Supplementary Material

The luminescence and thermal stability enhancement by the matrix luminescence center dispersion in $Sc(V, P)O_4$: Dy^{3+} nano/submicron phosphor

Lili Han [a*], Dongcheng Zhu [a], Yujiang Wang [a], Fan Jiang [c], Xiyan Yang [a], Shuo Wang [a], Juan Zhao [a], Zhipeng Ci [b*], Chengwei Wang [a]

[a] *Key Laboratory of Atomic and Molecular Physics & Functional Materials of Gansu Province, College of Physics and Electronic Engineering, Northwest Normal University, Lanzhou 730070, China*

[b] *Key Laboratory of Special Function Materials and Structure Design of the Ministry of Education, School of Physical Science and Technology, Lanzhou University, Lanzhou 730000, China*

[c] *School of public health, wannan medical college, Wuhu 241000, China*

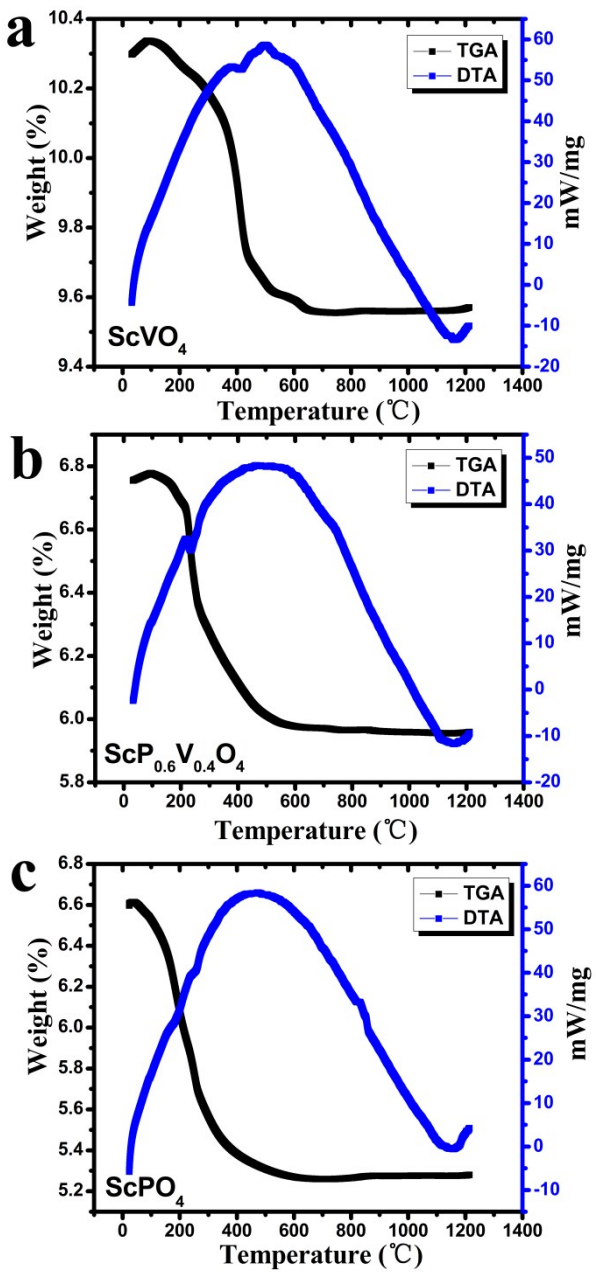

Figure S1 TG-DTA curves of as-prepared $ScVO_4$, $ScV_{0.6}P_{0.4}O_4$ and $ScPO_4$

The TG-DTA measurements are performed to investigate the phase formation of the samples synthesized in the aqueous solution. The TG-DTA curve of the as-prepared precursors for $ScVO_4$, $ScV_{0.6}P_{0.4}O_4$ and $ScPO_4$ heat-treated in air with a heating rate of 10 °C·min^{-1} is shown in Figure S1. From Figure S1a, TGA data of as-prepared powder shows a weight loss (about 8 wt. %) between the room temperature and 700 °C. The first 2 wt. % loss is observed below 400 °C due to the evaporation of

water and alcohol on the surface. The second 6 wt. % weight loss between about 400 and 700 °C can be mainly attributed to loss of crystal water. The weight loss is found to keep constant after 700 °C, which may be due to the crystallization process of $ScVO_4$. For the curve DTA, the obvious exothermic peak at about 500 °C implies that the crystallization process is easy to occur at this temperature point. After introducing 40 % P^{5+}, the total weight loss is above 12 wt. % and the exothermic peak is also at 500 °C. Till the position of V^{5+} is completely replaced by P^{5+}, the total weight loss reaches 20 wt. %. This is due to the loss surface water and crystal water is at the same weight while the corresponding molecular weight of $Sc(V, P)O_4$ is less. For the $ScVO_4$, $ScV_{0.6}P_{0.4}O_4$ and $ScPO_4$, all the weight remains steady after 800 °C. Thus, the heat-temperature of all samples is determined to be 800 °C.

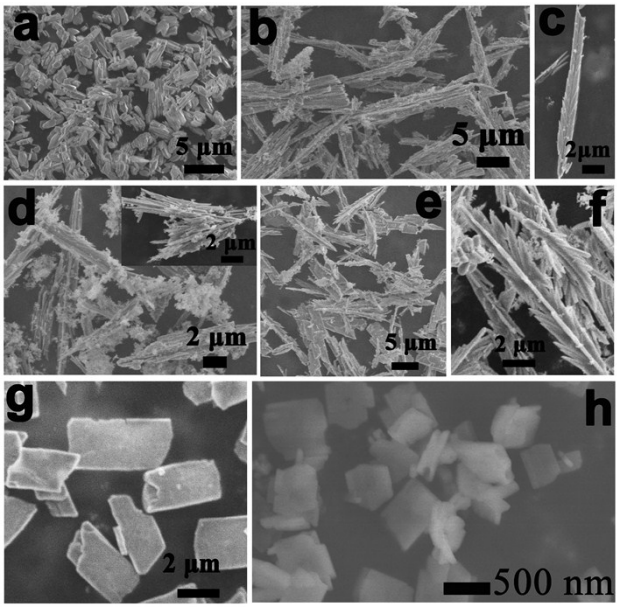

Fig. S2 SEM images of $ScV_{1-x}P_xO_4$ samples at pH=7, a-f, a′-f′ and a"-f" are the precursor at low and high magnification and the products after 800 °C heat treatment, respectively.

Whether the addition of P^{5+} has the same effect under neutral conditions, we investigated the SEM images of $ScV_{1-x}P_xO_4$ samples at pH=7, which are shown in Fig. S2. As shown in Fig. S2a, evenly distributed ear of wheat particles of about 1 μm are obtained. After introducing 0.2 P^{5+}, it is interesting that ear of wheat particles transform into long plume shape with larger diameter ratio (see Fig. S2b). From the high magnification image (see Fig. S2c), it is found that the sheets arrange densely and the stem of the feather is not insignificant. As the concentration of P^{5+} goes up to 0.4, the previous compact distribution seems to be dispersed. Obviously, there are a lot of fine particles scattered around the main structure shown in the inset of Fig. S2d. As expected, 0.6 P^{5+} will show a looser structure in which the feather is loosely distributed and the stem is very visible (see Fig. S2e and its high magnification Fig. S2f). More P^{5+} could result to thinner and smaller structure, which is verified in Fig. S2g. The feather changes into thin sheet when the concentration of P^{5+} is 0.8. When V^{5+} is completely replaced by P^{5+}, the wafer at the size of 500 nm is obtained shown in Fig. S2h. The above results show that the sample might prefer to form a two-dimensional plumage or flaky structure under neutral conditions.

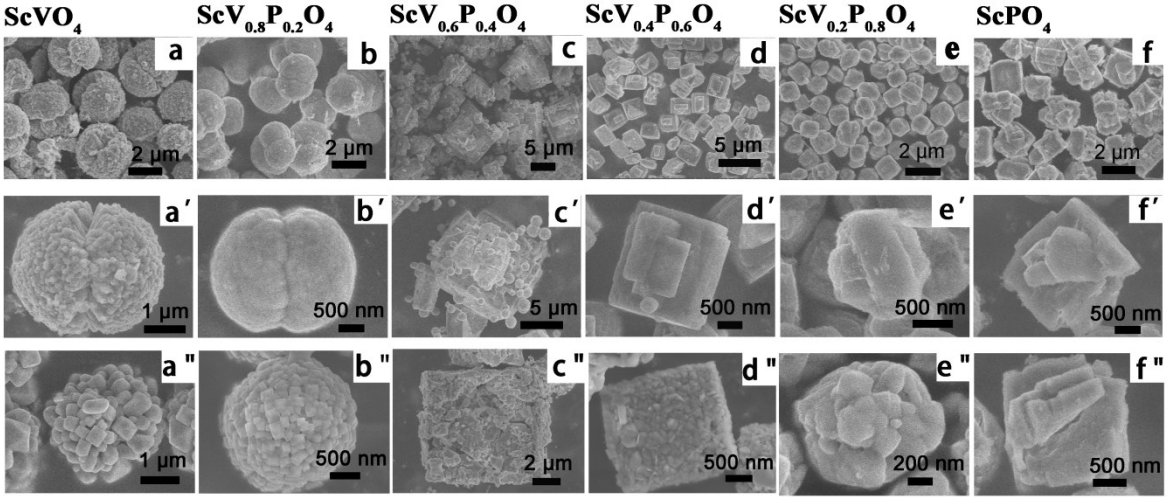

Fig. S3 SEM image of $ScV_{1-x}P_xO_4$ samples at pH=1

To further demonstrate the role of P^{5+}, morphological and size changes of $ScV_{1-x}P_xO_4$ samples at pH=1 were studied as shown in Fig. S3. Without P^{5+}, the precursor of $ScVO_4$ shows bilateral hemisphere of 3-4 μm composed of compact distribution granule at 200 nm (see Fig. S3a). After 800 °C heat treatment, small particles are reunited and it can't be distinguished between two halves (see Fig. S3a′). At this point, the overall size is slightly reduced but basically maintain in 3 μm. After introducing 0.2 P^{5+}, the sample still presents bilateral hemisphere but the smaller size of 2 μm (see Fig. S3b). When the content of P^{5+} is 0.4, the overall shape of the sample tends to the cube attached with particles of 1 μm (see Fig. S3c). As the concentration of P^{5+} goes up, the components that make up the particle are getting smaller and smaller (see Fig. S3d-f). The overall size of the sample is also smaller and smaller. The result shows that under acidic condition, the samples present homogeneous particles of sub-micron scale as a whole. And the addition of P^{5+} causes the samples to be transformed from the double hemisphere to the vertical square with the decreasing size. Again, the function of P^{5+} here is confirmed.

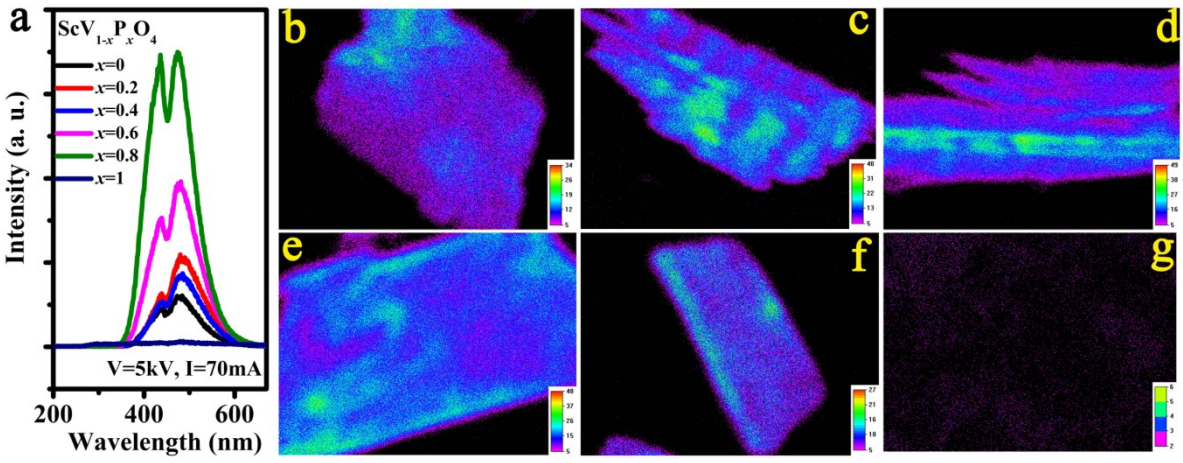

Fig. S4 (a) CL spectra and (b-f) CL mapping of $ScV_{1-x}P_xO_4$ ($0 \leq x \leq 1$) samples

As shown in Fig. S4a, all the spectra show two distinct broadband emissions. When the concentration of P^{5+} increases, the CL spectra intensity is increasing and the position is slightly shifted to the short wavelength direction, which are corresponding with the PL spectra. It turns out that the plan to enhance the luminescence by means of the introduction of P^{5+} has the same effect on electron beam excitation. Monitored at 480 nm, the CL mapping of $ScV_{1-x}P_xO_4$ has been measured and shown in Fig. S4b-g. In order to better compare the distribution of the luminescent center with different P^{5+} doping, the series of $ScV_{1-x}P_xO_4$ samples as pH = 7 are tested, whose morphologies present thin sheets. It can be observed that the emission light from $ScVO_4$ is focused on the edge of the columnar particles, implying VO_4^{3-} groups enrich at the grain boundary phases. In general, irregular morphology contains a lot of defects, and thus the emission light resulting from the defect is expected to lie in irregular morphology. This phenomenon has also been reported by Ru-Shi Liu, and Rong- Jun Xie. [1] As exhibited in Fig. S3e and f, the emission light is evenly distributed on the flaky surface. And no light has been detected in $ScPO_4$ particle, which is consistent with the guess.

1. L. Wang, X. Wang, T. Takeda, N. Hirosaki, Y. T. Tsai, R. S. Liu and R. J. Xie, Chem. Mater., 2015, 27, 8457-8466.