Yerevan State University
Institute of Physics
Center of Materials Science and Nanotechnologies

Neutron Physics and Radiation Materials Conference

Fabrication of Flexible Sensor Systems Based on Composite Nanostructures

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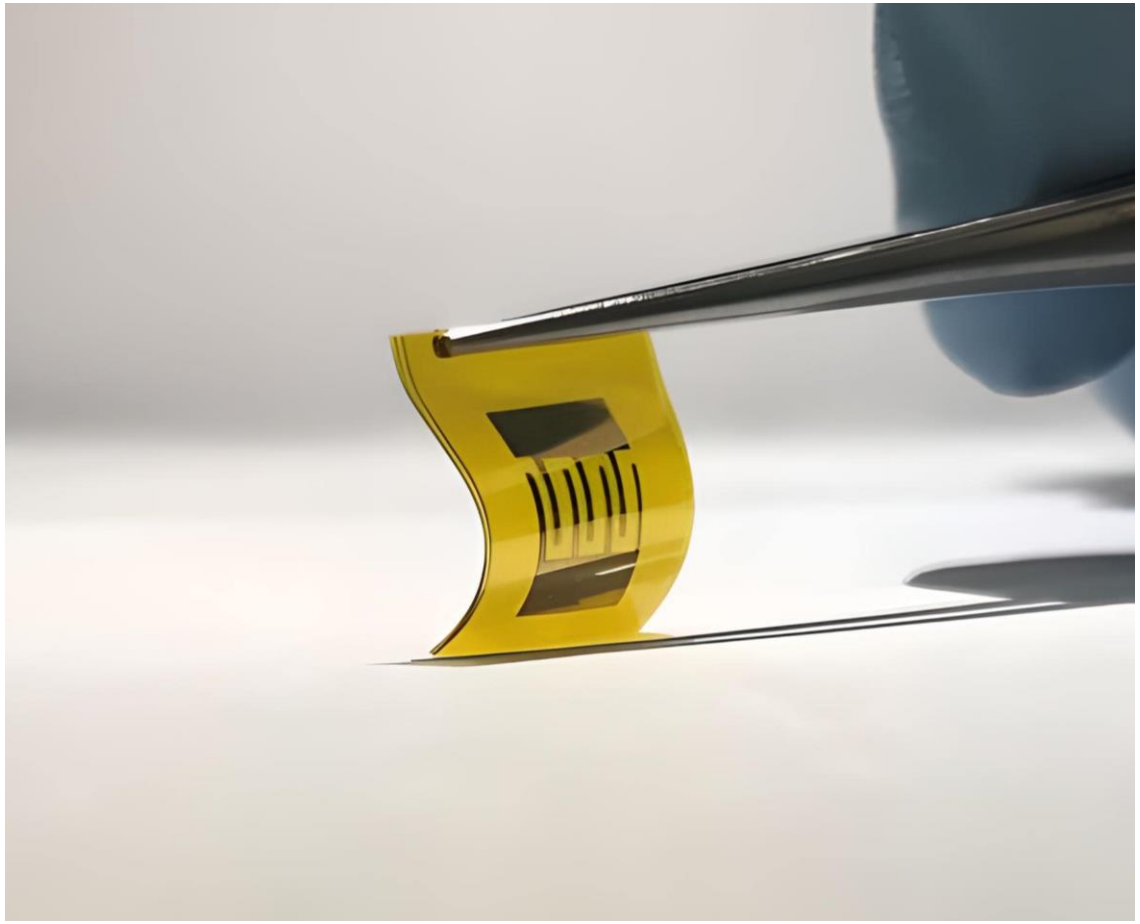
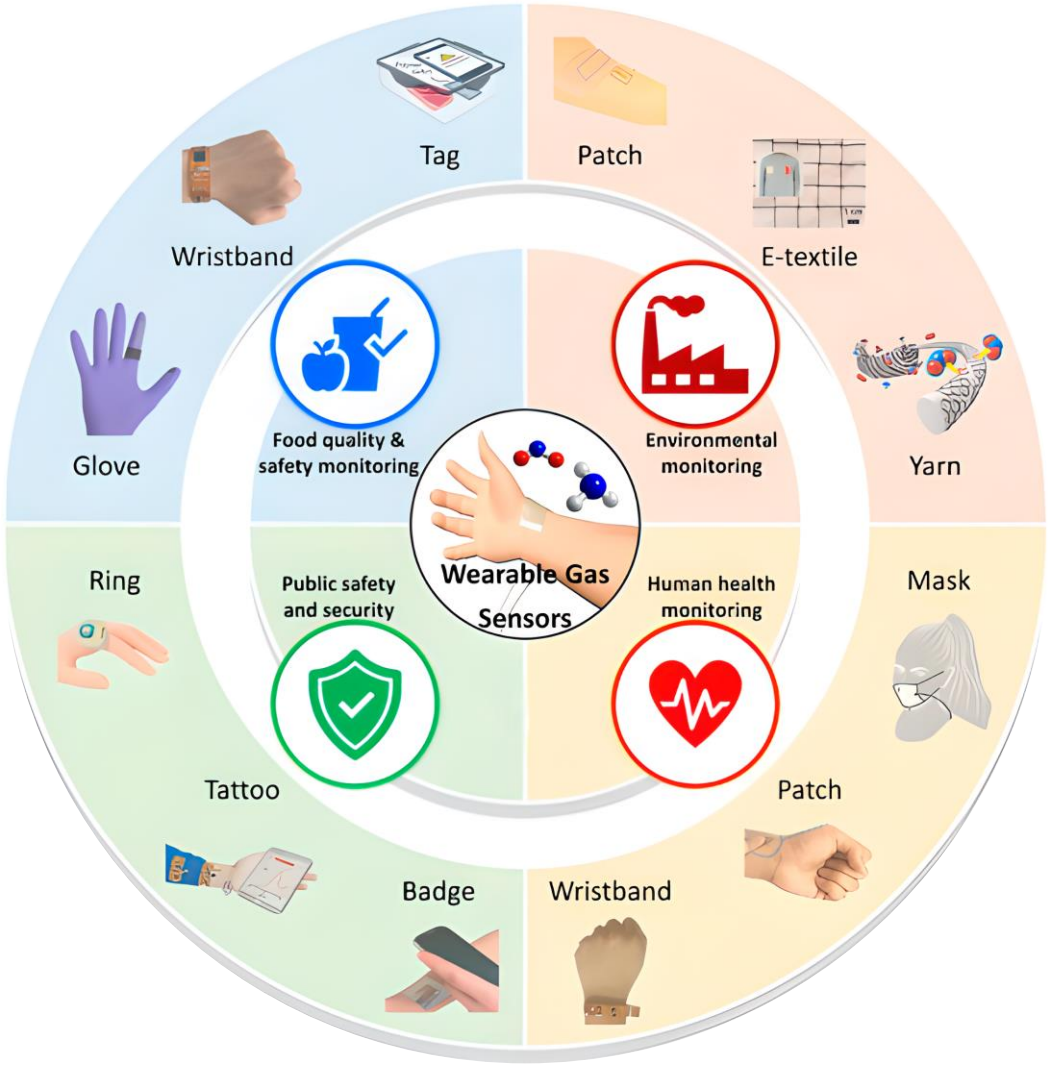
The Next-Generation of Electronics



Next-generation electronics demand lightweight, bendable, and stretchable sensors. From wearable health devices and smart clothing to soft robotics, these systems maintain full functionality on curved or moving surfaces, opening up new frontiers in technology.

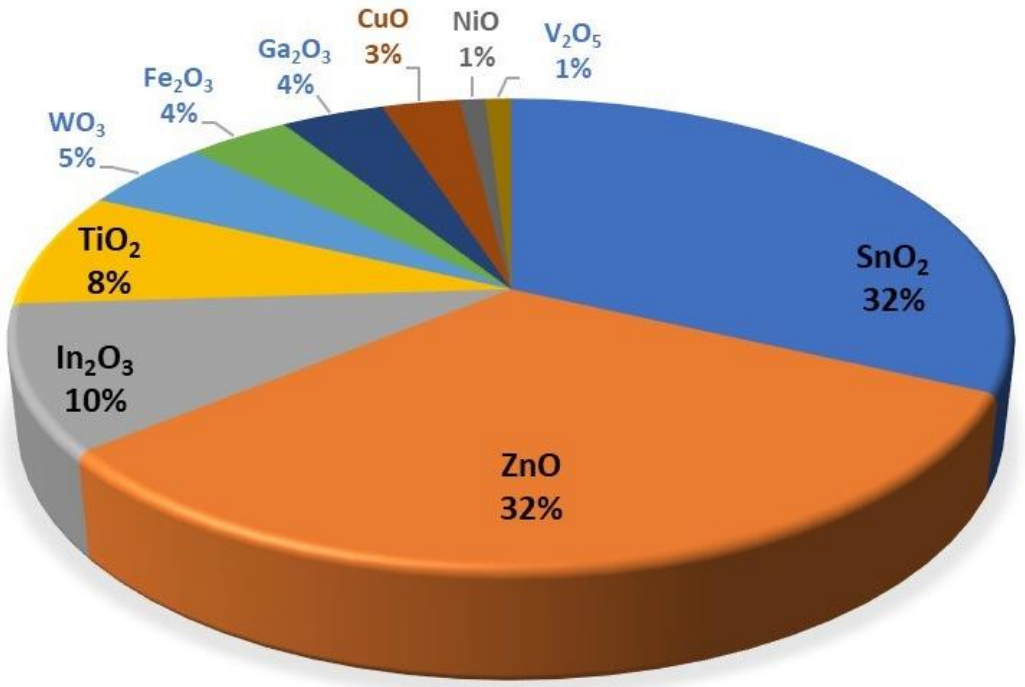
Application of flexible gas sensors

- **Environmental Monitoring**
- **Biomedical Diagnostics**
- **Wearable Electronics**
- **Food Quality and Safety Control**
- **Industrial Safety and Process Control**
- **Robotics and Artificial Skin**
- **Energy and Environmental Systems**

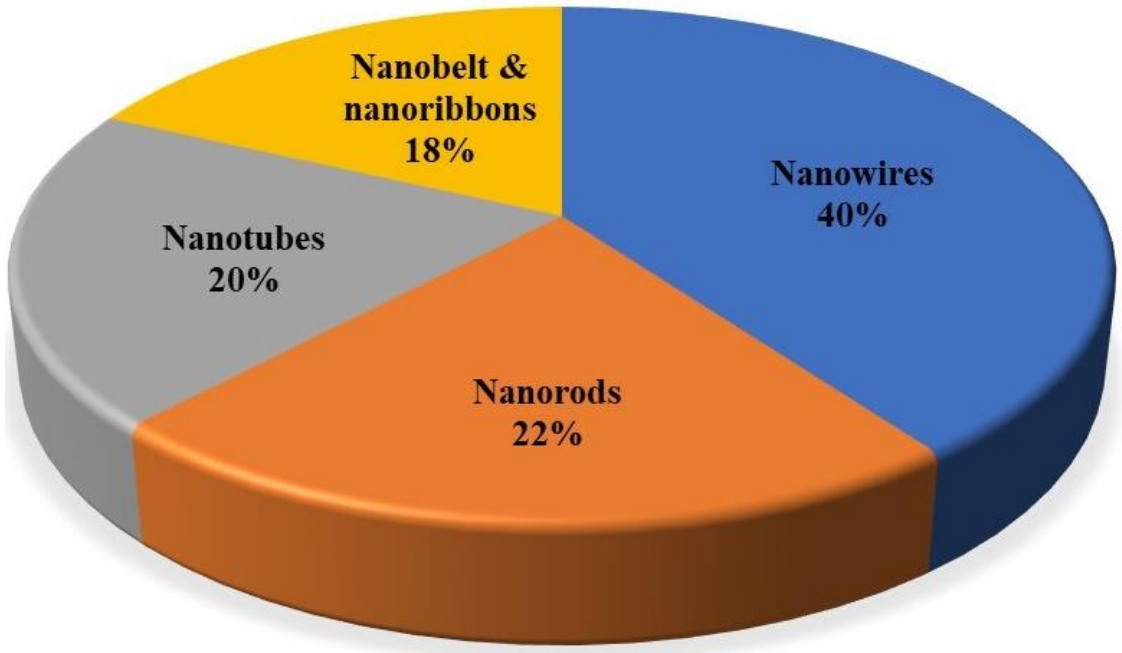


Key Nanomaterials in Flexible Sensors

Metal oxides



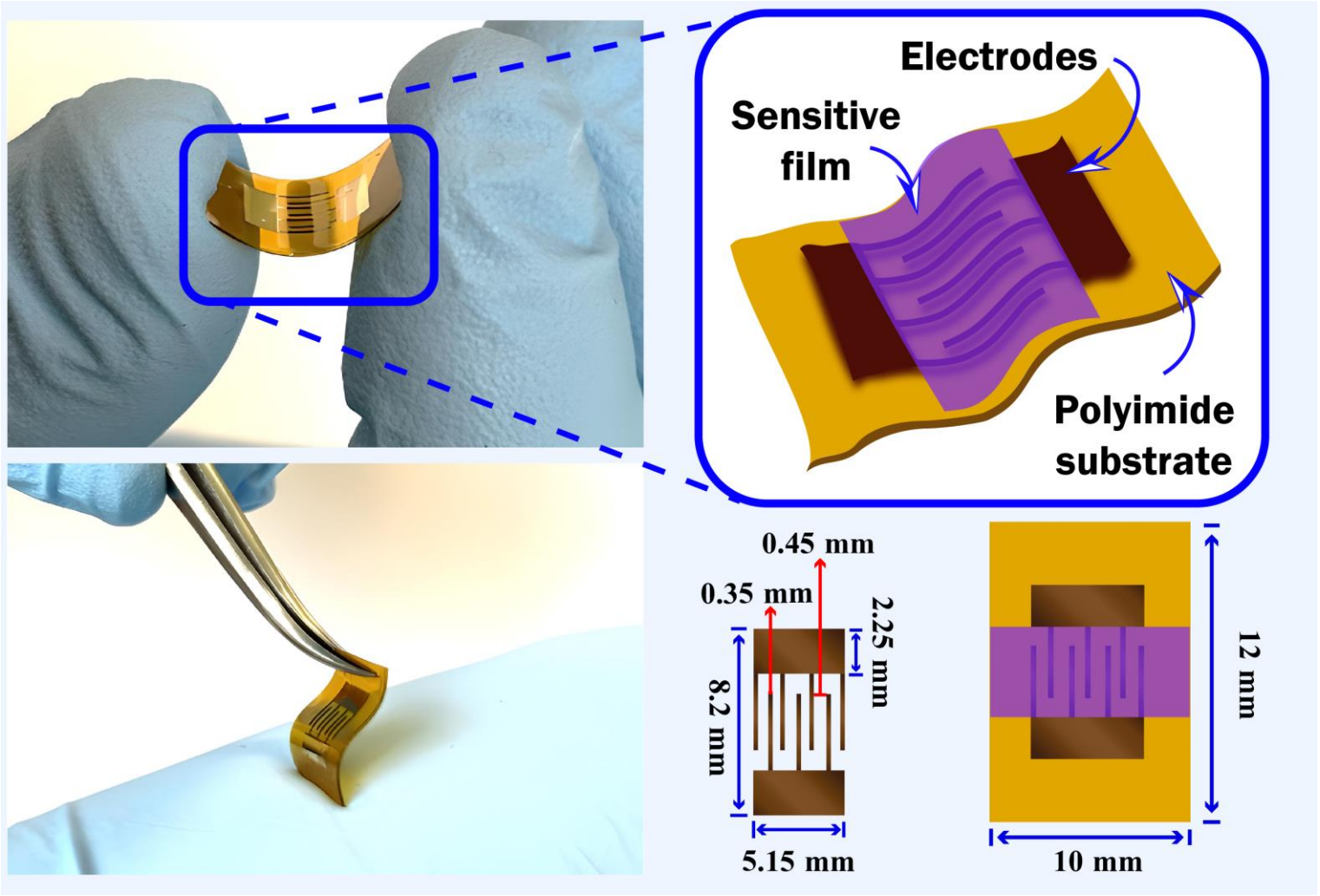
Nanostructures



Fabrication Process

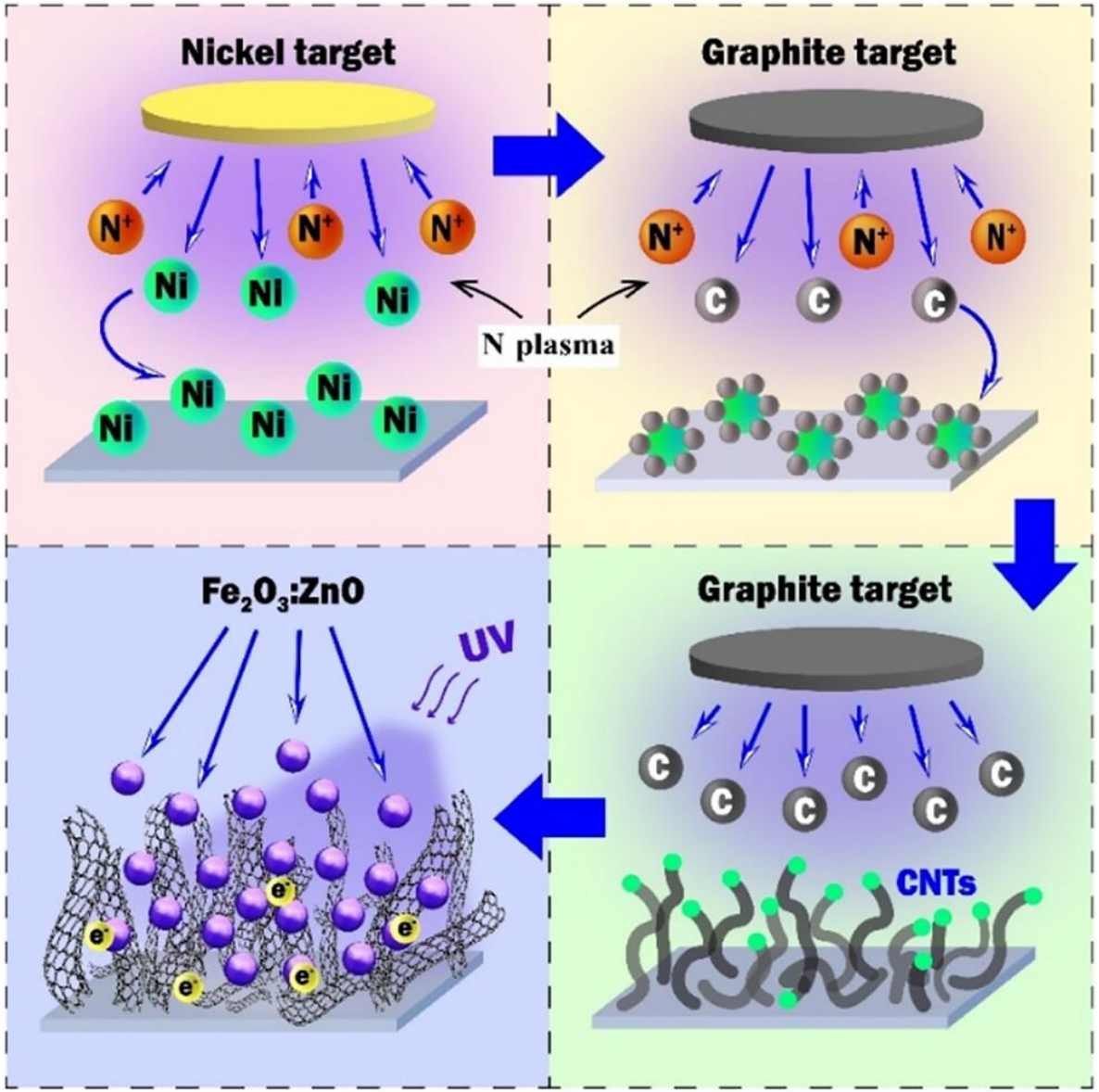
Flexible sensor structure

- Polyimide substrate
- Electrodes
- Sensitive film



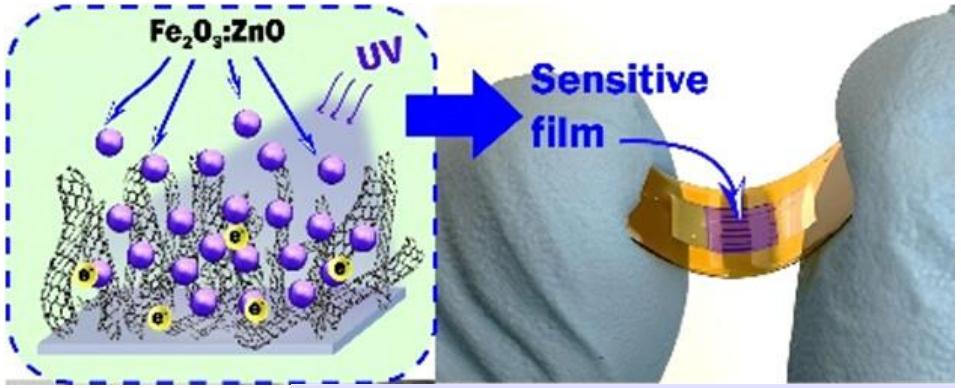
Fabrication Process

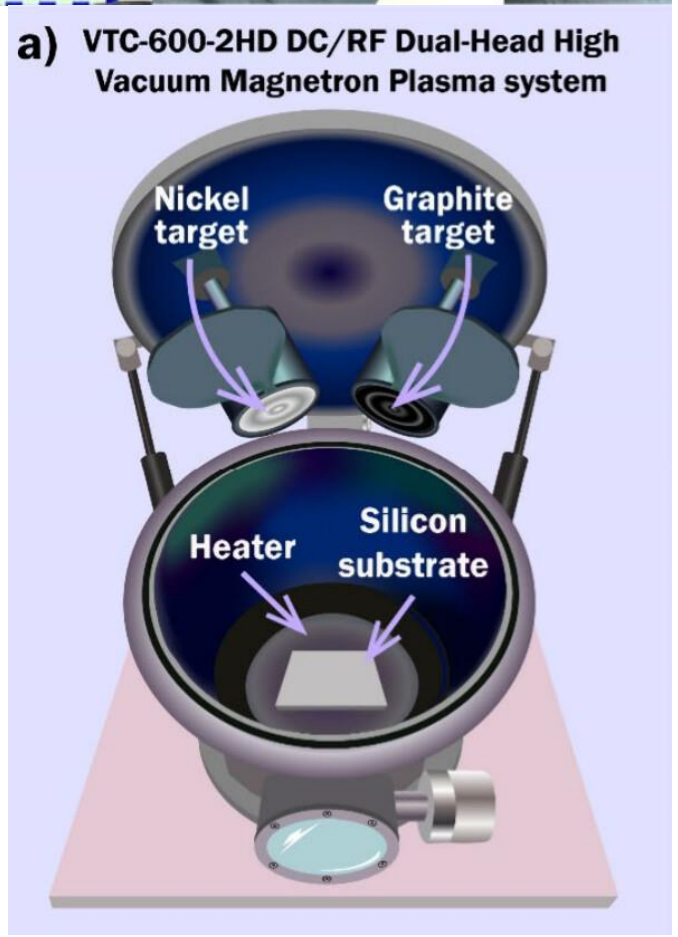
- Electrode printing
- Synthesis and deposition of **MWCNTs/Fe_2O_3:ZnO** Nanocomposite Material
- Annealing



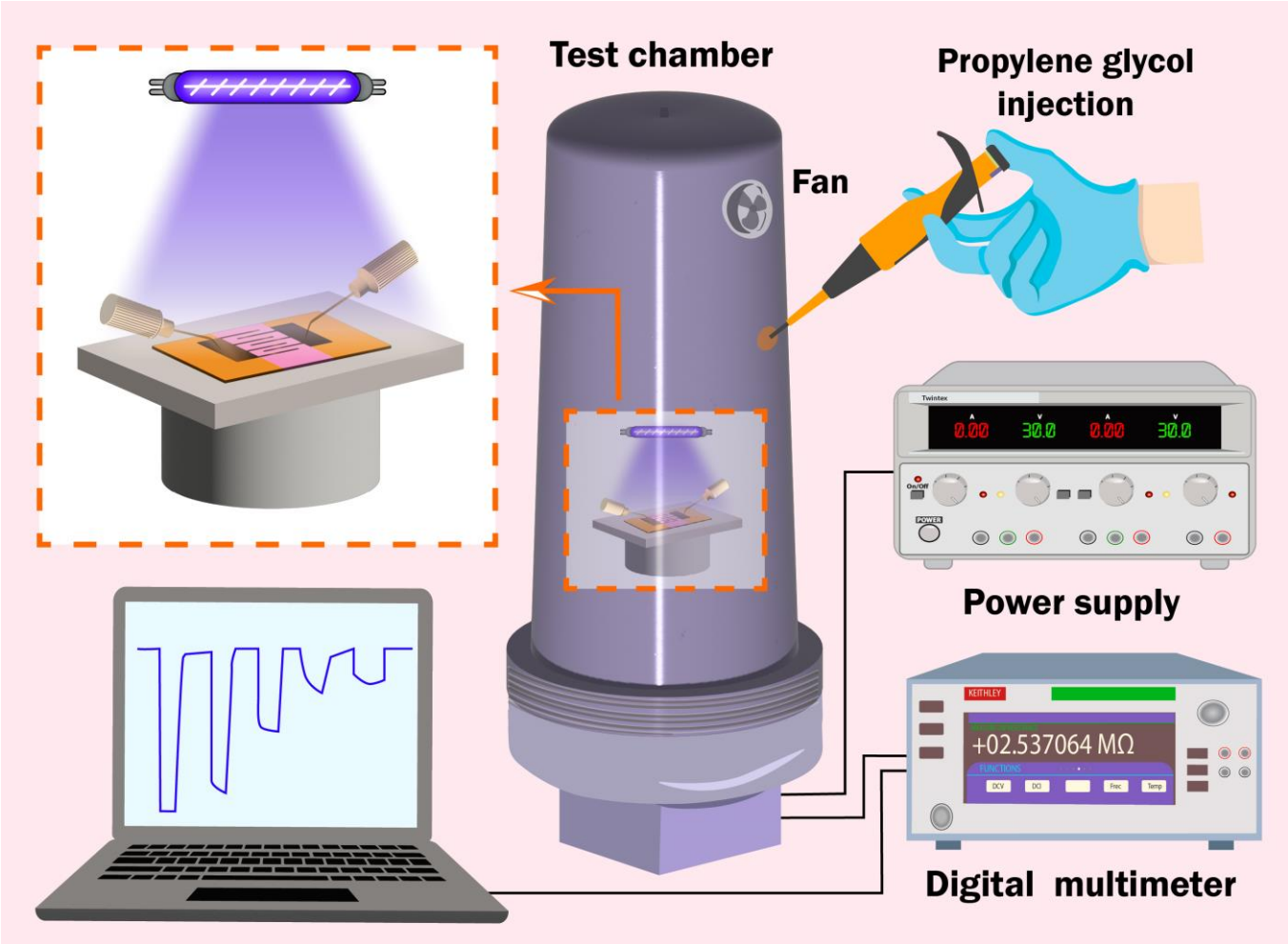
Fabrication Process

- **Methodology:** High-frequency Sputtering magnetron sputtering for thin film deposition.
- **Process:** A plasma is used to dislodge material from a target, which then deposits onto the flexible substrate.
- **Advantages:** Excellent control over film thickness, composition, and uniformity. Good adhesion to flexible substrates.
- **Use Case:** Ideal for creating high-performance, uniform composite films.



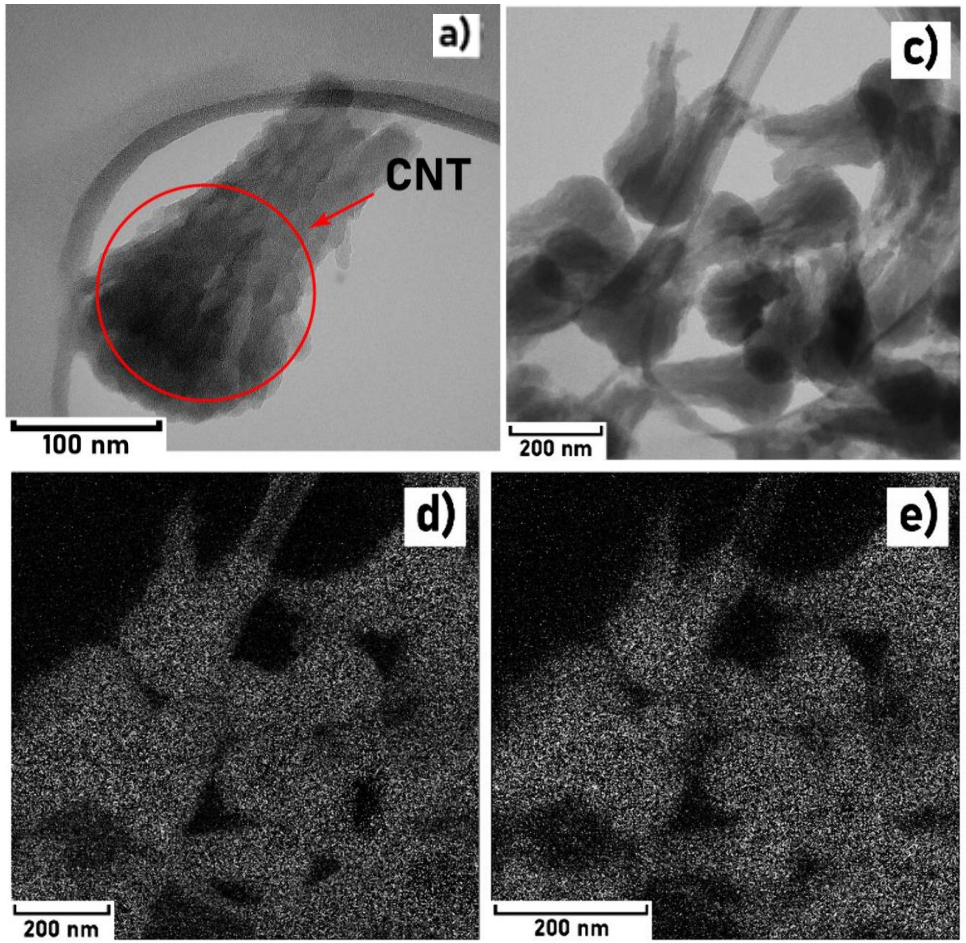


Testing System

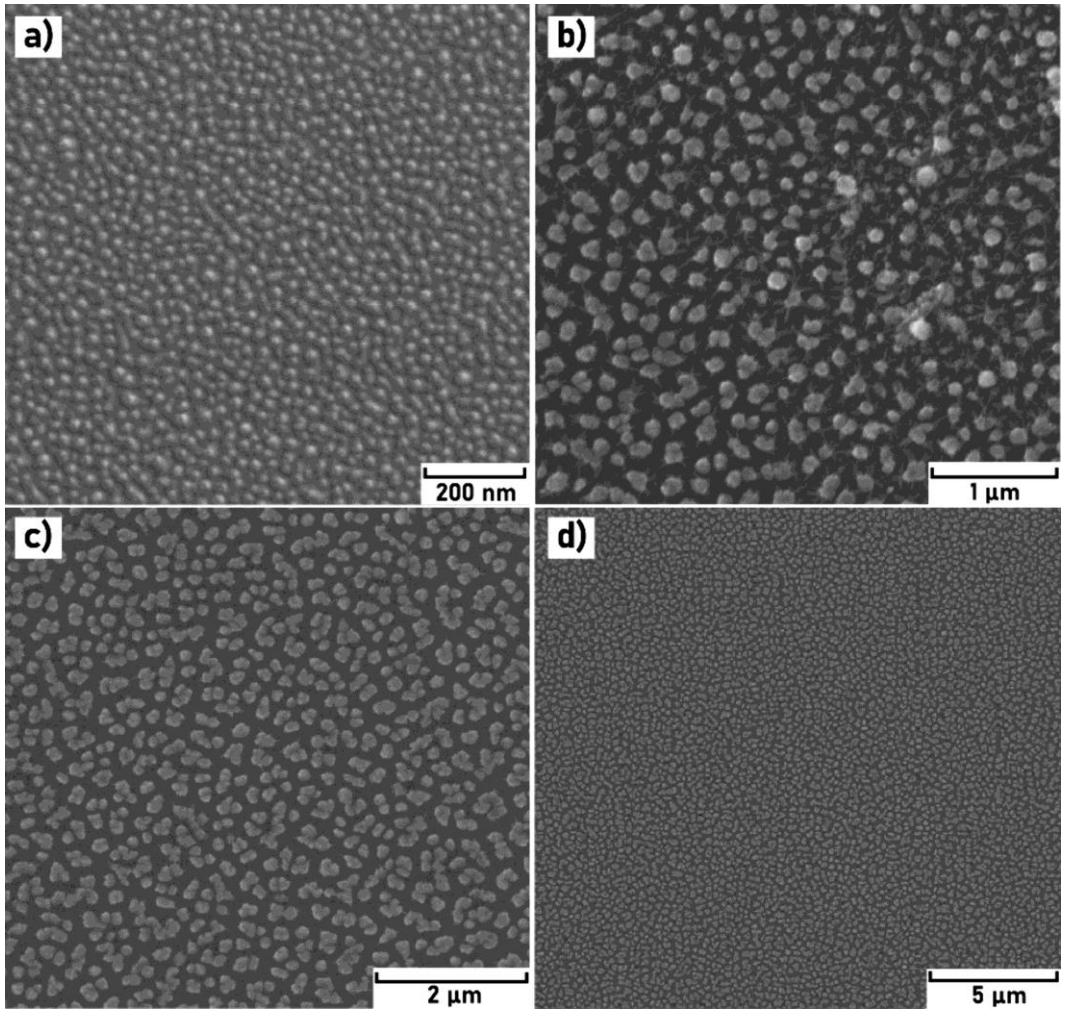


- The flexible sensor connected to a measurement system
- The baseline resistance is recorded in clean air until stabilization
- The target gas or vapor (e.g., PGV) is injected into the test chamber at a controlled concentration
- The change in electrical resistance of the sensor is monitored in real time

Structural and Morphological Results

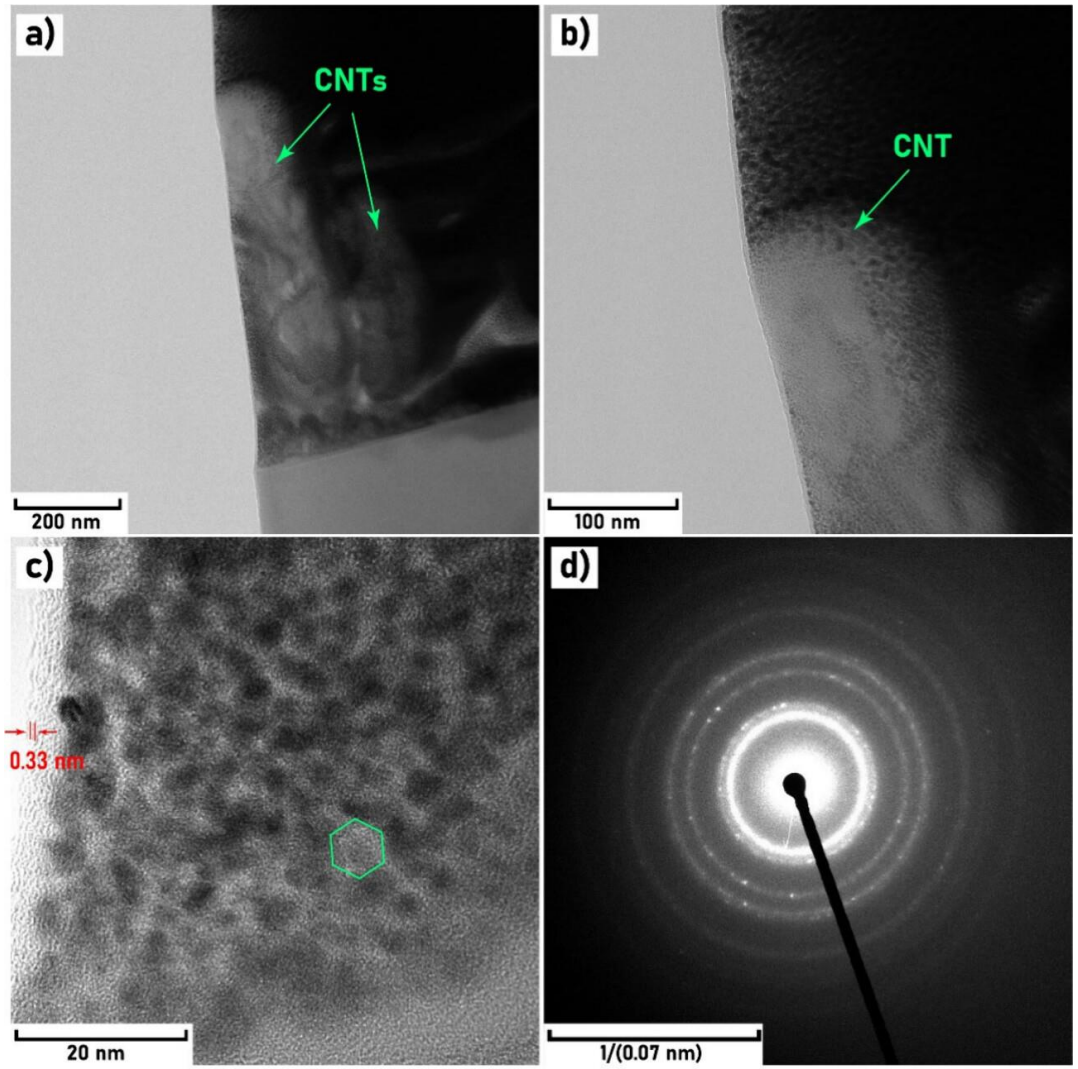


TEM image (a), EFTEM images of the CNT representing zero-loss energy shift for carbon (c), 284 eV energy loss for distribution of C (d), and 402 eV energy loss for distribution of N (e).

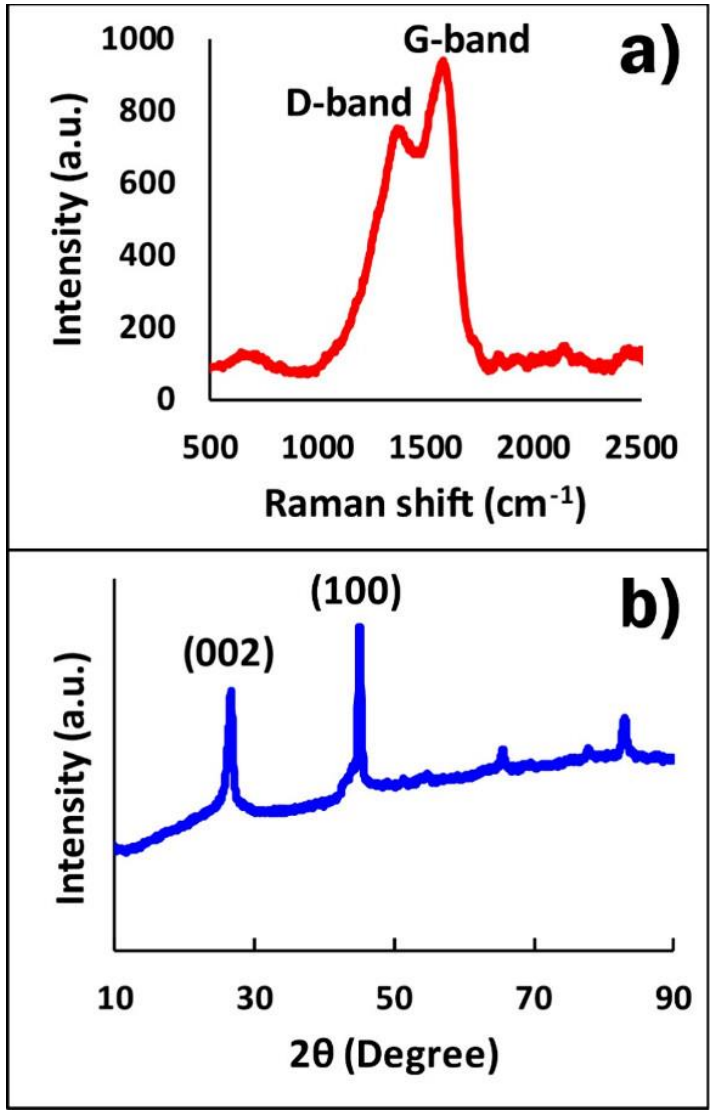


SEM images of short (a) and longer (b, c, d) CNTs.

Structural and Morphological Results

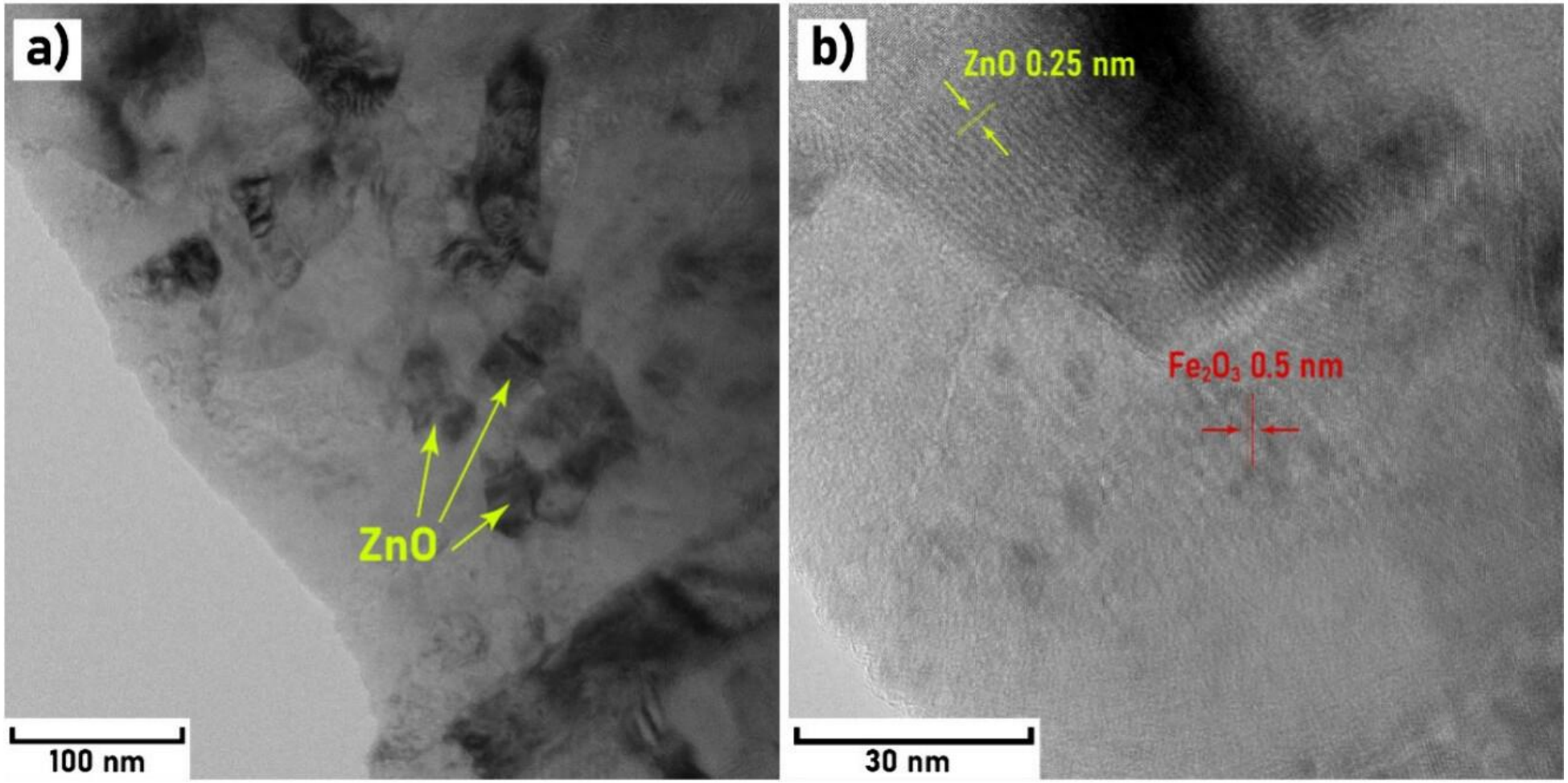


Low (a, b) and high (c) resolution TEM images and SAED pattern (d) for the CNTs measured on the lamellae prepared by the FIB.



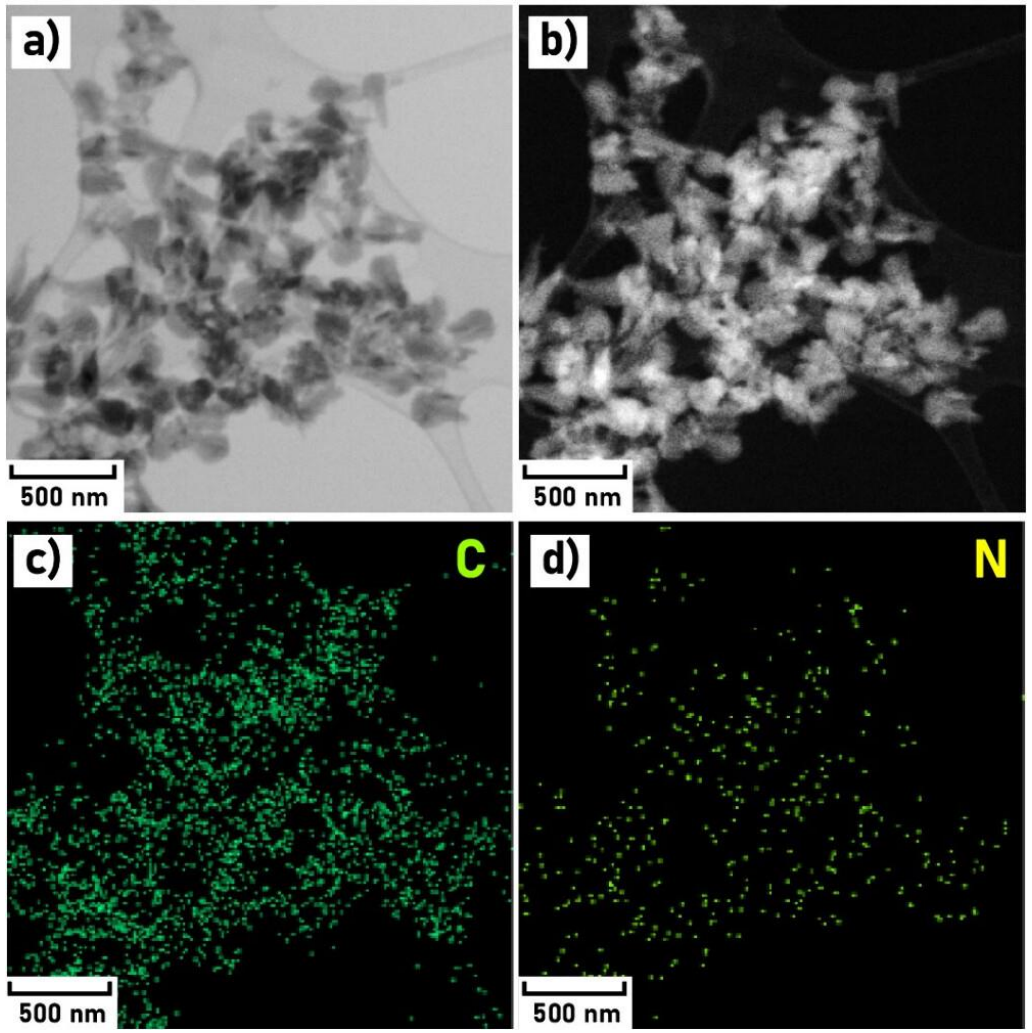
Raman spectra (a) and XRD pattern (b) of the CNTs.

Structural and Morphological Results

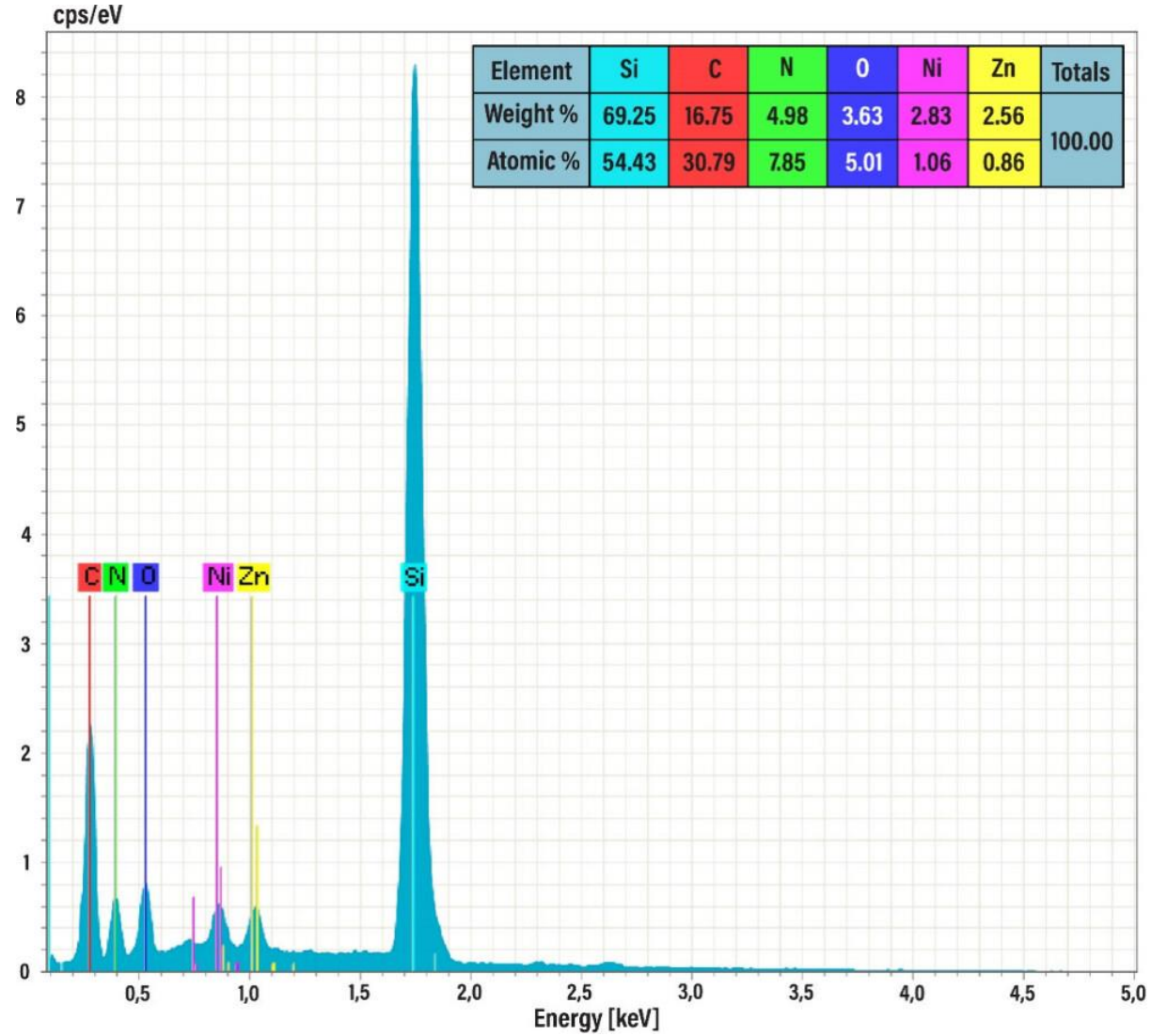


Low (a) and high (b) resolution TEM images of the Fe_2O_3:ZnO material.

Structural and Morphological Results

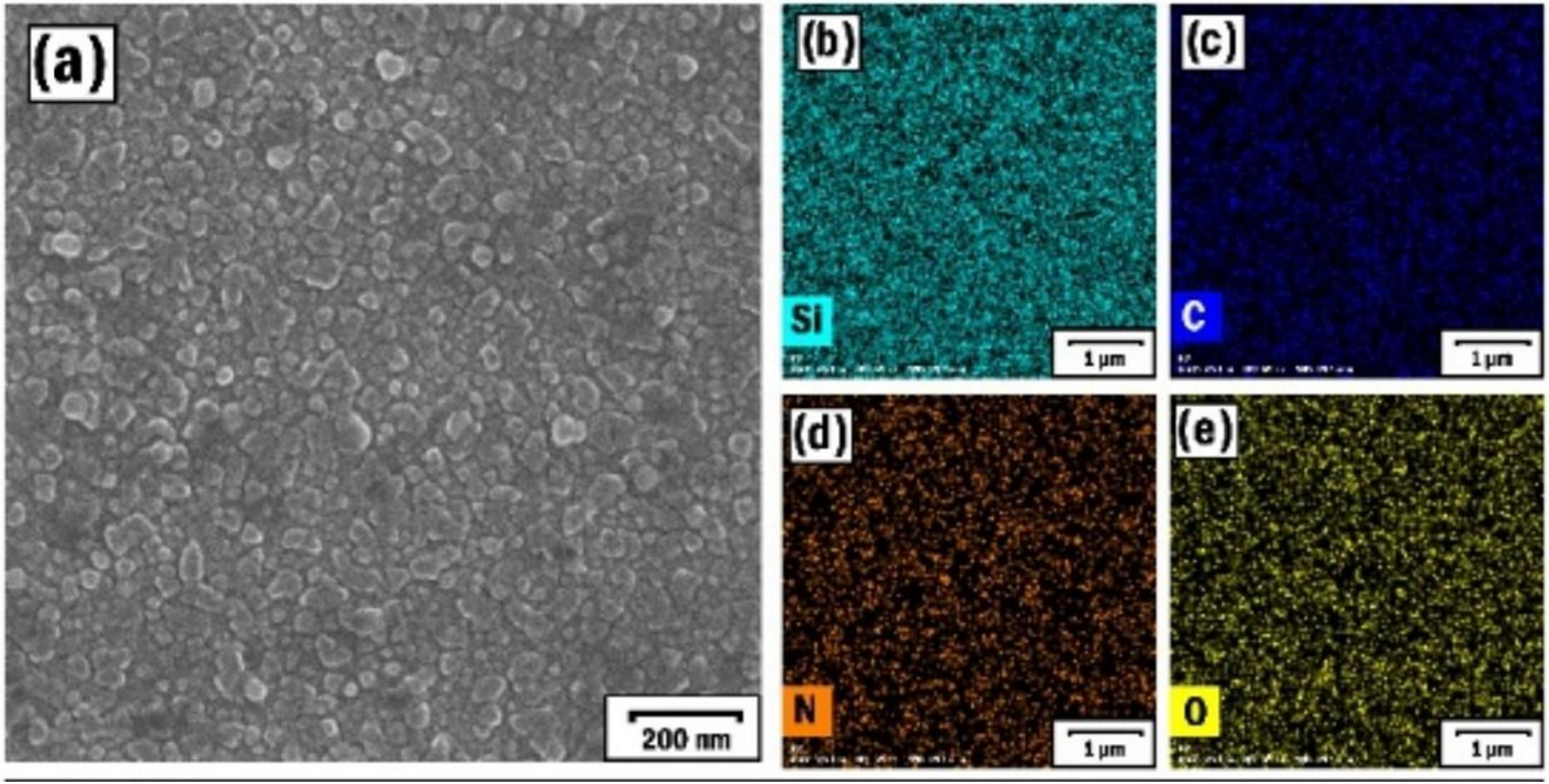


TEM images (a, bright field; b, dark field) and EDX elemental mapping analysis of C (c) and N (d) elements.



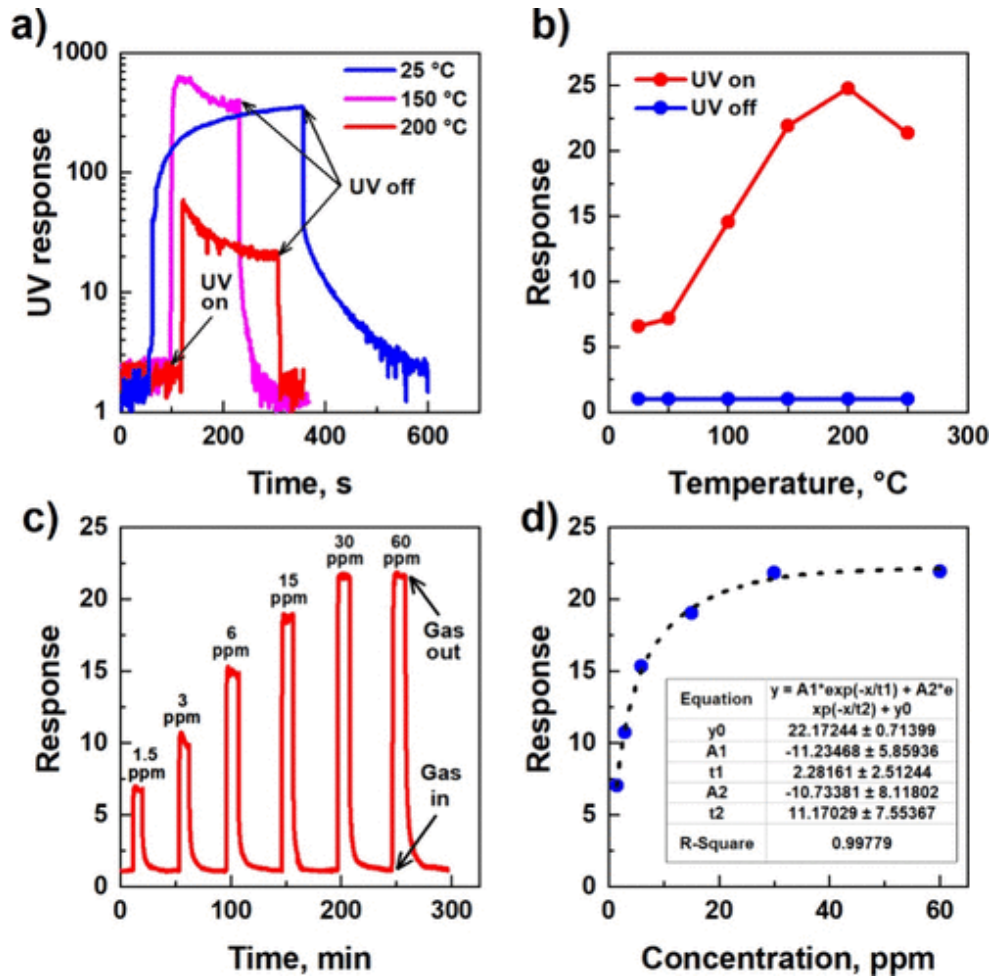
EDX spectrum of CNTs/Si structure.

Structural and Morphological Results



SEM image (a), low (b) and high (c) resolution TEM images, Raman spectra (d), SAED pattern (e), and EDX elemental mapping analysis of C and N elements (f) of the SP1 sample.

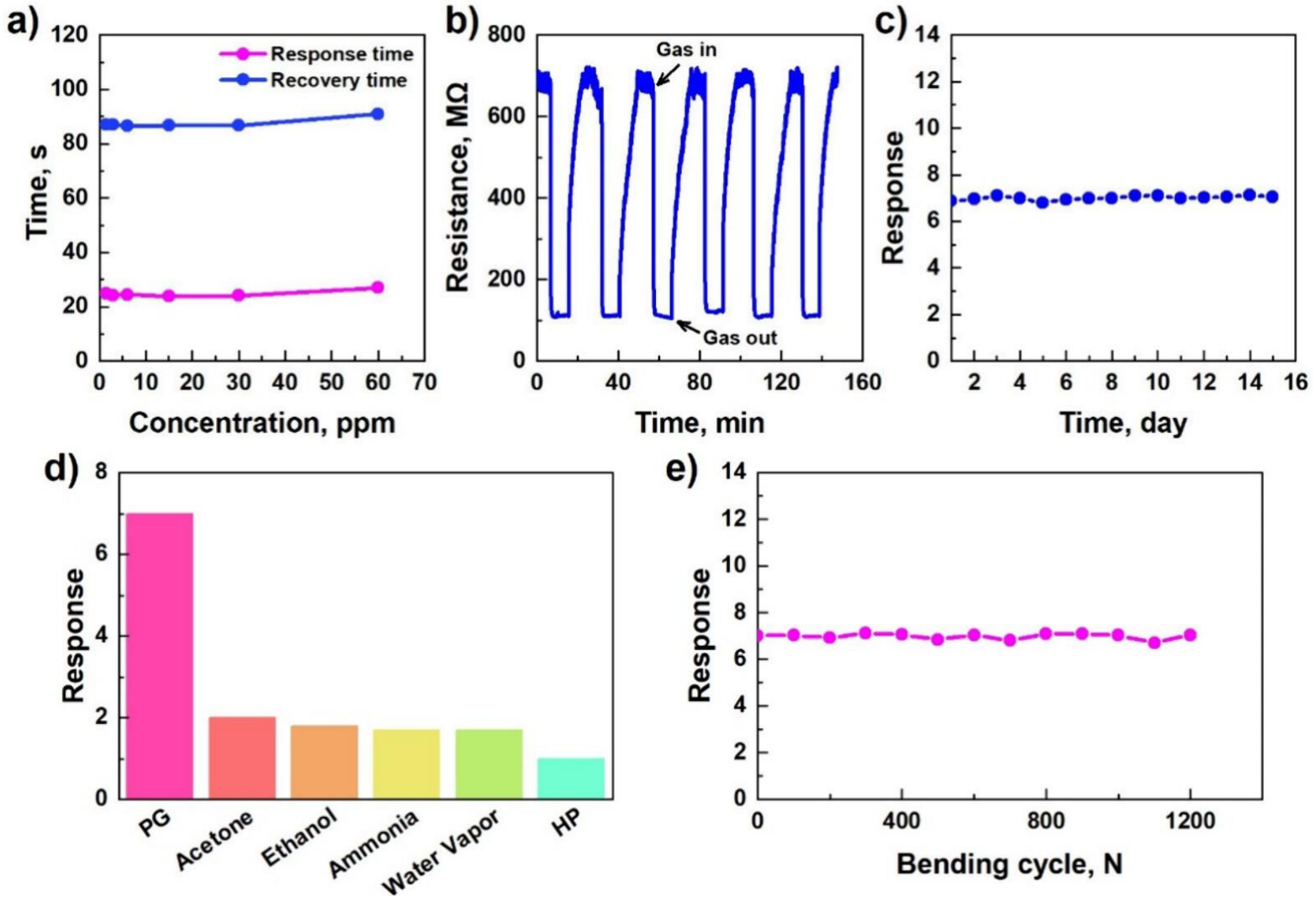
Electrical and Sensing Performance



(a) Sensor UV response at different temperatures (a), sensor response vs operating temperature with and without UV irradiation at 60 ppm PGV (b), dynamic response curves of the sensor to different concentrations of PGV at 150 °C (c), and PGV response vs concentration at 150 °C (d).

- High Sensitivity
- Fast Response and Recovery
- Good Repeatability
- Enhanced Selectivity
- Stable Electrical Behavior
- Mechanical Flexibility
- Long-Term Stability
- Low Operating Temperature

Electrical and Sensing Performance



Dependences of the response and recovery times on PGV concentration at 150 °C with UV illumination (a), repeatability tests of the sensor to 1.5 ppm PGV at 150 °C with UV illumination (b), long-term stability of the sensor (c), selectivity of the sensor for PGV at 150 °C (d), and change in the response during the multiple bends of the flexible sensor for 1.5 ppm PGV (e).

Thank you!