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DESIGN OF MOLECULAR SCREEN GENERATING ULTRA-HIGH VACUUM FOR PRODUCTION OF SEMICONDUCTOR MATERIALS USING MOLECULAR BEAM EPITAXY TECHNOLOGY ON THE CHINESE SPACE STATION

Abstract

Molecular beam epitaxy (MBE), a technique for depositing multilayer high-quality thin films at the atomic level, has an important role in the manufacture of semiconductor materials and is the most promising technology for modern electronic and communication devices. To obtain impurity-free homogeneous thin films, MBE requires an ultra-high vacuum producing environment. However, maintaining such an environment on Earth is challenging due to high cost. According to statistics from Siberian Institute of Semiconductors and Physics, over 75% of the cost is spent on vacuum pumping and energy consumption. As the cost of entering space continues to decrease, we propose to implement semiconductor production with MBE in space. Specifically, using the Chinese space station (CSS) to haul a molecular screen (MS), when the MS travels at 7.9 km/s, the gas density behind the MS decreases significantly, and the pressure is approximately 10e-8 - 10e-10 Pa, which meets the requirements of MBE technology. In order to design a MS that meets the requirements, its material and structure need to be investigated. In this paper, a metal matrix composite is designed to reduce the outgassing rate of the MS under the influence of space radiation and temperature changes. In terms of the structural design of the MS, we propose a deformable disk-shaped structure, which is in shrinking state during rocket's launch to save load space and spreads out after entering space. The front of the MS serves as a natural barrier, preventing gas molecules and particles with low thermal motion velocities from entering the MBE growth area. The periphery of the MS is angled at 45 degrees to the front to prevent hydrogen and helium molecules with high thermal motion velocities diffusing into the wake area from the side. To verify the effectiveness of the MS design, spacecraft rarefied dynamics simulation experiments are conducted using a smooth particle hydrodynamics (SPH) approach. The results show a residual rate of 0.008% for impurities with low thermal velocity of motion and 0.072% for molecules with high thermal velocity of motion in the wake region of the molecular screen, meeting the growth environment requirements of the MBE technology. In summary, we design a MS that creates conditions for using MBE technology to produce semiconductor materials in space. Further, a prototype of MS with a diameter of 450 mm and a weight of 30 kg will be sent to the CSS for real-environment experiments.