# Red and NIR persistent luminescence on $Eu^{3+}$ and $Yb^{3+}$-doped rare earth oxysulfides

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Persistent luminescence is a phenomenon whereby the light emission can last for a long time after ceasing the excitation source. With the discovery of $SrAl_2O_4:Eu^{2+},Dy^{3+}$ by Matsuzawa *et. al.* in 1996, several works were published over $Eu^{2+}$-activated (blue/green) persistent luminescent compounds[1]. This leds into a lack of red and near-infrared (NIR) emitting materials, which are promising for many applications, such as silicon solar cells sensitizers and nanoprobes for biomedical imaging[2]. The development of new red and NIR persistent luminescent materials is thus needed, and for that, the understanding of persistent luminescence mechanisms is essential. $Eu^{3+}$-doped yttrium oxysulfide is an efficient and well-established red phosphor since the 1960's. Strong red persistent luminescence was achieved by $Mg^{2+}$ and $Ti^{3+/IV}$ co-doping. However, as Ti presents a complicated electrochemistry, the persistent luminescence mechanism and the role of Ti ions are yet not-well understood[1,3].

In this work the $R_2O_2S:Ln^{3+}$ and $R_2O_2S:Ln^{3+},Mg^{2+},Ti^{3+/IV}$ materials ($R^{3+}$: La, Gd, Y) ($Ln^{3+}$: Eu, Yb) were prepared by a rapid solid-state microwave-assisted synthesis. $R_2O_2S:Eu^{3+}$ and $R_2O_2S:Eu^{3+},Mg^{2+},Ti^{3+/IV}$ materials presents a large number of narrow emission bands related to $Eu^{3+}$ $^5D_{2,1,0} \rightarrow {}^7F_J$ transitions. $R_2O_2S:Eu^{3+},Mg^{2+},Ti^{3+/IV}$ exhibt red persistent luminescence due to the $Eu^{3+}$ $^5D_0 \rightarrow {}^7F_J$ transitions and the $Ti^{3+}$ *d–d* broad band emission (**Fig. 1**). All $R_2O_2S:Yb^{3+}$ and $R_2O_2S:Yb^{3+},Mg^{2+},Ti^{3+/IV}$ materials presents NIR emission (~980 nm) due to the $Yb^{3+}$ $^2F_{5/2} \rightarrow {}^2F_{7/2}$ narrow emission bands. The NIR persistent luminescence were also verified in the $R_2O_2S:Yb^{3+},Mg^{2+},Ti^{3+/IV}$ materials.

A persistent luminescence mechanism for these materials were proposed based on spectroscopic data and thermoluminescence analyses. An energy transfer process $Ti^{3+} \rightarrow Eu^{3+}$ seems to occur in $Eu^{3+}$-doped materials, which improves the time and intensity of red emission. In the end, new NIR persistent luminescent materials were developed in this work, which can be later applied in a thin film form as silicon solar cells sensitizers.

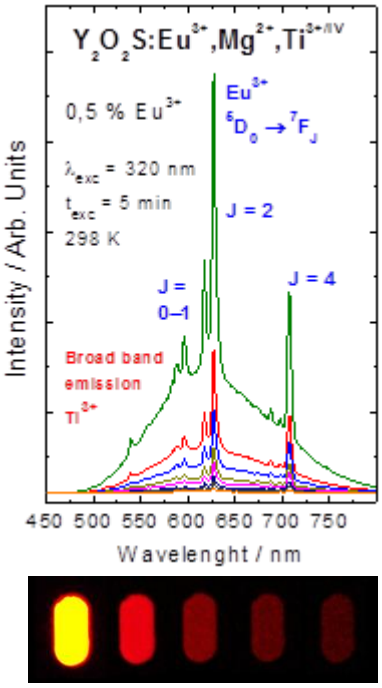


**Fig. 1** Persistent luminescence of $Y_2O_2S:Eu^{3+},Mg^{2+},Ti^{3+/IV}$

**References**

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