applying the following expressions:[S1]

$$CCT = -437n^3 + 3601n^2 - 6846n + 5514.31 \quad (1)$$

$$n = (x - x_e)/(y - y_e) \quad (2)$$

where (x_e,y_e) = (0.3320,0.1858) and (x,y) refers to the color coordinate of synthesized microparticles. With the aid of these functions, the CCT values of studied samples were calculated, as listed in Table S2 and S3.

References

S1. P. Du, L. Luo, W. Cheng, *J. Am. Ceram. Soc*. 2020, **103**, 1149-1155.

Table S1 Color coordinates of $ZrScW_2PO_{12}:Tm^{3+}/xYb^{3+}$ microparticles as a function of Yb^{3+} content.

Compounds	Color coordinate	
	x	*y*
$ZrScW_2PO_{12}:Tm^{3+}/0.03Yb^{3+}$	0.185	0.124
$ZrScW_2PO_{12}:Tm^{3+}/0.05Yb^{3+}$	0.187	0.125
$ZrScW_2PO_{12}:Tm^{3+}/0.07Yb^{3+}$	0.186	0.124
$ZrScW_2PO_{12}:Tm^{3+}/0.09Yb^{3+}$	0.186	0.123
$ZrScW_2PO_{12}:Tm^{3+}/0.11Yb^{3+}$	0.185	0.123
$ZrScW_2PO_{12}:Tm^{3+}/0.13Yb^{3+}$	0.185	0.123

Table S2 Temperature dependent color coordinates and CCT of $ZrScW_2PO_{12}:Tm^{3+}/0.11Yb^{3+}$ microparticles.

Temperature	CCT	CIE coordinates	
		x	*y*
303 K	3099.2 K	0.194	0.122
323 K	3059.9 K	0.195	0.122
343 K	2974.9 K	0.195	0.121
363 K	2974.9 K	0.195	0.121
383 K	2858.3 K	0.196	0.120
403 K	2858.3 K	0.196	0.120
423 K	2821.6 K	0.197	0.120
443 K	2749.7 K	0.199	0.120
463 K	2749.7 K	0.199	0.120
483 K	2714.3 K	0.200	0.120
503 K	2714.3. K	0.202	0.121
523 K	2677.8 K	0.205	0.122
543 K	2642.4 K	0.208	0.123
563 K	2532.2 K	0.215	0.125
583 K	2391.2 K	0.221	0.126
603 K	2376.2 K	0.227	0.129
623 K	2196.7 K	0.236	0.131

Table S3 Temperature dependent color coordinates and CCT values of$ZrScW_2PO_{12}:Tm^{3+}/0.05Yb^{3+}$ microparticles.

Temperature	CCT	CIE coordinates	
		x	*y*
303 K	3534.3 K	0.193	0.126
323 K	3428.2 K	0.193	0.125
343 K	3415.2 K	0.191	0.124
363 K	3189.1 K	0.194	0.123
383 K	3099.2 K	0.194	0.122
403 K	3099.2 K	0.194	0.122
423 K	3018.9 K	0.196	0.122
443 K	3812.4 K	0.192	0.128
463 K	3018.9 K	0.196	0.122
483 K	2940.3 K	0.198	0.122
503 K	2984.1 K	0.199	0.123
523 K	2901.6 K	0.199	0.122
543 K	2871.6 K	0.206	0.125
563 K	2797.4 K	0.214	0.128
583 K	2758.6 K	0.219	0.130
603 K	275.3 K	0.223	0.131
623 K	2542.5 K	0.234	0.135

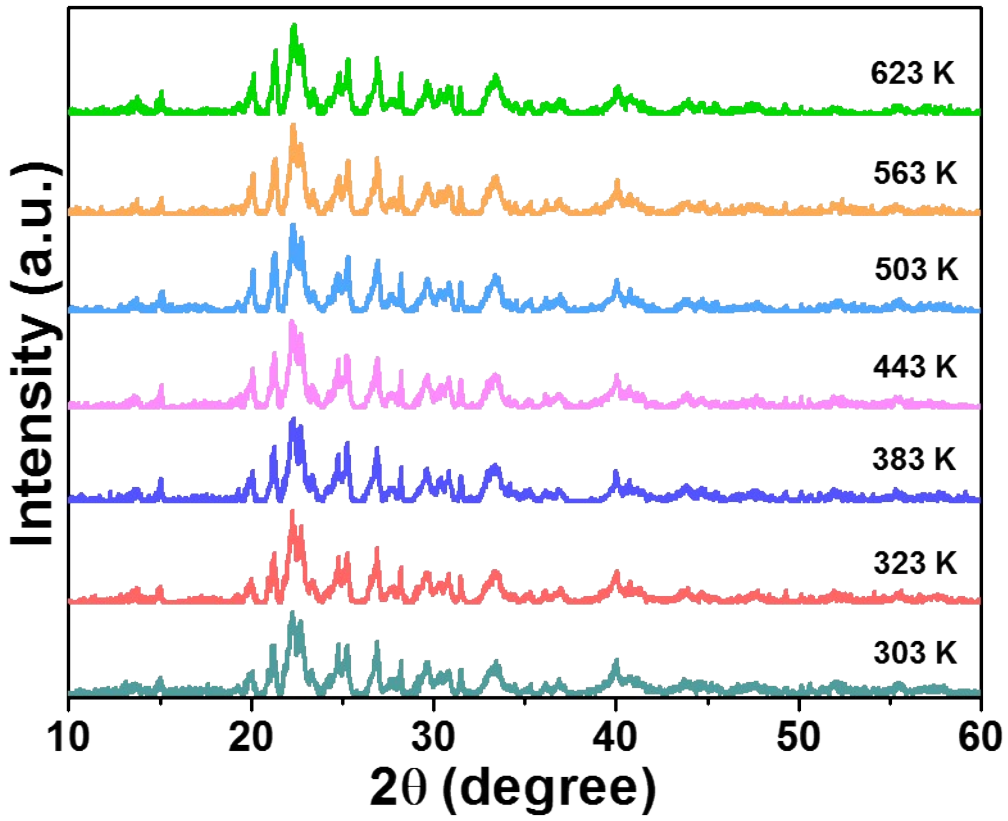

Figure S1. Temperature dependent XRD patterns of the $ZrScW_2PO_{12}:Tm^{3+}/0.11Yb^{3+}$ microparticles.

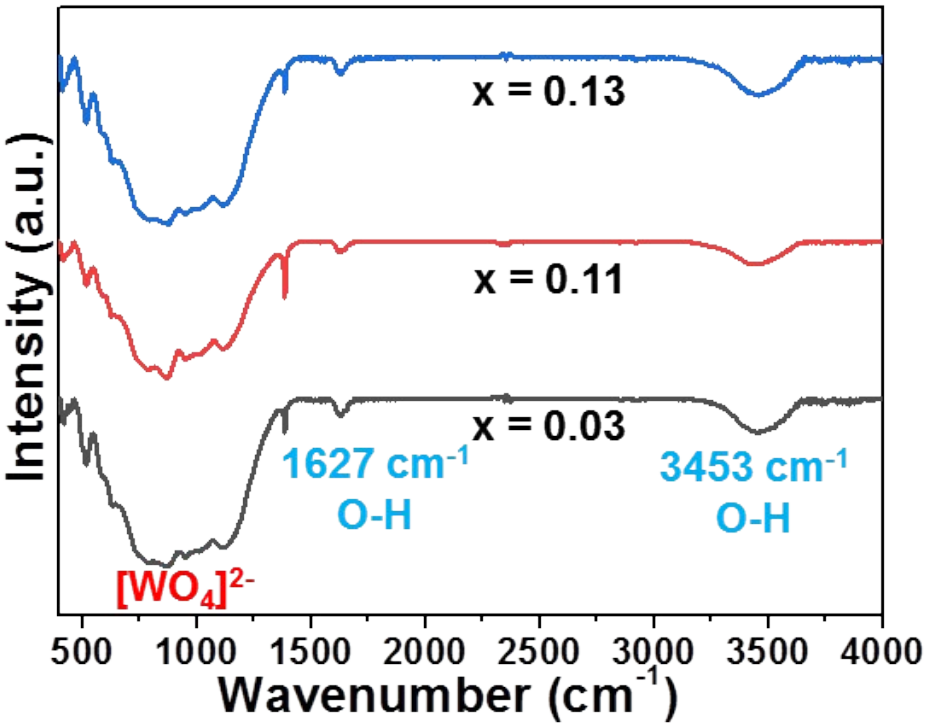

Figure S2. FT-IR spectra of $ZrScW_2PO_{12}:Tm^{3+}/xYb^{3+}$ microparticles with the doping content of 3, 11 and 13 mol%.

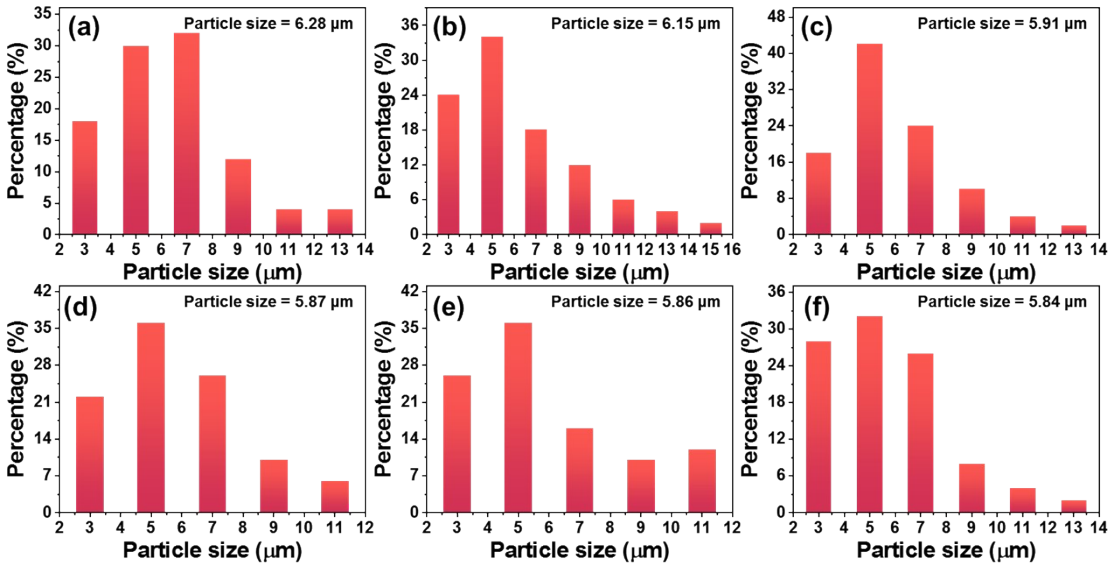

Figure S3. Particle size distributions of the $ZrScW_2PO_{12}:Tm^{3+}/xYb^{3+}$ microparticles doped with Yb^{3+} content of (a) $x = 0.03$, (b) $x = 0.05$, (c) $x = 0.07$, (d) $x = 0.09$, (e) $x = 0.11$ and (f) $x = 0.13$.

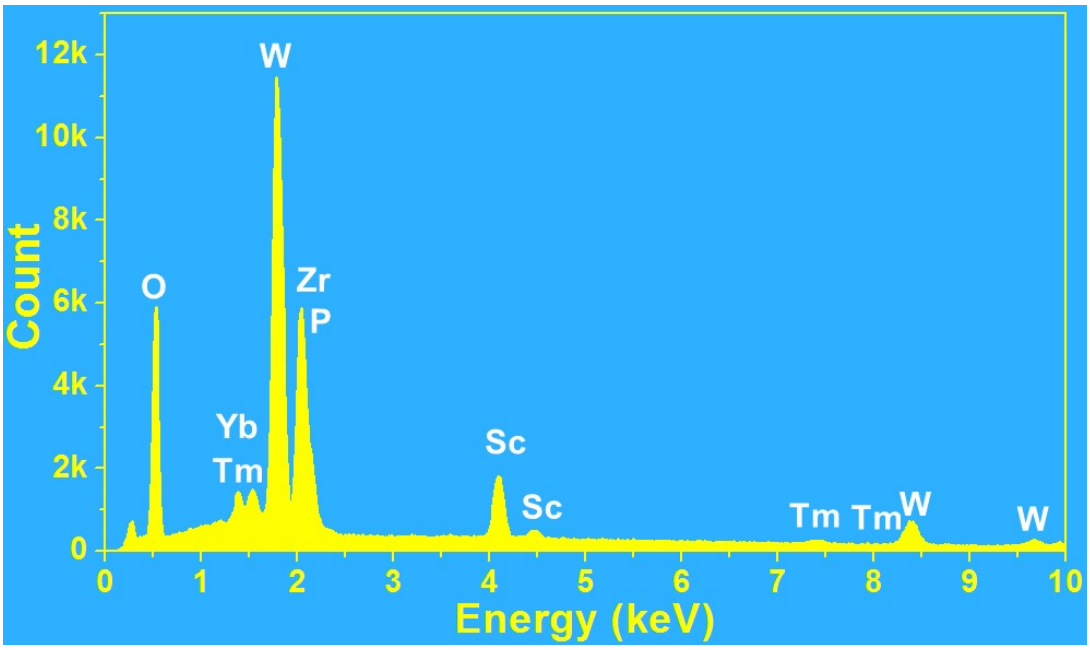

Figure S4. EDS spectrum of $ZrScW_2PO_{12}:Tm^{3+}/0.11Yb^{3+}$ microparticles.

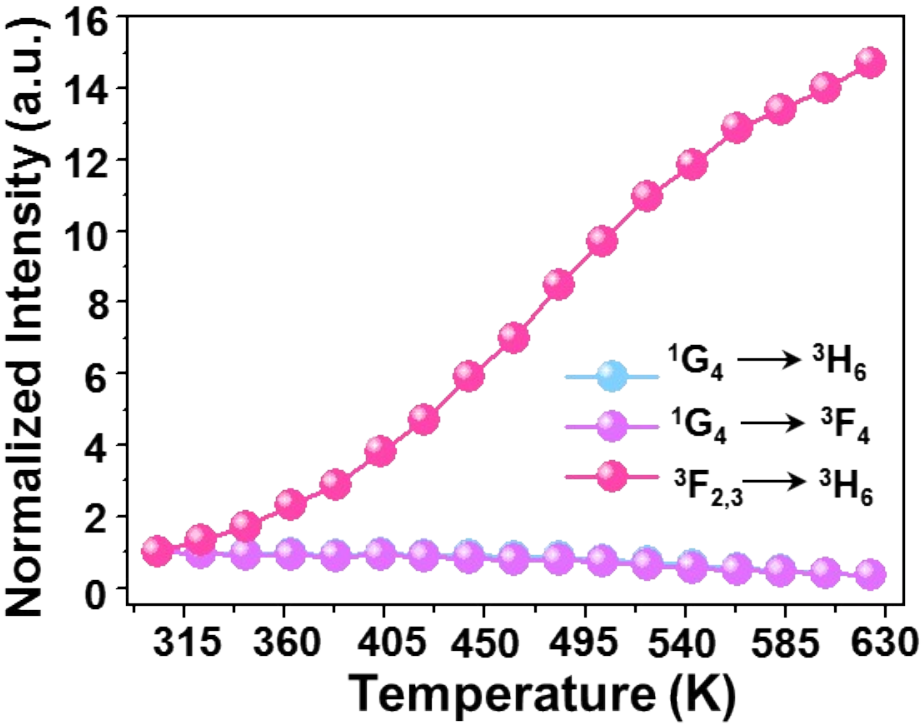

Figure S5. Normalized UC emission intensities of $ZrScW_2PO_{12}:Tm^{3+}/0.11Yb^{3+}$ microparticles as a function of temperature.

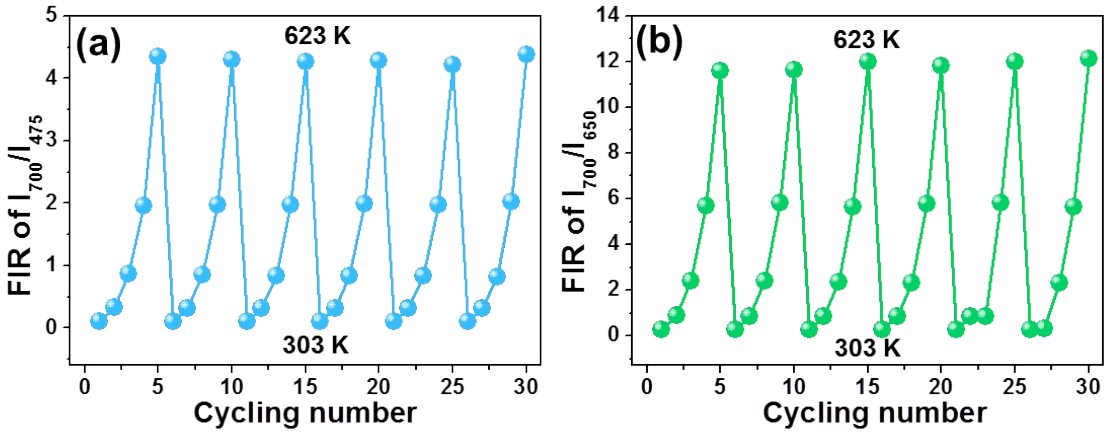

Figure S6 Temperature-dependent FIR values of (a) I_{700}/I_{475} and (b) I_{700}/I_{650} combinations with six cycles of heating and cooling between 303 and 623 K.

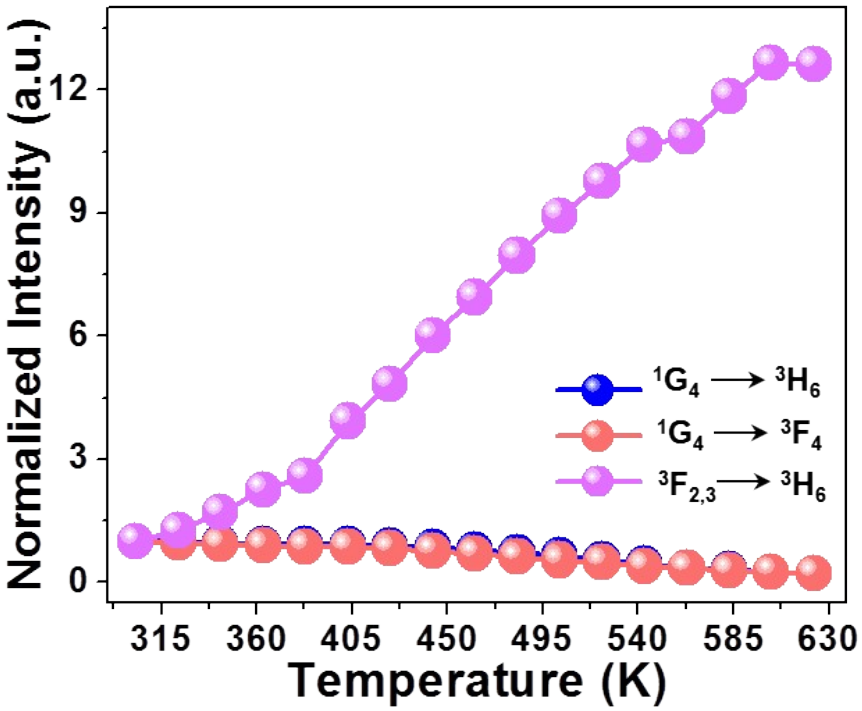

Figure S7. Normalized UC emission intensities of $ZrScW_2PO_{12}:Tm^{3+}/0.05Yb^{3+}$ microparticles as a function of temperature.

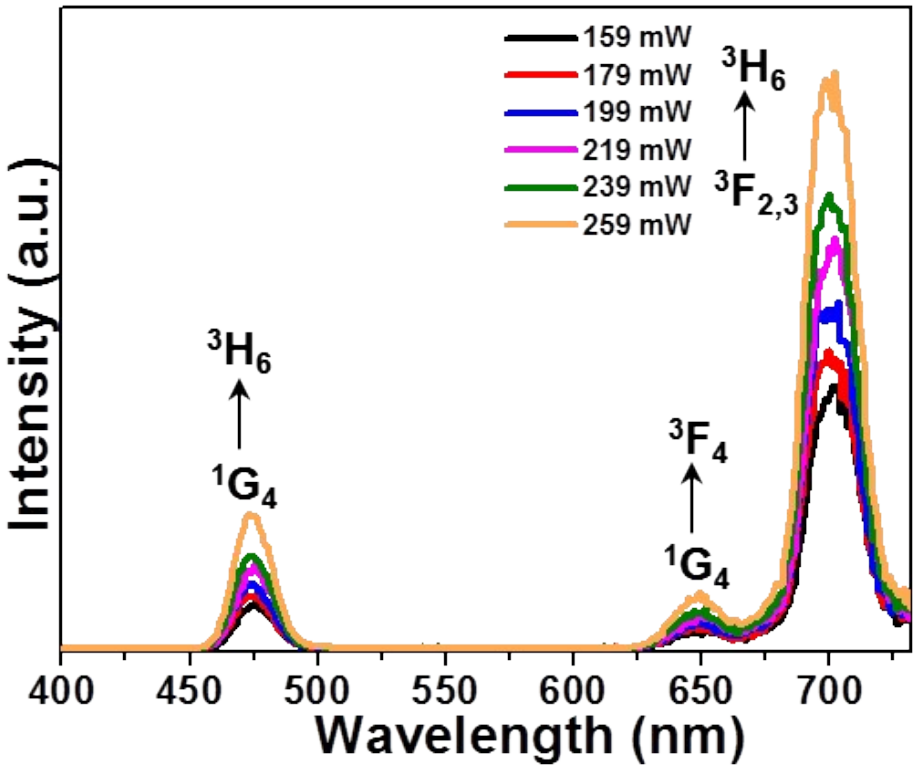

Figure S8. Laser pump power dependent UC emission spectra of $ZrScW_2PO_{12}:Tm^{3+}/0.05Yb^{3+}$ microparticles recorded at 623 K.