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Tahririyat manzili:
151100, Farg‘ona sh.,
Aeroport ko‘chasi 17-uy,
202A-xona
Tel: (+99899) 998-01-42
e-mail: info@al-fargoniy.uz

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BIMETALLIC CLUSTERS AND AREAS OF THEIR APPLICATION

Rasulov Akbarali Makhamatovich,
Doctor of physical and mathematical sciences, professor, professor of the "Information technologies" department of Fergana branch of TUIT

Ibrokhimov Nodirbek Ikromjonovich,
Doctor of philosophy (PhD) in physical and mathematical sciences, associate professor, head of the "Information Security" department of Fergana branch of TUIT

Minamatov Yusupali Esonali ugli,
Researcher, Trainee-researcher of Fergana Polytechnic Institute

Mukhtarov Farrukh Muhammadovich,
Doctor of philosophy (PhD) in technical sciences, associate professor, director of Fergana branch of TUIT

Abstract: Bimetallic clusters, composed of atoms from two different metals, have emerged as a fascinating class of nanomaterials with diverse applications across various scientific and technological domains. This article provides an overview of the unique properties of bimetallic clusters and explores their applications in key areas.

Keywords: bimetallic clusters, nanomaterials, catalysis, sustainable energy, atoms, nanoelectronics.

Introduction. Bimetallic clusters are unique structures consisting of atoms of two different metals combined into a single cluster. These nanoscale objects have unique physicochemical properties that make them interesting research objects, promising materials for various fields of science and technology.

A cluster is a group of computers, servers or processors united by high-speed communication channels, representing a single hardware resource from the user's point of view. A cluster is a loosely coupled collection of several computing systems that work together to run common applications and appear to the user as a single system.

A monocrystal is a single crystal that has a continuous crystal lattice (as opposed to a polycrystal, a body of intergrown crystals). Single crystals are characterized by anisotropy of physical properties.

One of the key aspects of bimetallic clusters is their structure. Combining atoms of different metals into a single cluster can lead to the formation of specific configurations that are caused by electronic, crystalline and magnetic interactions between the components. These features can significantly influence the properties of bimetallic clusters, making them unique compared to monometallic clusters.

One of the important aspects of the application of bimetallic clusters is their use in catalysis. These nanostructures have a high surface area and unique active sites, making them effective catalysts for various chemical reactions. For example, bimetallic clusters can be used to improve the efficiency of electrocatalysis in fuel cells or hydrogen production devices.

Another promising area of application for bimetallic clusters is medical diagnostics and therapy. Their unique properties, such as plasmonic resonances, can be used to enhance images in medical techniques such as tomography or photodynamic therapy.

In the field of nanoelectronics, bimetallic clusters also promise new opportunities. Their electronic properties can be tuned by controlling their composition and structure, opening the prospect of creating new types of nanoelectronic devices with improved performance.

Methodology. A lot of scientific research on bimetallic clusters has been conducted and is still ongoing. The main thing is that it has its place in the relevant parts of technology and scientific development.

Richard D. Adams and Captain Bourgeois provided a brief history of the main discoveries in the field of bimetallic cluster complexes and their structure in the course of their research. In addition, a review of recent studies of platinum-ruthenium cluster complexes has explored related processes discussing the application of these complexes in the field of homogeneous hydrogenation catalysis of alkynes[1].

Shang-Fu Yuan, Zong-Jie Guan, and Quan-Ming Wang, determining the actual active species of cluster catalysis is complex, and obtaining direct structural evidence is a costly and difficult process. As a result of studying the processes of the nanocluster depending on the Ag (I) Cu (I) bimetallic cluster combination, it was observed that the work modulates the catalytic performance of the metal nanoclusters by the correct regulation of the oxidation state of their metal atoms[2].

Hongbo Liu, Eliceo Sosa Hernandez's research is dedicated to the study of their structures, which is the starting point for understanding bimetallic clusters. Usually the most stable structure: cuboctahedron, decahedron, icosahedron and Marx decahedron, etc. According to the elemental distribution in bimetallic clusters, they are divided into solid solution type, core/shell, eutectic, etc. The most stable structure of a bimetallic cluster depends on the interatomic interaction potential, especially the alloying interaction, the radius of the metal atom or its nearest neighbor distance in a stable mass crystal, temperature, the concentration of each component, and the size of the clusters. makes a secret[3].

Bimetallic clusters, composed of atoms of two different metals, exhibit unique properties that make them valuable in various applications. Here is a list of bimetallic clusters and some of their prominent application areas:

1. Platinum-Gold (Pt-Au) Clusters:
    - Catalysis: Pt-Au clusters are widely used as catalysts for various chemical reactions, including oxidation and hydrogenation processes.
    - Electrocatalysis: Applied in fuel cells and other electrochemical devices to enhance catalytic performance.
2. Silver-Gold (Ag-Au) Clusters:
    - Biomedical Imaging: Ag-Au clusters show potential in imaging applications for diagnostics and therapeutics in medicine.
    - Catalysis: Used in catalytic reactions due to their unique electronic and surface properties.
3. Copper-Silver (Cu-Ag) Clusters:
    - Antimicrobial Coatings: Cu-Ag clusters are employed in antimicrobial coatings for various surfaces, reducing the growth of bacteria and other microorganisms.
    - Catalysis: Applied in catalytic reactions due to their synergistic effects on reaction pathways.
4. Gold-Palladium (Au-Pd) Clusters:
    - Catalysis: Utilized in heterogeneous catalysis for coupling reactions and hydrogenation processes.
    - Sensing: Applied in sensors for detecting gases and biomolecules.
5. Platinum-Nickel (Pt-Ni) Clusters:
    - Hydrogen Evolution Reaction (HER): Used in electrocatalysis for HER in fuel cells and water-splitting applications.
    - Electrochemical Devices: Pt-Ni clusters find applications in energy storage devices.
6. Gold-Copper (Au-Cu) Clusters:
    - Catalysis: Applied in selective oxidation reactions and other catalytic processes.

- Electronics: Used in nanoelectronics due to their unique electronic properties.

7. Palladium-Silver (Pd-Ag) Clusters:
   - Catalysis: Employed in various catalytic reactions, such as Suzuki-Miyaura coupling reactions.
   - Gas Sensing: Applied in gas sensors for detecting volatile organic compounds.
8. Rhodium-Iridium (Rh-Ir) Clusters:
   - Catalysis: Used in selective hydrogenation reactions and other catalytic processes.
   - Automotive Catalytic Converters: Rh-Ir clusters are crucial components in catalytic converters for reducing emissions in vehicles.
9. Gold-Cobalt (Au-Co) Clusters:
   - Catalysis: Employed in catalytic reactions, including selective oxidation reactions.
   - Magnetic Properties: Au-Co clusters exhibit interesting magnetic properties, making them valuable in nanomagnetic applications.
10. Silver-Palladium (Ag-Pd) Clusters:
    - Catalysis: Applied in selective hydrogenation reactions and other catalytic transformations.
    - Electrochemical Sensors: Used in the development of sensors for detecting various analytes.

The versatility of bimetallic clusters in terms of composition and structure makes them versatile materials with applications spanning catalysis, biomedical sciences, nanoelectronics, and environmental technologies. Ongoing research in nanoscience and nanotechnology continues to uncover new possibilities for these unique structures in various fields[4-6].

We also know that the most useful devices developed on the basis of bimetallic clusters have been found useful, which include:

Catalytic converters in cars: Bimetallic catalysts, often containing platinum and palladium, are an important component of catalytic converters. They help reduce emissions of harmful gases such as nitrogen oxides, carbon monoxide and hydrocarbons from internal combustion engines.

Fuel cells: Fuel cells use bimetallic catalysts such as platinum-gold (Pt-Au) or platinum-nickel (Pt-Ni) clusters. These clusters fuel electrocatalytic reactions involved in converting chemical energy (such as hydrogen and oxygen) into electrical energy.

Sensors for gas detection: Bimetallic clusters such as palladium-silver (Pd-Ag) or gold-copper (Au-Cu) clusters are used in gas sensors to detect various gases, including volatile organic compounds. Their unique properties make them suitable for sensing applications with high sensitivity and selectivity.

Biomedical imaging tools: Bimetallic clusters such as silver-gold (Ag-Au) or gold-cobalt (Au-Co) have been explored for applications in biomedical imaging. These clusters can serve as contrast agents in imaging techniques contributing to advances in medical diagnostics and therapeutics.

Hydrogen evolution reaction (HER) catalysts: Bimetallic clusters, particularly platinum-nickel (Pt-Ni) or gold-palladium (Au-Pd) clusters, are used as catalysts in the hydrogen evolution reaction. These clusters increase the efficiency of the water separation processes necessary for the development of sustainable energy systems.

Nanoelectronic devices: Bimetallic clusters such as gold-copper (Au-Cu) or gold-palladium (Au-Pd) are used in nanoelectronics due to their unique electronic properties. They play a role in the development of new electronic devices with improved performance and functionality.

Antimicrobial Coatings: Bimetallic clusters such as copper-silver (Cu-Ag) find applications in antimicrobial coatings. These coatings can be applied to various surfaces to inhibit the growth of bacteria and other microorganisms, contribute to hygiene and prevent the spread of infections.

Catalysts for selective oxidation reactions: Bimetallic clusters such as gold-copper (Au-Cu) or silver-palladium (Ag-Pd) are used in selective oxidation reactions. These catalysts are used in the production of fine chemicals and pharmaceuticals.

These devices demonstrate the versatility of bimetallic clusters in fields ranging from environmental protection and power generation to health and electronics. Ongoing research and development in nanotechnology and materials science may lead to further innovations and applications of bimetallic clusters in various technologies.

Conclusion. In conclusion, the exploration of bimetallic clusters and their diverse applications signifies a significant stride in the realm of nanoscience and materials engineering. These nanoscale entities, composed of two distinct metals, showcase remarkable properties that have led to the creation of a plethora of innovative devices with applications spanning various fields.

The catalytic potential of bimetallic clusters has been harnessed in the development of crucial technologies, from catalytic converters in automobiles that mitigate environmental impact to fuel cells that offer cleaner energy solutions. In biomedical sciences, these clusters serve as imaging agents, contributing to advancements in medical diagnostics and therapeutic interventions. Their deployment in gas sensors enhances our ability to detect and monitor environmental pollutants, furthering efforts in environmental protection.

In essence, bimetallic clusters stand as multifaceted building blocks with transformative potential, opening new frontiers in technology and science. The journey of exploration into the world of bimetallic clusters holds promise for future breakthroughs, with the potential to reshape industries, address global challenges, and enhance our understanding of materials at the nanoscale. As we move forward, the applications of bimetallic clusters are poised to play a vital role in shaping a more sustainable, technologically advanced, and interconnected world.

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