Biomachining: Nano-scale, Biologically-based Machining of Copper

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Objectives

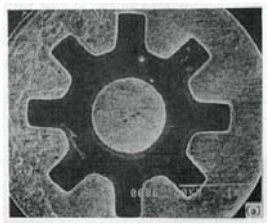
- Study the effects of biologically-induced machining of copper on surface finish and other material properties
- Create a process for fine control of material removal rate of copper for accurate production of micro- and nano-scale features on copper surfaces for applications in semiconductor and MEMS fields using bacteria

Thiobacillus ferrooxidans (left) can consume both iron and copper to survive

[Ehrlich, 1990]

State-of-the-Art

- Chemolithotrophic bacteria have been studied for almost a century and have been shown to have novel respiration mechanisms that consume metals such as iron and copper as electron donors rather than gases such as oxygen
- Small experiments involving controlled consumption of copper were conducted to show that nano-scale features can be created using *Thiobacillus ferroxidans* (Zhang and Li, 1998. Uno, et. All, 1993)
- Applied electric potential to the workpiece has been shown to accelerate the biomachining process and can be used as a control mechanism (Uno, et. All, 1993)



SEM photograph of the micro-gear on a Cu workpiece. [Zhang and Li, 1998]

Approaches

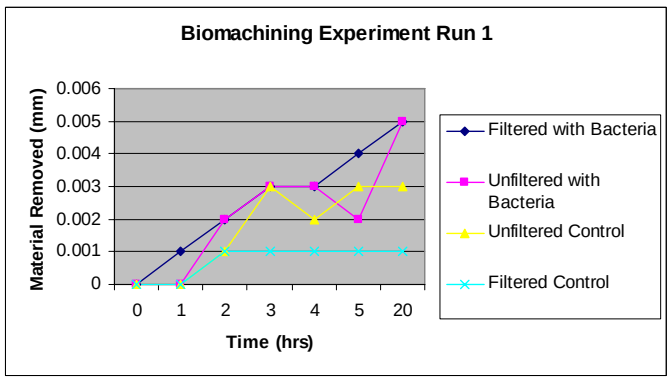
- *T. ferroxidans* cultures are running in WuMRC for study of population growth behavior and maintenance
- Experiments using 99.9% pure Cu were conducted to show the effects of the bacteria, if any, on material removal rate of Cu
- SEM is used to analyze the surface finish of machined samples, and microscopy and turbidity are used to estimate population density

Accomplishments

- Successful running cultures of *T. ferroxidans*, and preliminary population observation using optical microscopy.
- Experiments on 99.9% pure Cu samples incubated in 9K media at room temperature with bacteria showed some accelerated MRR when bacteria were present

Samples in 9K media were agitated in vented flasks. (Apparatus is shown at left)

9K media was used in all tests. Filtered media was passed through a .2µm filter



Future Work

- Create correlation/calibration curves for using turbidity alone as a population estimator.
- Use Environmental Scanning Electron Microscopy to image bacteria on surface of copper samples to study surface population, attachment behavior, and morphology
- Create experiments controlling for parameters such as population, temperature, and applied electric potential to understand process parameters of biomachining and their effects

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