



SEM photo showing black silicon formed by ICP cryo etching.

are planar, and can take advantage of 2D heat spreading over a surface vs. state-of-the-art 1D heat transport associated with heat pipes. The combined result of these

benefits promises to be a two-phase heat transfer device, which is very insensitive to a gravity field. Although liquid pressure drops may be relatively large depending

on the nanostructure density, the overall device dimensions of  $\approx 7 \times 7$  cm are expected to be well within the overall capillary limit. The novel aspects of the currently proposed effort include the use of the phenomenon of superhydrophilicity in a heat pipe, and the wick geometry, control of the nanotip height density, and the method for creating this nanotip texture. A cryo-etch inductively coupled plasma is used to make the nanotips, enabling the cost-effective, mask-free formation of a uniform black silicon surface over a large area, with nanotip heights exceeding 100 microns. Unlike nanotextured surfaces formed by the growth or deposition of materials (e.g. carbon nanotubes), the resulting formations are robust and compatible with liquid processes.

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## Robust Multivariable Optimization and Performance Simulation for ASIC Design

Systematic method automates the simulation and optimization of circuits.

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Application-specific-integrated-circuit (ASIC) design for space applications involves multiple challenges of maximizing performance, minimizing power, and ensuring reliable operation in extreme environments. This is a complex multidimensional optimization problem, which must be solved early in the development cycle of a system due to the time required for testing and qualification severely limiting opportunities to modify and iterate. Manual design techniques, which generally involve simulation at one or a small number of corners with a very limited set of simultaneously variable parameters in order to make the problem tractable, are inefficient and not guaranteed to achieve the best possible results within the performance envelope defined by the process and environmental requirements. What is required is a means to automate design parameter variation, allow the designer to specify operational constraints and performance goals, and to analyze the results in a way that facilitates identifying the tradeoffs defining

the performance envelope over the full set of process and environmental corner cases.

The system developed by the Mixed Signal ASIC Group (MSAG) at the Goddard Space Flight Center is implemented as a framework of software modules, templates, and function libraries. It integrates CAD tools and a mathematical computing environment, and can be customized for new circuit designs with only a modest amount of effort as most common tasks are already encapsulated. Customization is required for simulation test benches to determine performance metrics and for cost function computation. Templates provide a starting point for both, while toolbox functions minimize the code required. Once a test bench has been coded to optimize a particular circuit, it is also used to verify the final design. The combination of test bench and cost function can then serve as a template for similar circuits or be re-used to migrate the design to different processes by re-running it with the new process-

specific device models. The system has been used in the design of time- to-digital converters for laser ranging and time-of-flight mass spectrometry to optimize analog, mixed signal and digital circuits such as charge sensitive amplifiers, comparators, delay elements, radiation tolerant dual interlocked (DICE) flip-flops, and two of three voter gates.

The overall structure of the framework consists of two processes running independently and communicating with each other via a data and handshaking file interface. The master optimization process contains the multivariable optimization algorithm and performs top level analysis of results to select the best solution. It is currently implemented in the Scilab open source environment for numerical computation. This environment is supported on multiple platforms, is well suited to performing numerical analysis and data visualization, and has the advantage of being free to use. Cost can be a significant consideration since multiple copies of the environment may need to run for hours or even days at a time.

The simulation process acts as a slave process, simulating the circuit being optimized using the parameters specified by the optimization process and re-

turning the results. It is currently implemented in the Skill programming language running in the Cadence environment.

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