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In-situ investigation of melting characteristics of waste selective catalytic reduction catalysts during harmless melting treatment

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Paper content overview

- Thermal melting technology was applied to dispose of waste SCR catalyst.
- Additive formulas were determined by multicomponent phase diagrams.
- Melting characteristics and mineral phase transformation of waste SCR catalyst with additives were investigated by means of heating stage microscope, TG/DSC, Factsage simulation and XRD.
- The leaching toxicity of heavy metal elements was tested by ICP-OES.
- The additives formula of Fe_2O_3-CaO-SiO_2-Al_2O_3 demonstrated the optimal fluxing behavior.

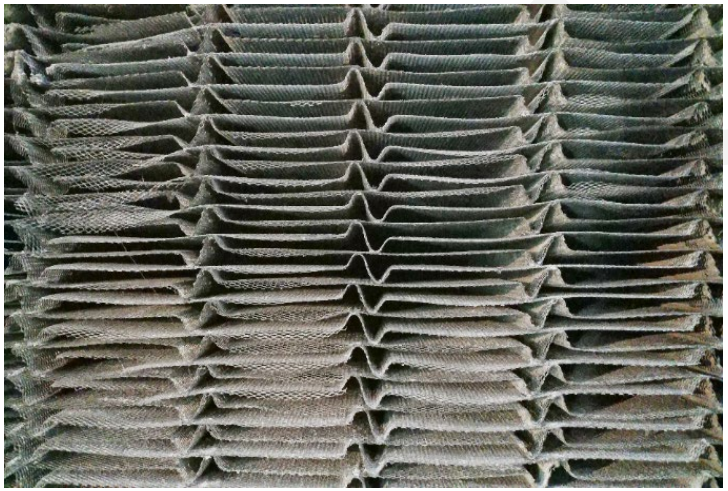
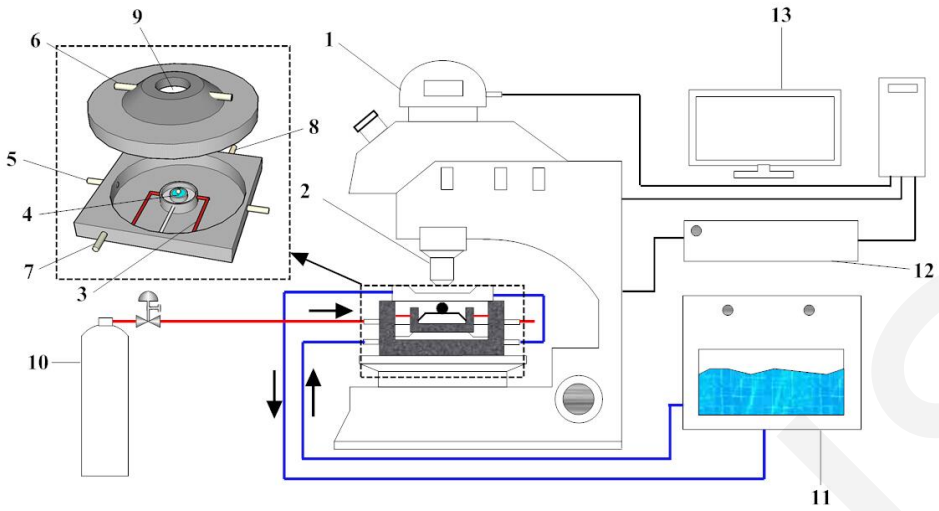


Plate type waste SCR catalyst

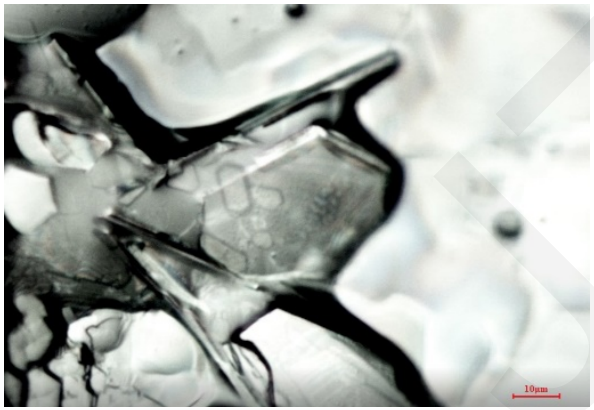
Pulverized waste SCR catalyst

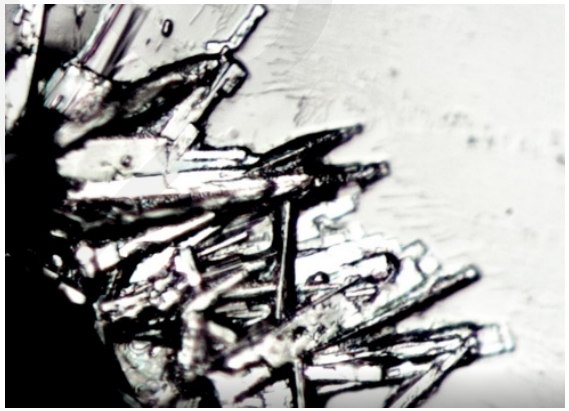
Experimental facility

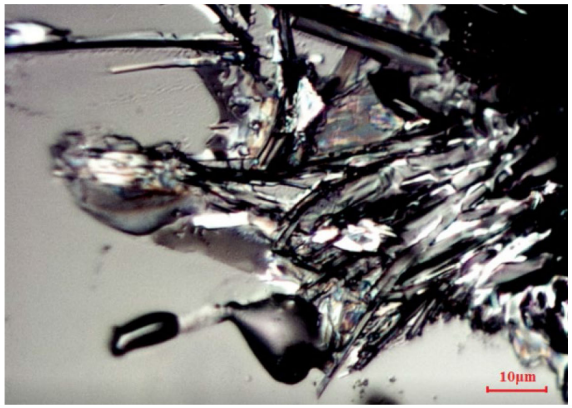


1. Digital Camera; 2. Microscope Lens; 3. Heating Wire; 4. Sapphire Substrate; 5. Water Inlet; 6. Water Outlet; 7. Gas inlet; 8. Gas Outlet; 9. Quartz Glass; 10. Air Cylinder; 11. Cooling Water Tank; 12. Temperature Controller; 13. Online Computer System

Heating stage microscope



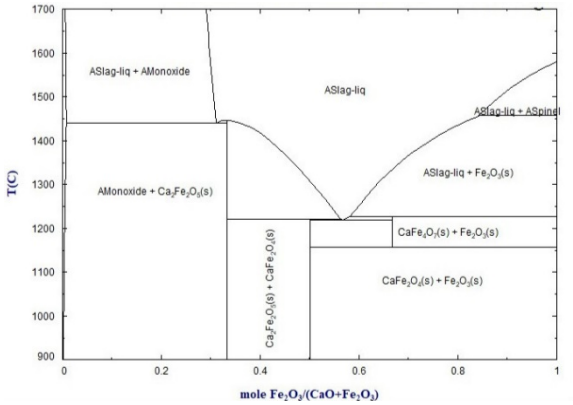




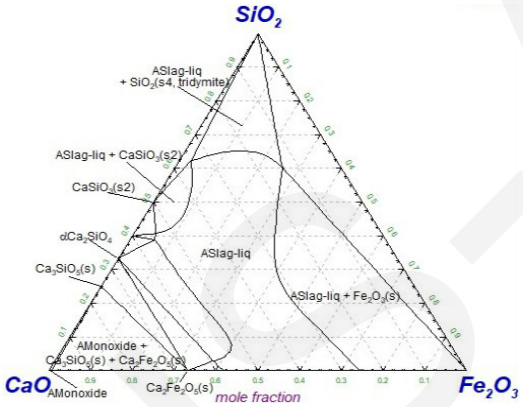
Melted samples with additives added

Experimental facility

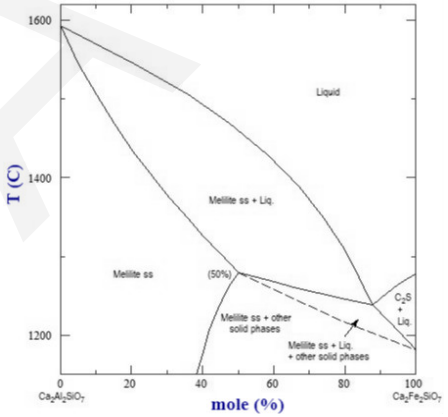
CaO-Fe_2O_3



CaO-SiO_2-Fe_2O_3



CaO-SiO_2-Fe_2O_3-Al_2O_3



Multicomponent phase diagrams

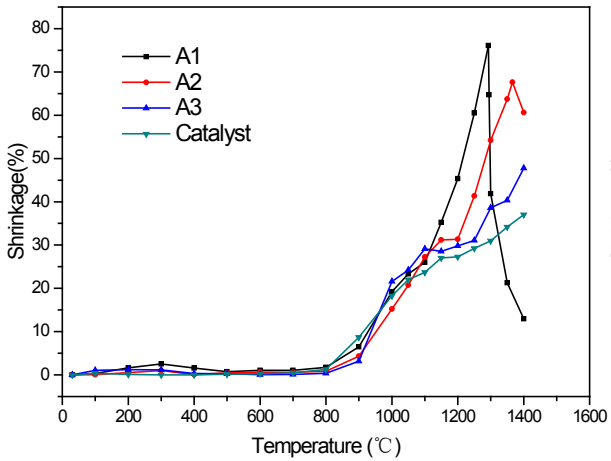
Samples	Catalyst	CaO	Fe_2O_3	SiO_2	Al_2O_3
A1	10.00	18.00	72.00	——	——
A2	50.00	10.00	40.00	——	——
A3	90.00	2.00	8.00	——	——
B1	10.00	24.30	54.00	11.70	——
B2	50.00	13.50	30.00	6.50	——
B3	90.00	2.70	6.00	1.30	——
C1	10.00	11.70	70.20	5.94	2.16
C2	50.00	6.50	39.00	3.30	1.20
C3	90.00	1.30	7.80	0.66	0.24

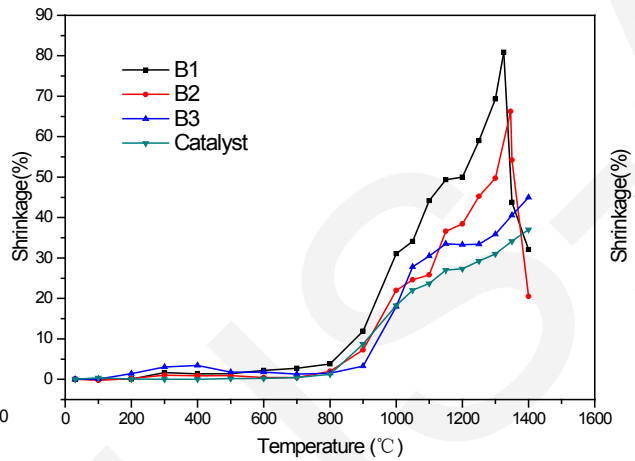
Optimal additive formula

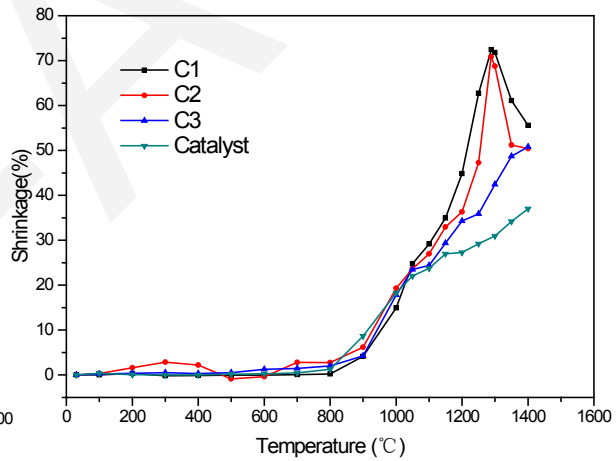
6.50 wt. % CaO
3.30 wt. % SiO_2
39.0 wt. % Fe_2O_3
1.20 wt. % Al_2O_3

Melting treatment results

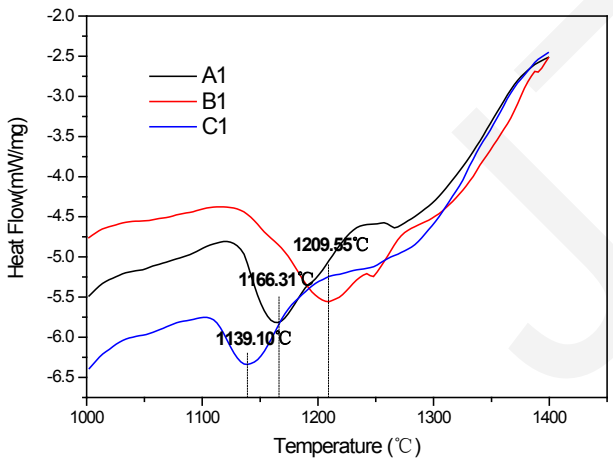
Effect of additives on the area shrinkage

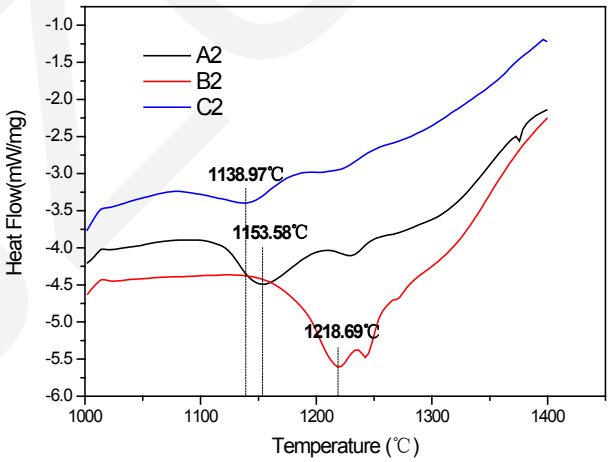


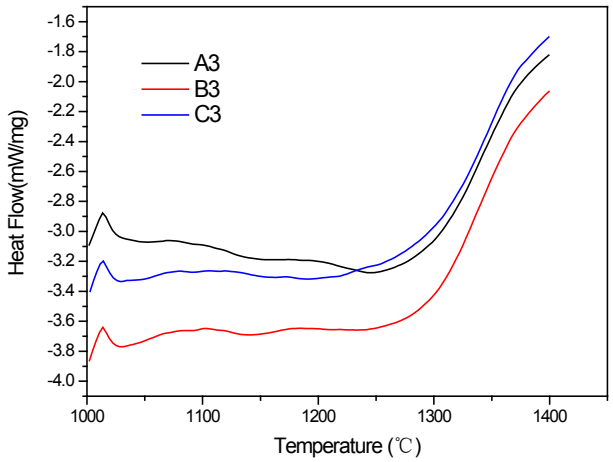




Effect of additives on the melting temperature (DSC curves)

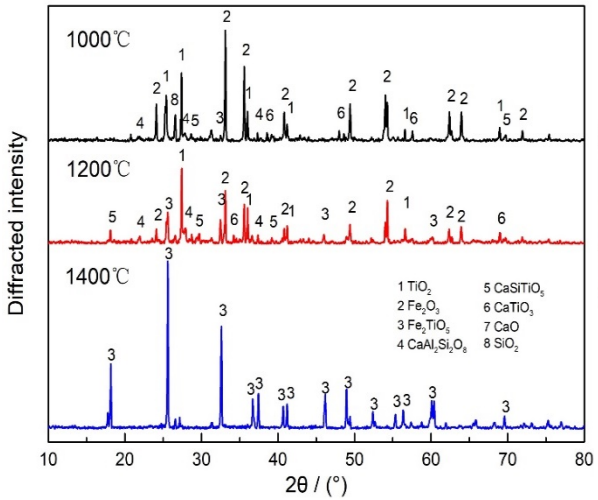


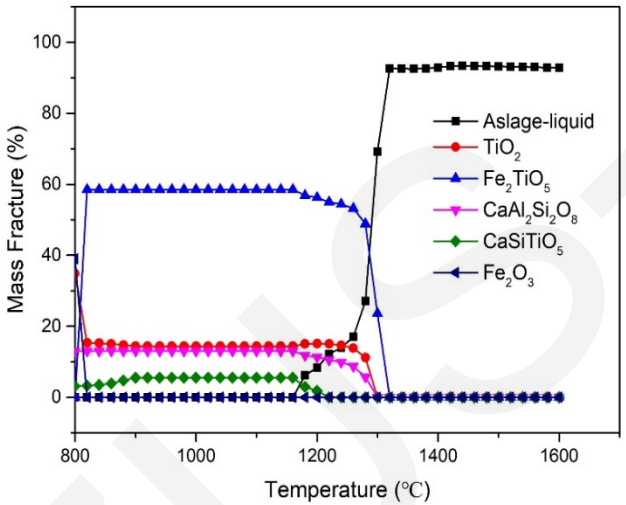




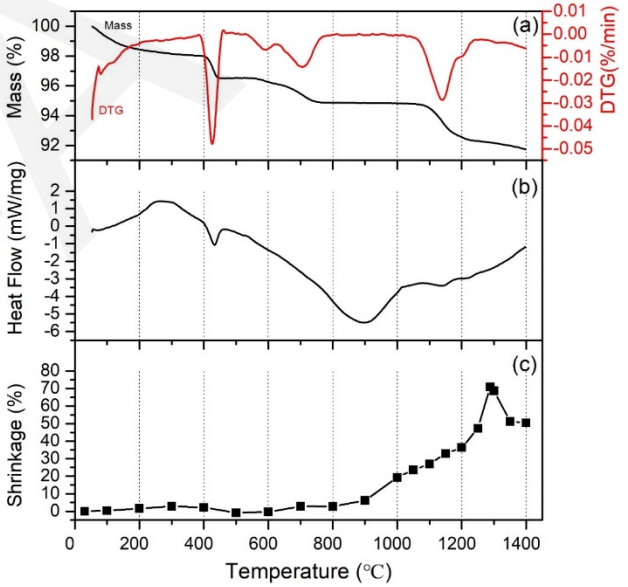
Melting treatment results

- **Melting characteristics and mineral phase transformation of samples with optimal additives**





XRD patterns and Factsage simulation results



TG-DSC results and Area shrinkage

- **Heavy metal leaching toxicity tested by ICP-OES**

Elements	V	As	Pb	Se
Raw sample	10.648	1.054	0.195	0.347
Molten slag	0.178	0.025	0.048	0.003
Regulatory standard limits	0.2	5	5	1

(ppm)

Conclusions

- The waste SCR catalyst is a TiO_2-based oxide mixture with a high melting point which can be effectively reduced with proper additives.
- The additive formula of C2, namely 39.00 wt. % Fe_2O_3, 6.50 wt. % CaO, 3.30 wt. % SiO_2, and 1.20 wt. % Al_2O_3 has the optimal fluxing behavior, decreasing the initial melting temperature from 1223 ℃ to 1169 ℃.
- The melting process includes three stages: the solid reaction stage, the sintering stage, and the primary melting stage.
- Liquid phase generated from the waste catalyst flows, wets, and spreads to the surfaces of TiO_2 particles and reacts with them to generate $CaTiO_3$ and Fe_2TiO_5. The later mineral phases form low-temperature eutectics, encapsulating TiO_2 and promoting the melting process.
- Leaching concentrations of heavy metals of samples with additives added after melting treatment were much lower than those of the raw waste catalyst, which demonstrated that such a method has a strong immobilization capacity for heavy metals in waste SCR catalysts.