MIGRATEWS2016-14

IMPACT OF RAREFIED GAS FLOWS IN LOW PRESSURE LITHOGRAPHY

Erik Arlemark
ASML Netherlands B.V., De Run 6501, 5504 DR Veldhoven, The Netherlands
erik.alremark@asml.com

KEY WORDS

Heat load study, DSMC wall-kernel for skew TMAC/TAC

ABSTRACT

ASML is market leading supplier of photolithography systems for the semiconductor industry. ASML manufactures machines for the production of integrated circuits such as CPUs, DRAM memory and flash memory. As the new generation of EUV machines is specified to produce line features of about 10 nanomenter and operate in medium vacuum conditions the understanding of rarefied gas flow dynamics becomes important in the context of low pressure maintenance, suppression of contaminants and thermal loads. The medium vacuum condition allows for acceptable transmissivity of the developing light; suppression of contaminants is crucial for maintaining acceptable optical life time of the machine and prediction of thermal load is needed for the nanometer exposure accuracy. Different simulation methods such as network models, CFD, lattice-Boltzman method, DSMC and molecular dynamics have been applied depending on complexity, size of simulation domain, Knudsen number range, Mach number and compressibility. In this presentation ASML will focus on challenges faced when validating DSMC models. Experiments to determination momentum and thermal accommodation factors showed remarkable results, which requires further understanding of underlying physics. A new wall kernel collision scheme is proposed to adhere to the measured results.

Experiments in deriving TMAC and TAC for certain relevant surface and gas type combinations where performed in-house of ASML. For one of the most common gas/wall combination it was found that the TMAC was close to unity while the TAC was closer to zero. Flow calculations where performed with these parameters using DSMC with CLL wall kernel of Graeme Bird [1] and of OpenFOAM [2], where wall kernel was implemented according to Padilla and Boyd [3]. The CLL wall-kernel is dependent on the tangential, normal and rotational energy accommodation coefficients α_t, α_n and α_t. As α_t is determined close to unity through the relation:

$$\alpha_t = TMAC(2 - TMAC) \tag{1}$$

It is found that α_n and α_r need both be close to zero in order to satisfy TAC=0.3.

Since the CLL wall kernel produced unphysical results, as later shown, the alternative wall kernel insulated-Maxwellian was introduced by mixing the three types of wall collision types: Maxwellian-diffusive, specular and Maxwellian-adiabatic illustrated in Figure 1.

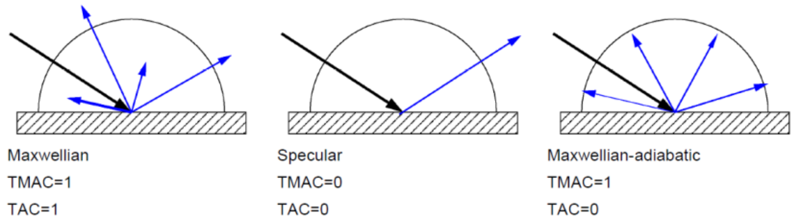

Figure 1: Alternative "insulated-Maxwellian" composed of three types of wall kernels.

An axi-symmetric case, was designed to reproduce a flow situation occurring in the real machine, where flow is distributed through a downward leading pipe connected to two parallel discs leading the flow radially outwards. Inlet flow and wall temperatures where set to 300 K. DSMC with either CLL or insulated-Maxwellian wall kernels produced similar Kn and temperature contours showed in Figure 2 and Figure 3. The heat loads on the bottom wall surface are plotted in Figure 4, where it is shown that the CLL wall kernel has heat conducting from cold to warm at stagnation, which is considered unphysical.

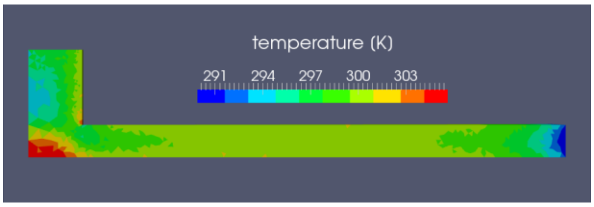

Figure 2: Temperature contour of flow case, Stagnation point ~305 K i.e. warmer than surface.

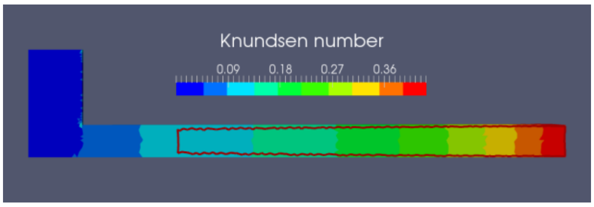

Figure 3: Knudsen number contour, isoline indicates Kn=0.1.

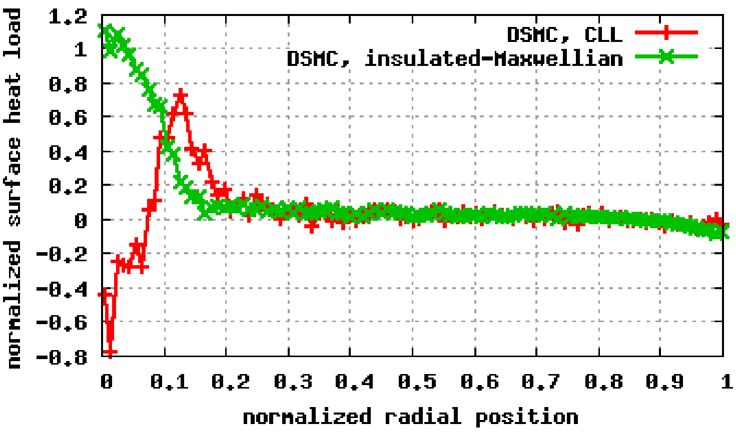

Figure 4: Heat load profiles on bottom surface.

Acknowledgements

Colleagues Nico ten Kate and Kursat Bal at ASML has had large involvements in problem sharing and solution making.

References and Citations

[1] http://www.gab.com.au, visited 26th of May 2016
[2] http://www.openfoam.com, visited 26th of May 2016.
[3] Padilla, J. F. & Boyd, I. D. (2009). Assessment of Gas-Surface Interaction Models for Computation of Rarefied Hybersonic Flow. *Journal of Thermophysics and heat transfer*, **23,** 96-105.