A miniature high-vacuum valve

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We present a robust design for a small on/off high-vacuum valve which can be easily manufactured and scaled for use in a variety of compact high-vacuum instruments. These instruments require a valve that can become part of their main embodiment when tubing connections would otherwise be inconvenient, such as in the application of a dewar for a cryo-electron microscopy holder. The valve establishes a vacuum seal by utilizing rubber o-rings and provides a minimal pressure rating of 10^{-7} Torr.

High-vacuum valves are an essential component for instrument designs. However, finding miniature high-vacuum valves to attach directly to instruments can be a challenge to find through commercial retailers. Here we present a miniature high-vacuum valve rated for vacuum sealing at pressures down to 10^{-7} Torr through the use of Viton (fluorocarbon) or nitrile rubber o-rings. A relevant application of such a valve can be seen in the establishment of vacuum in a cryo-electron microscopy holder (Fig. 1),[1,2] where high-vacuum conditions between the inner and outer walls of the liquid-nitrogen dewar provide the best possible thermal insulation. Through the illustrated figures and drawings, we hope that this design can be useful for those looking for a simple and effective solution for applications involving high vacuum on/off sealing.

FIG. 1. Miniature high-vacuum valve attached to the dewar of a cryo-electron microscopy holder.

In Fig. 2(a) an exploded three-dimensional (3D) view of the high-vacuum valve produced by computer-aided design (CAD) is shown. Only a small number of components need to be machined, with the other components (e.g., screws and o-rings) being readily available from hardware suppliers.

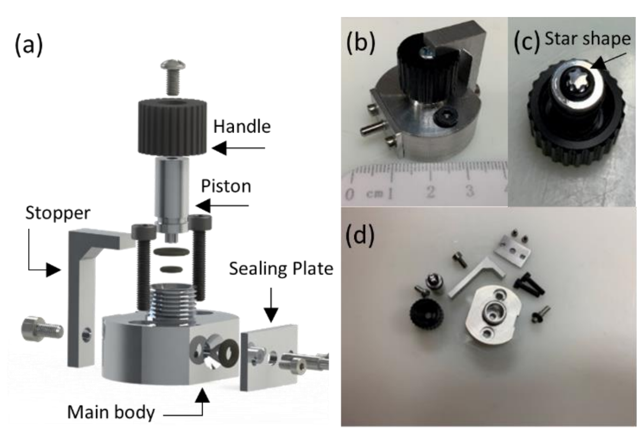

FIG. 2. (a) An exploded 3D-CAD view of the high-vacuum valve with the main components labelled. (b) A machined high-vacuum valve. All metal components were machined from aluminum 6061, the handle was machined from polyoxymethylene, o-rings and screws were purchased from a commercial retailer. (c) The star shaped design on the bottom of the sealing piston ensures the passage of gas in the open position. (d) A disassembled high-vacuum valve.

As shown in Fig. 2, the high-vacuum valve is simply constructed. Depending on the application, materials may vary. In our case, aluminum 6061 was employed to machine the stopper, piston, main body, and sealing plate owing to the ease in machining this material. Overall, the dimensions of the vacuum valve are roughly 38 x 30 x 36 mm, making it a practical solution for applications where space is limited and where dynamic sealing is required. In addition, the size of the valve can be modified and scaled as desired to fit the requirements of specific applications. The components of the high-vacuum valve are designed to be easily replaceable. O-rings can be tested and replaced as necessary depending on the frequency of usage. This flexibility in the design ensures that this valve can be used for prolonged periods of time for various applications.

Figs. 2(b)-(d) show some images of the high-vacuum valve after machining. The piston component seen in Fig. 2(c) has a star-shaped feature on the bottom so that the o-ring is well centered and remains in this centered position relative to the o-ring groove during the movement of the piston. This shape also ensures that the decompression process occurs without any inhibition of the gas flow. Furthermore, sharp edges within the high-vacuum valve are removed during the machining process to guarantee that the o-ring is not damaged during usage.

Sealing is attained through the use of two o-rings positioned on the piston of the valve. By rotating the handle, the valve can easily be opened or closed so that the bottom o-ring decompresses or compresses, respectively. A cross-section view of the high-vacuum valve can be seen in Fig. 3.

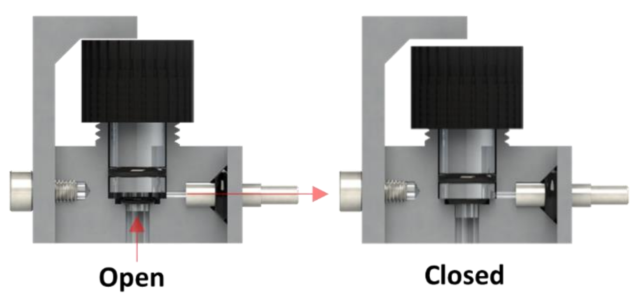

FIG. 3. A 3D-CAD cross-sectional view of the high-vacuum valve

illustrating the o-ring sealing process. As the handle is rotated, the o-ring decompresses or compresses by about 30 % of its cross-section.

The stopper provides the user with a defined open position and ensures that the star-shaped part of the piston never leaves its receiving hole. In this position, vacuum suction is enabled through the outlet connected to a vacuum line. This is illustrated by red arrows in Fig. 3. The valve can easily be connected to a flat surface to form a seal against an external o-ring, and thus the valve can be integrated with the body of a given device.

SUPPLEMENTARY MATERIAL

Detailed drawings and specifications of the high-vacuum valve components are available through the supplementary material provided.

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DATA AVAILABILITY

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

REFERENCES

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