Multiphysics Simulation of Conjugated Heat Transfer and Electrostatic Field on Application of Electrostatic Chucks (ESCs) Using 3D-2D Model Coupling

K. Hsu[1], C. Li[1], J. Yang[1], J. Chen[1], J. Chang[1]

[1]Institute of Applied Mechanics, National Taiwan University, Taipei, Taiwan

Abstract

The temperature control of semiconductor wafers during processing is critical to maintain device characteristics and to control deposited film stresses. To ensure homogeneous film processing over the entire area of the wafer, a uniform wafer temperature must be produced and maintained at the wafer surface. There has been considerable interest in the electrostatic chuck (ESC) in recent years. Wafer cooling by means of a gas (usually helium) at the backside of wafers plays an important role in electrostatic chucks and it uses an electrostatic potential to secure the wafer, and many advantages over mechanical clamps. In this study, the correlation of the electric voltage and electrostatic force distribution are considered to the ability of heat conductance. For this purpose, the multiphysics simulation has been carried out to study the influence of electrostatic on temperature distribution of a wafer. The heat transfer path and schematic presentation of electrostatic chuck are shown [Figure 1]. The resulting temperature distribution on a wafer held by a ceramic body of the electrostatic chuck is investigated and conduct the conjugated heat transfer in 3D and electrostatic force is presented in 2D.

The results of this study indicate: (a) the temperature uniformity effect of the ceramic material-aluminium nitride (AlN), substituted for aluminium oxide (Al2O3) [Figure 2]; (b) The relationship of the wafer temperature uniformity and top temperature with controlling the backside pressure and electric potential [Figure 3]; (c) The electrostatic force distribution on bipolar electrodes embedded under the ceramic [Figure 4] and it is a significant factor on the wafer temperature distribution.

Figures used in the abstract

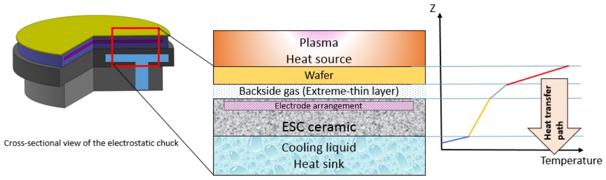

Figure 1: Schematic presentation of electrostatic chuck with heat transfer path. The thermal process can be explained: uniform heat source is applied to the surface of wafer and amounts of heat is brought out from the wafer by means of backside gas and flowing liquid. In this study, heat source from plasma seems to be uniform and heat radiation is less enough to be neglected.

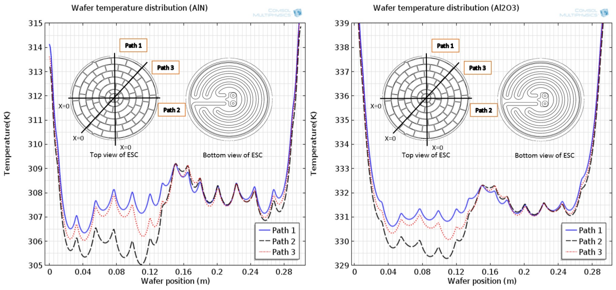

Figure 2: The wafer temperature distribution in three of the paths. The nonsymmetrical distribution is mainly due to the geometry of cooling water and groove of backside gas. AlN ceramic body (left) Al2O3 ceramic body (right).

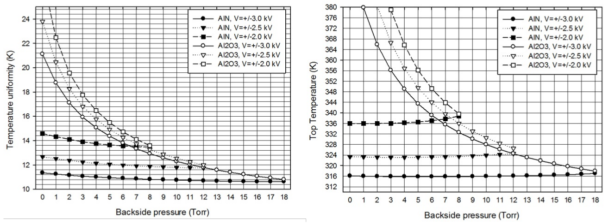

Figure 3: Wafer temperatures as a function of backside pressure and electric voltage. The effect of chucking voltage could be explained: with chucking force increase as voltage, the polymide deformed and resulted in an effective large area for thermal conductance.

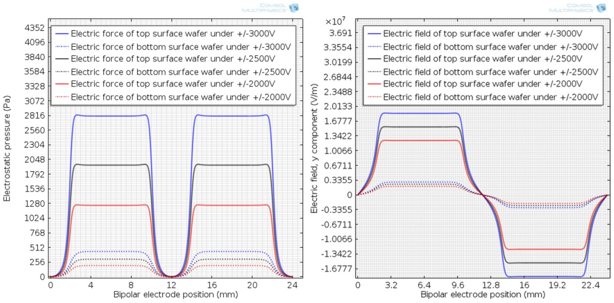

Figure 4: Electrostatic pressure distribution(left) and electric field distribution (right).