Low-Temperature Reduction of Metal Oxide Semiconductors Using Open-Air Plasma

Jacob Burrows, Electrical Engineering
Mentor: Nicholas Rolston, Assistant Professor of ECEE
School of Electrical, Computer and Energy Engineering

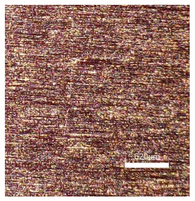
Summary:

Using a plasma system utilizing a gas combination of 95% nitrogen and 5% hydrogen is employed to treat damaged or degraded semiconductor devices. This treatment aims to restore the devices' usefulness by removing oxide accumulations on their surfaces. Through the application of this specialized gas environment, oxides react and are then released into the atmosphere, effectively renewing the semiconductor material.

Challenges:

- Controlling the conditions like temperature.
- Uniformity was a struggle due to the small form factor of the system
- Cost of testing for results.

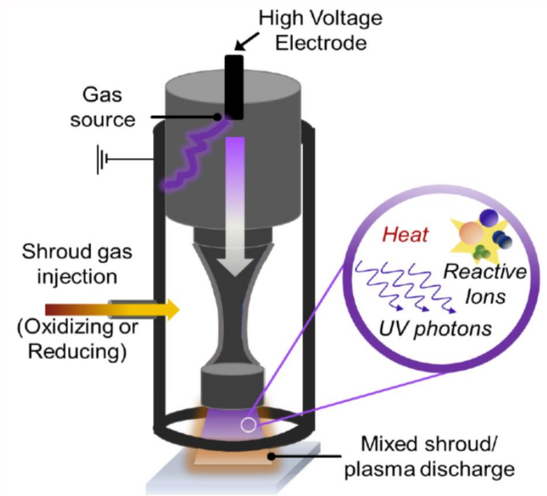
Before Treatment



After Treatment

Goal:

To remove oxide so we can re-use/recycle semiconductor devices at low temperature so not to damage them.



Results:

In the XPS Wide Scan we saw a reduce in oxygen signaling a decrease of oxygen on the copper surface. In the XPS Cu Scan we see the peaks of copper oxide reduce signaling a consistent copper surface. By using the satellite features we can distinguish Cu oxidation state. This shows us the use of Low-Temperature Open-Air Plasma has worked in reducing of Metal Oxide in Semiconductor materials.

Future:

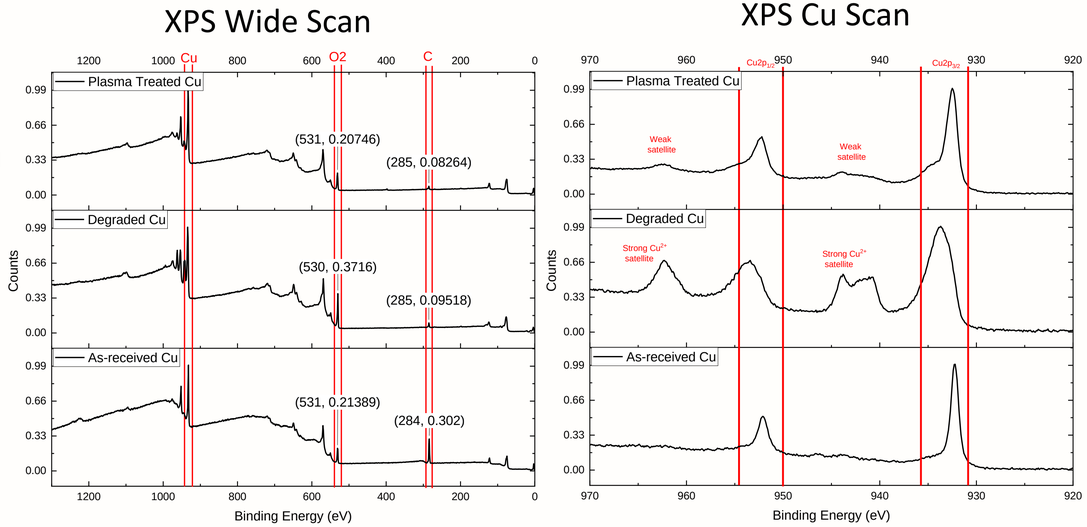
Expand plasma use to metals like nickel and tin for low-temperature oxide removal, aiming to enable efficient recycling of electronic components while maintaining metal integrity and reducing environmental impact. This work will also fine-tune plasma settings for better treatment outcomes.

Plasma:

Plasma, sometimes referred as the fourth state of matter, is an ionized gas composed of electrons, ions, and neutral particles. Its reactive nature allows it to alter material surfaces, making it valuable for industrial and scientific uses.

System:

The Electrode is where a high voltage is applied to ionize the gas to create plasma. The gas source provides gas, such as argon or nitrogen, to create plasma. Shroud gas Injection is a secondary gas that modifies the plasma's effect, aiding in surface treatments by providing either oxidizing or reducing conditions.



Graphs:

The XPS scans display elemental state information of samples. The wide scan graph shows clear peaks around 531 eV and 285 eV, associated with oxygen and carbon. The Cu scan zeroes in on the copper binding energy.

Acknowledgments:
GWC Facilities, the Rolston Lab and a special thanks to Daphne Pappas (Plasmatreat North America), Nicholas Rolston, Hunter Mantle, Muneeza Ahmad, Saivneeth Penukula.

FURI

Ira A. Fulton Schools of Engineering
Arizona State University