ABSTRACT

MEMS based micropropulsion devices are becoming highly demanding for the repositioning of micro/nano satellites. Microthruster is the solution for the re-orbiting of small satellites whereas the microvalve controls the propellant flow and micropump keeps the propellant pressure constant.

The microvalve consists of a silicon membrane, two holes made in silicon wafer and a commercially available piezoelectric stack having overall dimensions of $1 \times 1 \times 16$ cm^3. The silicon membrane has a boss tip at the centre of top side and is structured using conventional KOH bulk micromachining. The inlet/outlet holes are at the bottom silicon structure which is bonded at the periphery to the membrane structure using eutectic bonding. The microvalve is designed to be normally closed and the boss tip area closes the outlet to block the flow initially. The membrane is directly attached to the piezoelectric stack actuator which moves in an out-of-plane motion against the bottom structure. The flowrate of microvalve has been measured varying the applied voltage 30 V to 160 V and found increasing almost linearly with the applied voltage as well as applied pressure. The maximum achievable flowrate of helium was 192 sccm at 160 V and 6 bar applied pressure. Three microvalve devices have been tested for 50000 cycles individually and found average 1 sccm flowrate variation among three devices. The microvalve developed here is a low cost, capable of controlling the flow of gases as well as liquids, leak tight and can be used for high pressure application.

The micropump developed and presented in this dissertation is silicon based valveless diffuser micropump which is basically a silicon diaphragm pump where the passive check valves are replaced by diffuser/nozzle elements to rectify the fluid flow. Piezoelectric actuation is used in this case for diaphragm vibration. The diffuser elements and the pump chamber are realized in the same plane of silicon substrate whereas inlet and outlet holes are made in pyrex7740 using Electro Chemical Discharge Drilling (ECDD) technique. Finally, both the structures are bonded using the anodic bonding technique. The micropump is tested at dry condition using MSA 400 of Polytec and at 5.009 kHz frequency 5.34 µm deflection of the membrane is achieved. The water flowrate of the micropump is measured using water collection for a fixed time method and maximum flowrate is achieved 15µl/min at 25 V applied voltage to the piezo disc. The flowrate variation with frequency is also observed.

An approach to integrate the microvalve, micropump along with the microthruster has been described briefly as the future work.

Keywords: MEMS, Microvalve, Micropump, Micropropulsion, Piezoelectric actuation, Microfabrication, Microstructure, KOH micromachining, Photolithography, Eutectic Bonding, Anodic Bonding, Electro Chemical Discharge Drilling.