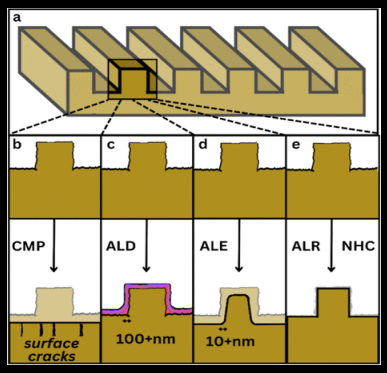
Atomic Smoothing of Metal Surfaces Using N-Heterocyclic Carbenes

Developed through collaborations within the Carbon to Metal Coating Institute (C2MCI).



Methods of smoothing atomically rough surfaces: (a) Cross-section of gold surfaces (b), (c), and (d) show treatments using conventional techniques; (e) shows the surface treated with the proposed method.

Inventors:

P. J. Ragogna, C. M. Crudden, S. T. Barry, M. Karttunen, M. Davies, E. Goodwin, M. Y. Bakiro, E. Desroche, F. Tumino,

Protection Status:

PCT filed on April 2, 2025

Stage of Development:

Proof of Concept

Seeking:

Development Partners
Licensees

Contact:

Paul Cogswell, PhD
Assistant Director, Innovation and Partnerships
Paul.Cogswell@carleton.ca

Carleton University, Ottawa, Canada

Background

As the semiconductor industry enters the Ångström era, the surface roughness of metals used in interconnects and complex patterns has become a critical challenge. Conventional surface smoothing techniques, including chemical mechanical planarization (CMP), atomic layer deposition (ALD), and atomic layer etching (ALE), face significant limitations: they often involve excessive material removal or addition, generate significant waste, or struggle to maintain conformity to three-dimensional nanoscale features. These limitations underscore the urgent need for innovative, non-invasive surface smoothing technologies that can meet the stringent demands of next-generation microelectronics manufacturing.

Description of the Invention

Researchers at Carleton, Western, Queen's, and St. Andrews Universities have collaboratively developed a vapor-phase process that achieves significant smoothing of nanometer-scale rough metal surfaces using N-heterocyclic carbenes(NHCs). These molecular adsorbates induce atomic layer restructuring (ALR) by interacting with metallic surfaces to abstract adatoms and facilitate self-assembly into ordered monolayers. Unlike traditional methods, this process does not add or remove bulk material, preserving the substrate's integrity while achieving Ångström-scale smoothness. Smoothing occurs within seconds to minutes under mild conditions, making the technology highly compatible with existing vapor-phase manufacturing workflows. Initial studies have been conducted on gold substrates and show significant surface smoothing on both polished and roughened samples.

Publications:

Goodwin E, et al. ACS Nano 2025, (https://doi.org/10.1021/acsnano.4c17517)

Key Benefits

- Enhanced Surface Precision: Achieves subnanometer smoothness while maintaining conformity to three dimensional patterns and features critical for microelectronics and nanotechnology applications.
- Non-Invasive Process: Maintain the original film thickness and avoids debris generation associated with mechanical or chemical methods.
- Environmental and Cost Advantages: Minimize waste and operational complexity, enable sustainable manufacturing.
- Scalability: Proven performance across micro- and macroscale surfaces, with seamless integration into diverse manufacturing settings, including in-situ vapor phase processes.

Applications

- Microelectronics: Surface smoothing for interconnects, sensors, and semiconductor devices.
- Nanofabrication: Precision engineering of nanostructures and thin films.