Parallel Monte Carlo Calculation of Exchange Factors

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The serial code for a direct simulation Monte Carlo calculation of radiative exchange factors between surfaces was parallelized using Message Passing Interface (MPI). An event parallelization strategy was used since each of the individual Monte Carlo calculations occurs completely independently. The program was tested on the MIT 12 node SP2 machine. It was found that the efficiency of the parallel implementation approached 90% of the ideal efficiency calculated using Amdahl's Law.

The exchange factors calculated in this program are used in the simulation of Rapid Thermal Processing (RTP) reactors, which are used in silicon wafer processing for oxidation, implant annealing, and silicidation. As illustrated below high intensity lamps are used to heat the wafers to greater than 1000^{o}C at rates up to 100 K/s. For successful processing the silicon wafer must have small spatial temperature variations and be under tight temperature control. Because of the high heating rates these systems are far from equilibrium. For successful design and control of these reactors, accurate models that take into account radiation, conduction, and convection heat transfer phenomenon must be used. The Monte Carlo simulation parallelized here calculates radiative exchange factors between surfaces in RTP reactors. These exchange factors can then be incorporated into finite element method simulations of the conductive and convective heat transfer as boundary conditions.

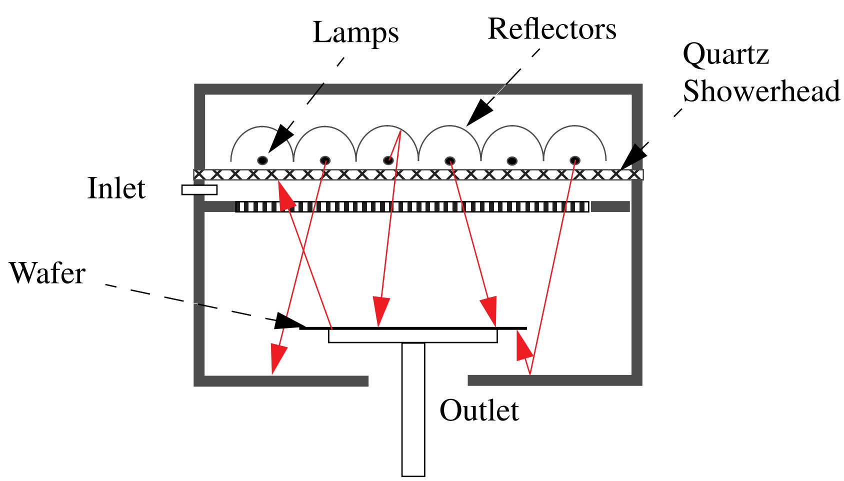

FIGURE 1. RTP reactor schematic.

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Two different parallel versions of the Monte Carlo code were developed. One was based on splitting the photon emission simulation for each surface among the *P* processors available (Version 1). The other had each processor perform calculations on different surfaces (Version 2). Figure 2 shows the parallel efficiency of the two implementations as well as the ideal parallel efficiency (this efficiency was calculated using Amdahl's Law). As indicated in Figure 2, Version 2 is the superior algorithm because it trades many small communications for one very large communication at the end.

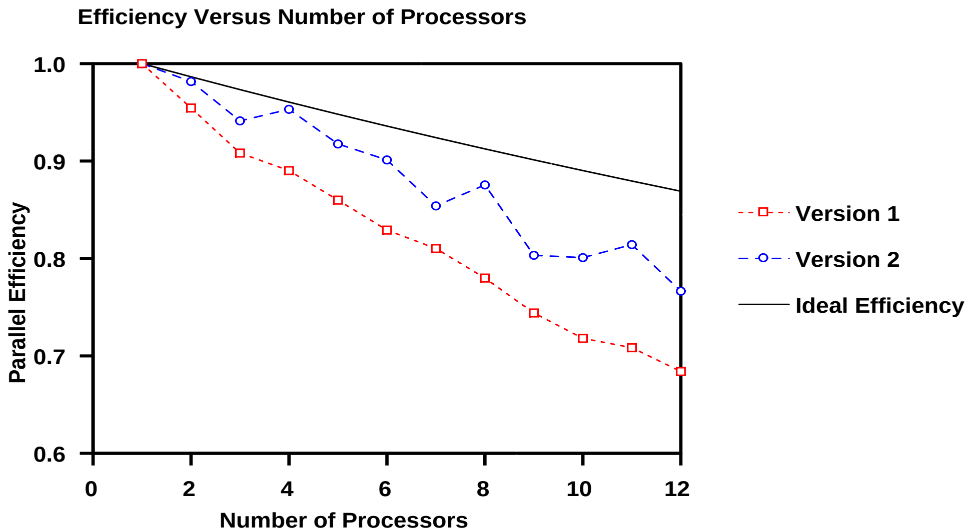

FIGURE 2. Parallel efficiency versus the number of processors. Note the ideal efficiency deviates from one due to the necessary serial reading of the model data into each processor.

References

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