# Integrating Sustainability into Semiconductor Manufacturing: A Comprehensive Approach to CMP Consumables

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As semiconductor technologies enable innovations in autonomous systems, artificial intelligence (AI), 5G communications, the Internet of Things (IoT), and large-scale data processing, the demand for reliable, high-performance semiconductor manufacturing is on the rise. Meeting this demand requires cutting-edge device architectures that depend on two critical fabrication steps: Chemical Mechanical Planarization (CMP) and post-CMP cleaning.

This work focuses on the development of advanced CMP slurry formulations and effective post-CMP cleaning solutions, emphasizing their pivotal roles in modern semiconductor processing. We examine how different slurry synthesis methods influence the surface chemistry of ceria abrasives, thereby affecting silicon dioxide ($SiO_2$) removal rates during shallow trench isolation (STI) CMP. Our results demonstrate that the optimized cleaning solutions can remove ceria abrasive particles as small as 10 nm from $SiO_2$ surfaces, ensuring thorough removal of these residual contaminants and improved process efficiency. Furthermore, we explore the incorporation of aliphatic amino acids as environmentally friendly corrosion inhibitors in CMP slurry formulations. These amino acids offer a sustainable alternative to the conventional benzotriazole (BTA) inhibitor, helping to mitigate the environmental and safety concerns associated with CMP chemicals.

In light of the semiconductor industry's rapid expansion, our research also addresses critical sustainability and environmental health and safety (EHS) objectives in CMP. We propose a comprehensive methodology to evaluate the sustainability of CMP consumables, with an emphasis on slurries given their significant market share and short usage lifetimes. This approach lays the groundwork for future CMP sustainability assessments and encourages proactive improvements within the CMP community to minimize environmental impact. Finally, we establish a framework for Life Cycle Assessment (LCA) of CMP consumables, representing a significant step toward integrating sustainable practices into semiconductor manufacturing. In summary, this study not only advances the technical understanding of CMP and post-CMP processes crucial for next-generation semiconductor devices, but also aligns these processes with pressing environmental sustainability objectives.