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Grips

Cu–Ru Bimetal-Dcorated Siloxene Nanosheets Synthesis

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Research Objective:

- Develop a novel RuCu/Siloxene catalyst to improve the efficiency and selectivity of ammonia decomposition. Utilizing siloxene's high surface area and in situ reduction capabilities, the aim is to demonstrate superior catalytic performance over traditional Ru-Cu alloy catalysts on conventional supports like silicon dioxide.

Background:

- Traditional Cu-based catalysts result in over-hydrogenation and unwanted byproducts, reducing selectivity. To address this, adding a second metal, like Ru, to form a bimetallic alloy with Cu can improve selectivity and efficiency. Most researches focused on single metal based catalysts (Cu or Ru only) instead of bimetallic alloy for decomposition[1].

Method:

Preparation of Siloxene Support:

$CaSi_2$ was etched with 5 M NaOH solution to remove impurities.

The resulting solid was treated with 1 M HCl at 30°C for 4.5 days in an N_2 atmosphere.

The solid was separated by centrifugation, washed with ethanol, and dried under vacuum.

Synthesis of RuCu/Siloxene Catalyst:

Siloxene was mixed with $RuCl_3$ and $Cu(NO_3)_2$ solutions, then sonicated.

The mixture was centrifuged, washed with ethanol, dried under vacuum, and calcined at 400°C for 2 hours.

Result & Discussion:

The RuCu/Siloxene catalyst, developed as a replacement for Pd by literature, demonstrated distinct characteristics due to the different metal loading used. The performance under TEM presented a success loading of Ru and Cu. However, the selectivity of metal loading on the siloxene was affected by different metal combination during process.

Samples	Cu (wt%)	Ru (wt%)
Ru & Cu / 2D Si	1.45	0.27
Cu / 2D Si	0.1	/
Ru / 2D Si	/	0.27
Literature (Pd & Cu)	3.2	0.1(Pd)

Table 1. Metal loading on siloxene support.

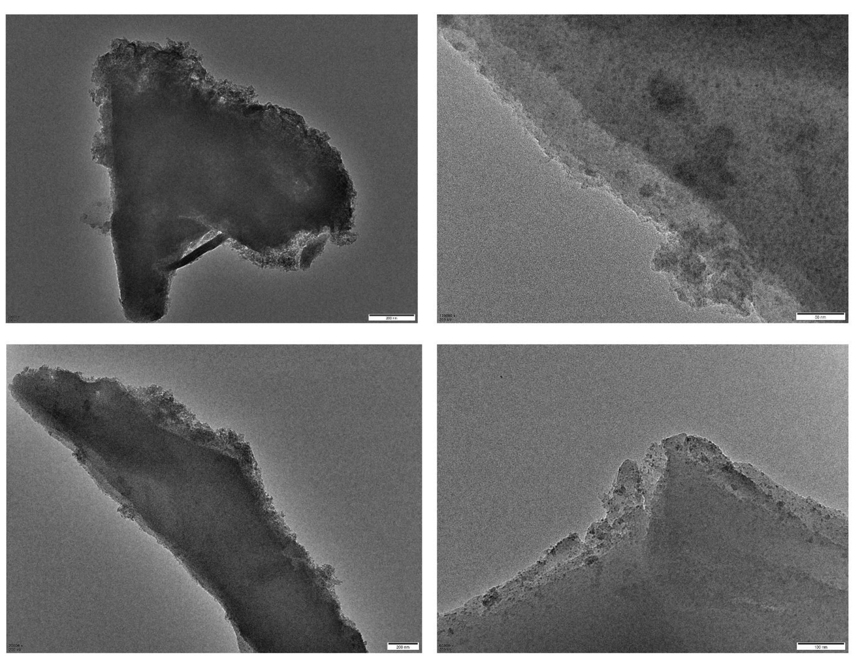

Figure 1. RuCu/Siloxene under TEM.

TEM mapping

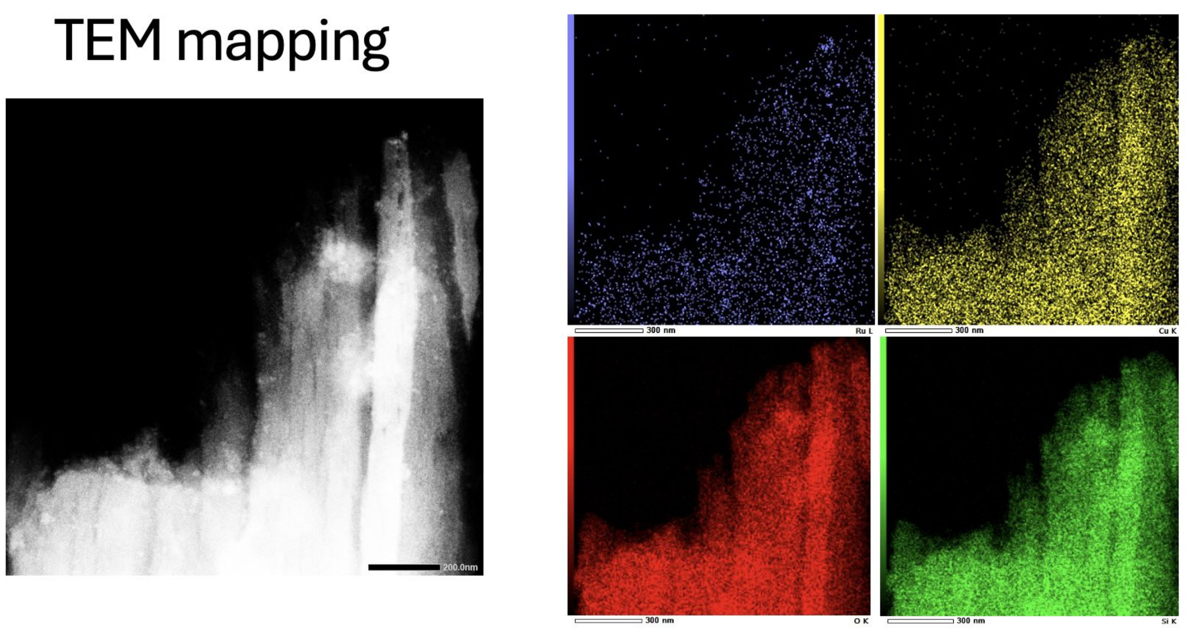

Figure 2. RuCu/Siloxene under TEM mapping.

Applying transmission electron microscopy (TEM), the metal sites were revealed, and the nanoparticles were observed to be small and uniform on the layered siloxene support at a scale of 100 nm. Figure 1 on the right displayed a series of particles at scales ranging from 200 nm to 50 nm. The layered structure of the siloxene was evident at the edge of the sample. TEM mapping (Figure 2) depicted Si and O atoms on the siloxene support in red and green, respectively, showing an even distribution[2]. However, due to the different metal loading selectivity, the Cu atoms, represented in yellow, were significantly more abundant than the Ru atoms, shown in purple. This disparity was attributed to the twentyfold molar ratio used during the synthesis process. However, due to the time constraints and experimental conditions, the activity and stability of the 2D Si samples could not be promptly tested by ammonia decomposition but only the complete characterization[3].

Conclusion :

The RuCu/Siloxene catalyst, developed as a Pd replacement, exhibited unique characteristics due to distinct metal loading. TEM analysis confirmed the successful loading of Ru and Cu, showing small, uniform nanoparticles on the siloxene support at a 100 nm scale. Elemental mapping revealed an even distribution of Si and O, with Cu atoms more abundant than Ru due to the synthesis molar ratio. Despite promising structural findings, time constraints and experimental conditions limited the study to characterization, preventing immediate testing of activity and stability through ammonia decomposition. These results highlight the potential of RuCu/Siloxene catalysts and the need for further catalytic performance evaluation.

Reference :

(1)Pei, X.; Zhang, D.; Tang, R.; Wang, S.; Zhang, C.; Yuan, W.; Sun, W. Cu-Pd Bimetal-Decorated Siloxene Nanosheets for Semi-Hydrogenation of Acetylene. Nanoscale 2024, 16 (26), 12411–12419. https://doi.org/10.1039/d4nr01911c.

(2)Feng, X.-J.; Wilder Carrillo-Cabrera; Alim Ormeci; Mitja Krnel; Burkhardt, U.; Bodo Böhme; Grin, Y.; Baitinger, M. Deciphering the Polymorphism of CaSi2: The Influence of Heat and Composition. Inorganic Chemistry 2024, 63 (23), 10557–10567. https://doi.org/10.1021/acs.inorgchem.4c00902.

(3)Ristig, S.; Poschmann, M.; Folke, J.; Gómez-Cápiro, O.; Chen, Z.; Sanchez-Bastardo, N.; Schlögl, R.; Heumann, S.; Ruland, H. Ammonia Decomposition in the Process Chain for a Renewable Hydrogen Supply. Chemie Ingenieur Technik 2022, 94 (10), 1413–1425. https://doi.org/10.1002/cite.202200003.