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Modeling of a Roll-to-roll Plasma CVD System for Graphene

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ABSTRACT

Graphene is a 2D carbon material that has extraordinary physical properties relevant to many industrial applications such as electronics, oxidation barrier and biosensors. Roll-to-roll plasma chemical vapor deposition (CVD) has been developed to manufacture graphene at large scale. In a plasma CVD chamber, graphene is grown on a copper foil as it passes through a high-temperature plasma region. The temperatures of the gas and the copper foil play important roles in the growth of graphene. Consequently, there is a need to understand the temperature and gas velocity distributions in the system. The heat generated in the plasma creates a thermal field that enhances natural convection inside the system enclosure. The analysis of temperature and fluid flow of hydrogen was carried out numerically using FLUENT, a commercial computational fluid dynamics package. A three-dimensional model has been built including the heat source from the plasma, natural convection, radiation and simple gas reactions. The plasma is generated between two rectangular parallel plates whose major axis can be oriented either vertically or horizontally. The temperature and flow for the vertical plasma electrodes configuration exhibit higher values than the horizontal configuration due to increased interactions of the heated plates with the buoyancy-driven flow. Furthermore, the presence of the copper foil that is used as the substrate for graphene deposition decreases the temperature and velocity in the adjacent regions because the copper foil acts as a fin and impedes fluid flow, respectively. Finally, adding methane as a mixture with hydrogen increases the gas temperature in the plasma region due to the lower thermal conductivity of methane. The numerical results help in understanding the temperature and the flow in the roll-to-roll CVD plasma system that makes it suitable for modeling graphene production for the purpose of optimizing manufacturing process conditions.

KEYWORDS

Chemical vapor deposition, natural convection, plasma, graphene manufacturing