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UHV PIEZOELECTRIC TRANSLATOR

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ABSTRACT

A UHV compatible piezoelectric translator has been developed to correct for angular misalignments in the crystals of a UHV x-ray monochromator. The unit is small, bakeable to 150°C, and uses only ceramic materials for insulation. We report on the construction details, vacuum compatibility, mechanical properties, and uses of the device.

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INTRODUCTION

Piezoelectric translators have been successfully used for many different purposes and in many different devices. In our case, such a device was needed to provide the necessary correction for angular misalignment between the crystals of a UHV monochromator.[1]

Because of the UHV compatibility of this monochromator, we needed a piezoelectric translator that would be able to operate in a UHV environment and without undue outgassing characteristics. However, we were unable to obtain such a device. Commercial piezoelectrics typically use insulation and other construction materials which are, because of their high vapor pressure, unsuitable for use in a UHV environment. As a result, we set out to build such a device, using only UHV compatible materials.

CONSTRUCTION

We needed a translator which would give us the longest possible stroke and would be small enough to fit our standard crystal holder. To accomplish this, we chose the readily available disk type of piezoelectric material. This has the advantage of giving us some control over the stroke of the device by adding or subtracting disks. The material used in these disks is lead Titanate, lead Zirconate, 12.7 mm o.d. x 4 mm i.d. x 0.9 mm thick.[2] The piezoelectric constant of this material is 4×10^{-10} m/V, the curie point 350°C. This allows for a safe bakeout temperature of 150°C without fear of depolarization. Thin, round copper washers, each provided with a tap, are used as electrical contacts between the piezoelectric disks. They are identical in size to the piezo disk but made from 0.05 mm soft copper foil to minimize any spring action of these washers.

A 3 x 4 mm dia. quartz tube is used as a center stay on which the piezoelectric disks and the electrical contacts are centered and stacked. This tube makes the whole assembly rigid as well. Because the disks are electrically parallel, the positive sides of a pair of disks and the negative sides of a pair of disks always face each other with a contact washer in between.

A Macor[3] washer at each end of the stack provides the necessary electrical insulation, so that mechanical connections can be made to the rest of the system. A small stainless steel threaded shaft, passing through the bore of the quartz tube and provided with a number of belleville spring washers, ties the assembly together, preloads the stack, and allows flexibility in the axial direction for the expansion of the device (Fig. 1).

We used 36 disks in the 5 cm space available. All parts are ultrasonically cleaned in alcohol before assembly. In addition, the piezoelectric disks are baked overnight in a vacuum oven at 150°C. All stainless steel fasteners are silverplated to prevent galling and seizures.

VACUUM COMPATIBILITY

We have no quantitative data on the outgassing characteristics of this device. However, we have four of these devices routinely operating at pressures between 5×10^{-10} - 5×10^{-9} Torr for the past year, and have not noticed any effects on the vacuum.

MECHANICAL PROPERTIES

The stroke of the translator was measured by mounting a mirror on a lever arm. One end of the arm was attached to one end of the translator while the other ends, of both the lever arm and translator, were fixed. Rotations of the mirror were observed with an autocollimator.[4] A typical plot of the elongation vs. voltage (see Fig. 3) shows the hysteresis common to the piezoelectric material. Starting at 500 volts on the top branch of the hysteresis, the translator creeps 0.3 microns in the first five seconds, and an additional 0.3 microns in the next 45 seconds.

The average stroke of our translators is 15.5 microns over a 1050 volt range. Strokes as high as 18.9 microns have been measured. The piezoelectric constant corresponding to a stroke of 15.5 microns is 4.1×10^{-10} m/V. This agrees well with the published value of 4.0×10^{-10} m/V suggesting that the losses of the system are negligible.

The stroke of the translator depends on the preload force applied by the Belleville washers (Fig. 4). A torque on the end nut (Fig. 1, #12) of 4 oz.-in. was necessary to achieve full stroke. This corresponds to a force of 8 pounds across the stack of disks. Below 4 oz.-in. the stroke fell off dramatically. We suspect that this may be due to the copper washers acting as springs and absorbing some of the movement.

USES

The hysteresis and creep inherent in the piezoelectric material limits its uses. For applications which require precise movements some sort of feedback system is necessary.[5] The device is particularly useful where small dynamic adjustments are necessary.

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- [3] Corning Machinable Glass Ceramic, Corning Glass Works, Corning, N.Y. 14830.
- [4] Micro Radius Instruments, 350 Mulberry Drive, San Marco CA 92069, #MRA-150.
- [5] See for example J.A. Golovchenko, R.A. Levesque, and P.L. Cowan, Rev. Sci. Instrum. 54 (1981) 509-516.

FIGURE CAPTIONS

- Fig. 1. 1) Piezoelectric disk; 2) Copper contact disk; 3) Quartz center stay; 4) Macor end plates; 5) Contact rod; 6) Contact spacer; 7) Stainless steel pressure plate; 8) Stainless steel nose piece; 9) Coarse adjust; 10) Belleville spring washer; 11) Stainless steel tie rod. 12) End nut.
- Fig. 2. Photograph of the completed and partly completed device and parts.
- Fig. 3. Graph of elongation vs. voltage for a typical translator.
- Fig. 4. Graph of the stroke of the device as a function of the torque applied on the end nut.

FIG 2

Elongation vs Voltage

Applied Torque vs Stroke