

## Research Article

## Open Access

Lei Wu and Yong Zhang\*

# Enhanced thermal oxidative stability of silicone rubber by using cerium-ferric complex oxide as thermal oxidative stabilizer

## Supplementary material

### 1 The details of swelling measurement for crosslink density

The crosslink density of SR composites was evaluated via the equilibrium swelling method in toluene according to literature (1-3). First, a silicone rubber sample was submerged in 100 mL of toluene in a sealed bottle. The equilibrium weight was reached after swelling in toluene for 5 days. Wiping residue solvent on the sample surface gently and weighting immediately. Then a drying process was given in vacuum oven at 70°C to evaporate the solvent completely, and the samples were reweighted. Molecular weight between crosslinks ( $M_c$ ) was estimated using Flory and French equation (Eq. S1).

$$M_c = \frac{-\rho_r V_0 \phi^{1/3}}{\ln(1-\phi) + \phi + \chi \phi^2} \quad (\text{S1})$$

where,  $M_c$  is the average molecular weight between two crosslink points;  $\rho_r$  is the density of silicone rubber before swelling.  $V_0$  is the mole volume of solvent;  $\phi$  is the volume percent of silicone rubber in the swelling rubber; and  $\chi$  is Flory-Huggins interaction parameter between polymer and solvent (taken at a value of 0.465 as a fair approximation). In this system,  $\phi$  is calculated as follows

$$\phi = \frac{W_1 / \rho_r}{(W_2 - W_1) / \rho_s + W_1 / \rho_s} \quad (\text{S2})$$

where,  $W_2$  and  $W_1$  are the weight of SR composite before and after swelling, respectively.  $\rho_r$  is the density of toluene under room temperature.

### 2 The surface modification of CeFeO-0.8

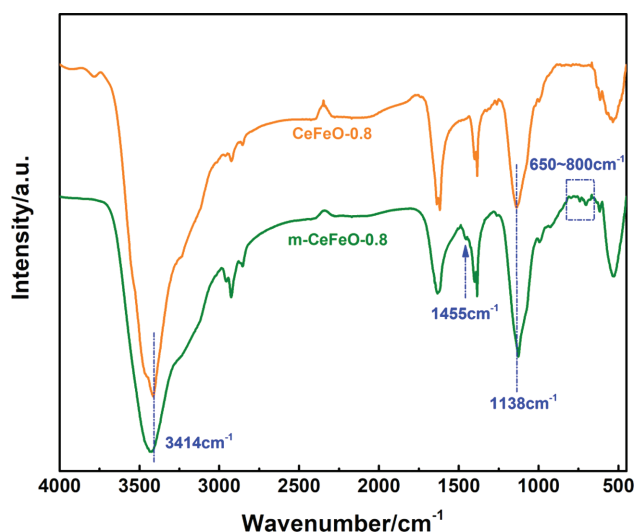
FTIR spectroscopy was performed to following up the variations in the functional groups of the synthesized particles before and after surface modification (CeFeO-0.8 and m-CeFeO-0.8). For m-CeFeO-0.8 (Figure S1), the characteristic band of metal-OH shifts from 3414  $\text{cm}^{-1}$  to 3432  $\text{cm}^{-1}$  and the density of metal hydroxyl decreases obviously. Besides, the other characteristic peak at 1138  $\text{cm}^{-1}$  assigned to the bending vibration of metal-OH shifts to 1126  $\text{cm}^{-1}$ , indicating the chemical environment variation for metal-OH after the modification of Ce-Fe complex oxide. Moreover, the appearance of the characteristic peaks observed at 1455  $\text{cm}^{-1}$  and 650~800  $\text{cm}^{-1}$  belongs to the phenyl group and Si-C bond, respectively. All features listed above supported the fact that PTES was successfully grafted onto the surface of CeFeO-0.8 particles via chemical reaction.

### 3 The dispersion of CeFeO-0.8 in the SR composites before and after modification

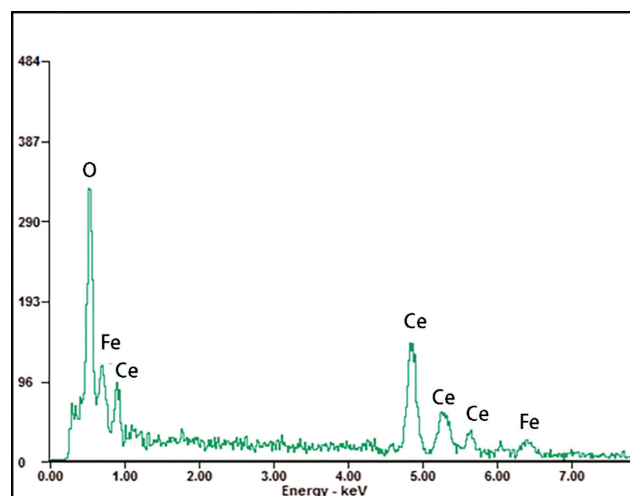
Figure S2 depicts the distribution of CeFeO-0.8 particles before and after modification in the SR matrix. Large particle agglomerates can be seen obviously in SR/CeFeO-0.8 composite whereas modified CeFeO-0.8

\* Corresponding author: Yong Zhang, School of Chemistry and Chemical Engineering, State Key Laboratory for Metal Matrix Composite Materials, Shanghai Jiao Tong University, Shanghai 200240, PR China, e-mail: yong\_zhang@sjtu.edu.cn, Tel: +86-21-54743261.

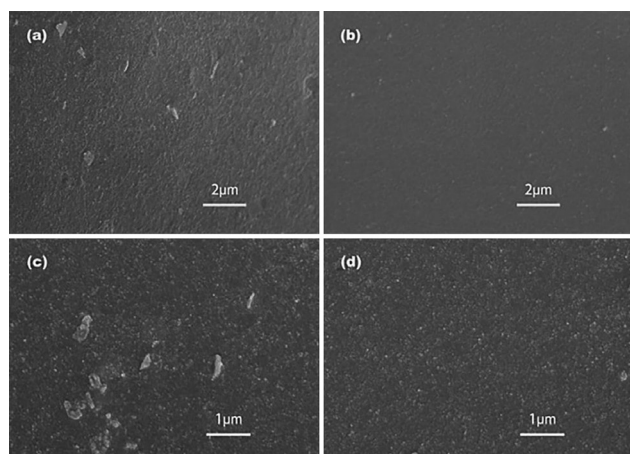
Lei Wu, School of Chemistry and Chemical Engineering, State Key Laboratory for Metal Matrix Composite Materials, Shanghai Jiao Tong University, Shanghai 200240, PR China.



**Figure S1:** FTIR spectra of CeFeO-0.8 complex oxide before and after modification.



**Figure S3:** Energy dispersive spectroscopy of CeFeO-0.8 complex oxide.



**Figure S2:** SEM images of SR/CeFeO-0.8 ((a), (c)) and SR/m-CeFeO-0.8 ((b), (d)).

particles show smaller aggregates in SR. The different morphologies present the positive role PTES plays in the dispersion of CeFeO-0.8 in silicone rubber.

## 4 Energy dispersive spectroscopy of CeFeO-0.8

From the EDS analysis of the labelled spot in Figure S3, the mole ratio of Fe/Ce is a little above 0.25.

## References

1. Diao S., Jin K., Yang Z., Lu H., Feng S., Zhang C., The effect of phenyl modified fumed silica on radiation resistance of silicone rubber. *Mater Chem Phys*, 2011, 129(1-2), 202-208.
2. Jiang Z., Jie Z., Feng S., Effects of polymethylvinylsilicone oil with side tetraphenylphenyl groups on the radiation resistance of addition-type silicone rubber. *J Appl Polym Sci*, 2010, 104(6), 4144-4148.
3. Maxwell R.S., Chinn S.C., Alviso C.T., Harvey C.A., Giuliani J.R., Wilson T.S., et al., Quantification of radiation induced crosslinking in a commercial, toughened silicone rubber, TR55 by <sup>1</sup>H MQ-NMR. *Polym Degrad Stabil*, 2009, 94(3), 456-464.