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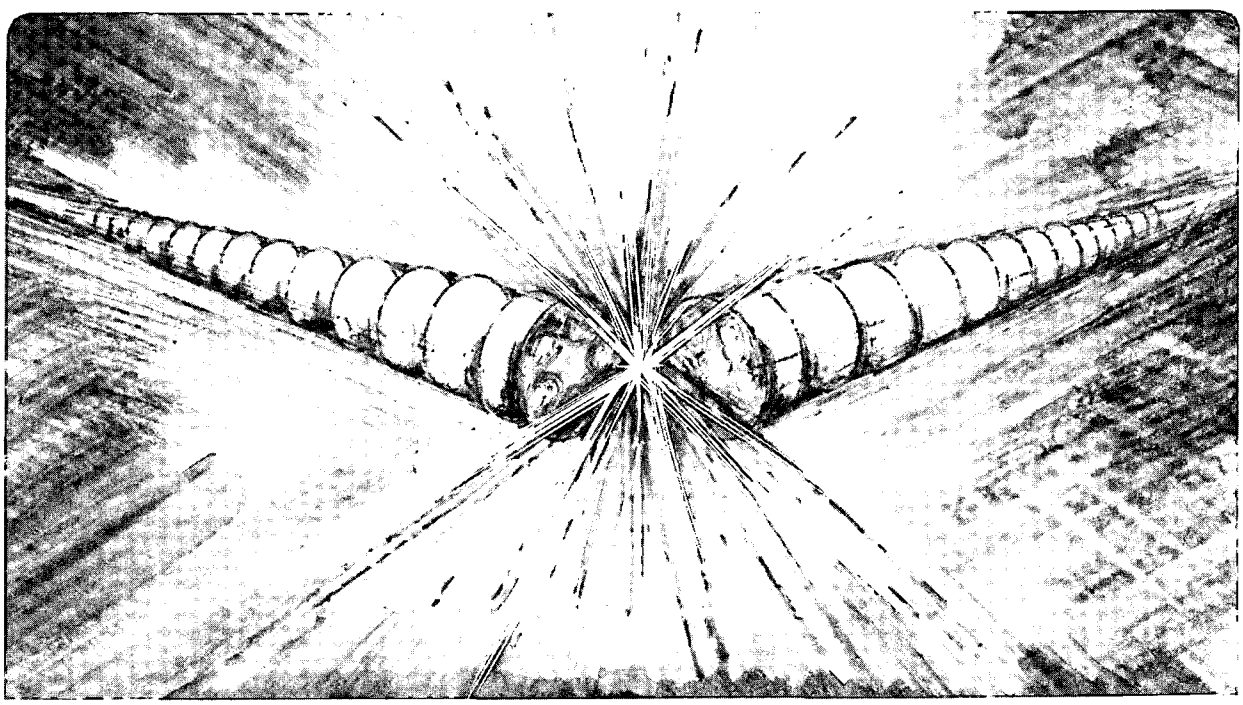

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ABSTRACT

The thermal coefficient of expansion of lanthanum hexaboride(LaB_6) as a function of material density has been measured in the temperature range of 1000 °C to 2000 °C. Though there was not a large variation in thermal expansion, the coefficient of thermal expansion did vary directly with LaB_6 density. The coefficient increased from 8.8×10^{-6} / °C at 61 % density to 11.5×10^{-6} / °C at 95 % density.

* Work is supported by the Aero Propulsion and Power Laboratory, Wright-Patterson AFB and the U.S. DOE under contract No. DE-AC-76SF00098.

It has been known for some time that lanthanum hexaboride (LaB_6) is a good material for use as an electron emitter. [1-3] It has also been demonstrated that directly-heated LaB_6 cathodes, either in the form of filaments or in a coaxial geometry can be operated successfully in a plasma source. [4-6] In some applications, such as high power free electron lasers, large area cathodes are required. A directly-heated LaB_6 electron emitter has been proposed for the generation of intense electron beams. [7] Due to the high temperatures required for cathode operations and the brittleness of lanthanum hexaboride, matching its thermal expansion characteristics as closely as possible to those of the mounting materials would aid in reducing thermal stresses. However, there are no available data on the thermal coefficient of expansion of LaB_6 as a function of material density or at temperatures above 1000 °C. To aid in the design of the proposed cathodes, measurements of the thermal expansion of LaB_6 samples of various densities and at temperatures above 1000 °C have been performed. This paper describes the apparatus, test procedures and the results of these measurements.

The manufacture of solid lanthanum hexaboride is normally accomplished by sintering of LaB_6 powder under various temperatures and pressures to obtain the desired material density. [1,8] The maximum obtainable theoretical density is 4.7 g/cm^3 Densities ranging from 60% to 95% of this value are readily available. Higher densities can be produced, but at a considerably higher manufacturing cost. LaB_6 material with densities lower than 60% is quite soft and structurally weak, and therefore is not suitable for cathode use. For the higher densities, LaB_6 has ceramic-like properties in hardness and requires special tooling and techniques for machining.

The experimental set-up is shown in Fig.1. The test apparatus was installed in a vacuum chamber equipped with a window which provided a full view of the LaB_6 sample. The test fixture was designed to hold one end of the LaB_6 sample rigidly and to allow the other end to slide freely. To prevent chemical

reaction at the contact points, graphite was used to hold the LaB_6 samples. The LaB_6 test samples were viewed through a window with an optical pyrometer fitted with a telescopic lens. The pyrometer was mounted on a rack and pinion assembly and mechanically connected to an linear variable differential transformer (LVDT). The LVDT has a resolution of 6.35×10^{-5} cm and a linearity of $\pm$ 0.25 % of full scale. The LVDT was set up with a calibrated range of $\pm$ 2 cm. The window transmission was separately checked with a reference light, and a transmission correction of 2% was determined. All temperatures were corrected by using the emissivity values published by Storms. [9]

The LaB_6 samples were cylindrical rods of approximately 0.63 cm diameter and 5 cm length.[10] Small notches were ground at 0.5 cm intervals over the center 3 cm of the samples. Material density of the tested samples varied from 60 to 95 %. The central, most uniform temperature section of the LaB_6 rod was chosen for the measurements. Temperature variations along the section were in the range of 4%.

Each LaB_6 sample was in turn installed in the assembly. The distance between two notches was measured at room temperature. The heating current was then increased gradually until the LaB_6 temperature came within the pyrometer's range (~ 800 ^{o} C). The temperature was allowed to stabilize and then recorded along with the measured distance between the reference notches. This procedure was repeated at various temperatures. All LaB_6 samples were tested several times to assure repeatability.

Fig. 2 is a plot of the expansion characteristics of a 61 % dense LaB_6 sample, which is typical of the data from all test samples. It can be seen that the expansion can be described by two linear functions. One from 20 to 1000 °C and a second from 1000 to 2000 °C. The slope of the first segment (20 to 1000 °C) gives a thermal coefficient of expansion of 6.6×10^{-6} / °C, which agrees closely to previously reported coefficients.[11,12] The second segment (1000 to 2000° C) has a slope of 8.7×10^{-6} / °C, which is slightly larger than the first

segment.

Figure 3 is a graph which shows the relationship between a 61 % and a 95 % dense sample. Added to the graph is the thermal expansion characteristics of tantalum.[3] Since the difference in thermal expansion between tantalum and LaB_6 is small and tantalum has a lower reactivity with LaB_6 than other refractory metals, it is commonly used as an interface material for LaB_6. Table 1 lists the measured coefficients of expansion (1000 to 2000 °C) for the various test samples. Although the differences are minor, the thermal coefficient of expansion does vary directly with material density.

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Figure Captions

Figure I. Schematic of the apparatus used for measuring the thermal coefficient of expansion of LaB_6.

Figure 2. A graph of the thermal expansion characteristics of a 61 % dense sample of LaB6. Note that the expansion can be described by two linear functions as shown.

Figure 3. A graph showing the relationship of the thermal expansion characteristics of 61 % and 95 % samples

Table 1. Thermal coefficient of expansion of LaB_6. (1000 to 2000 °C)

Material density [%]	Coefficient [10^{-6} / °C]
61	8.7
75	9.0
80	9.8
95	11.5

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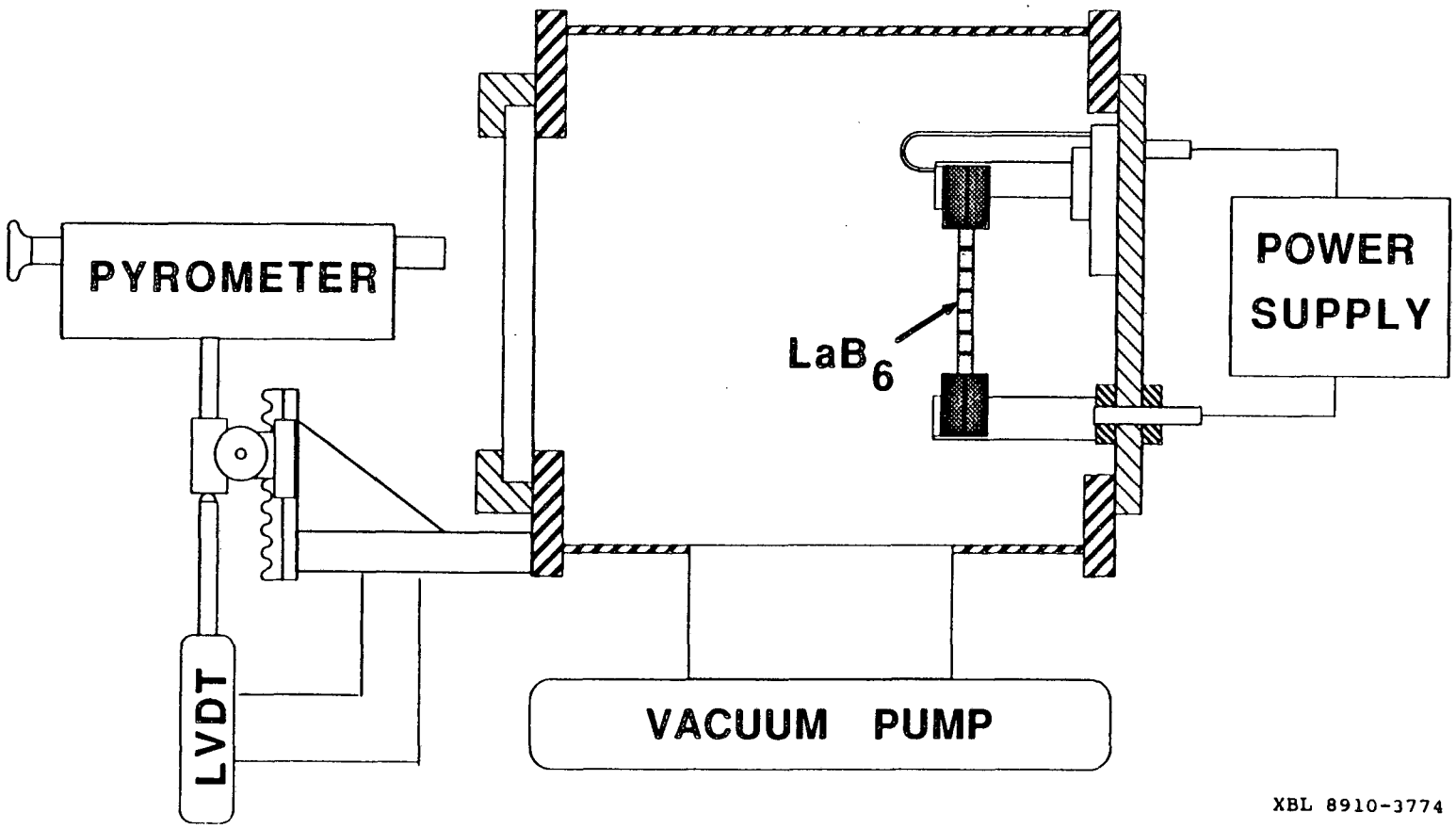

Figure 1

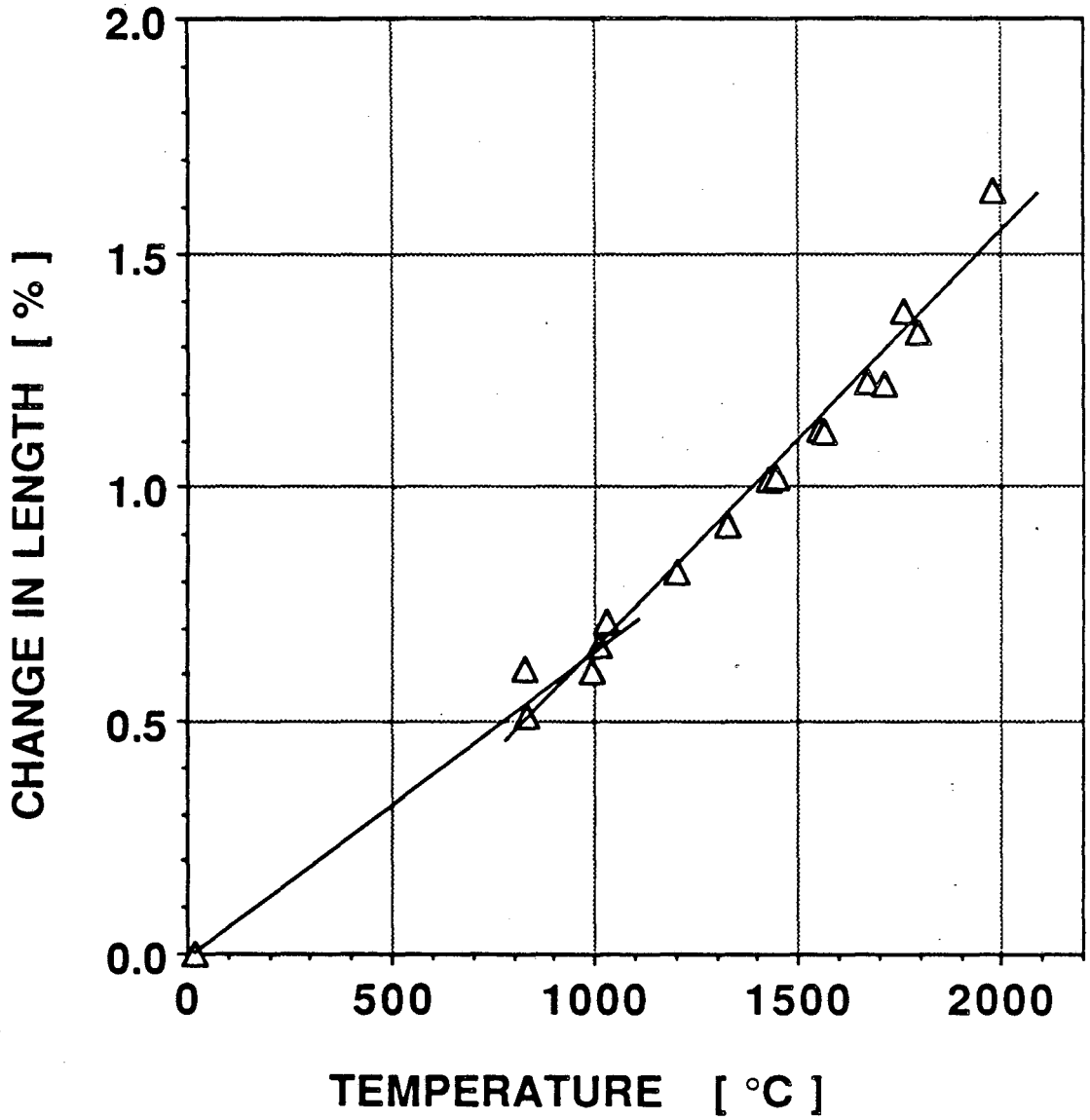
2.0
1.5
1.0
0.5
0.0
CHANGE IN LENGTH [%]
0
500
1000
1500
2000
TEMPERATURE [°C]

Figure 2

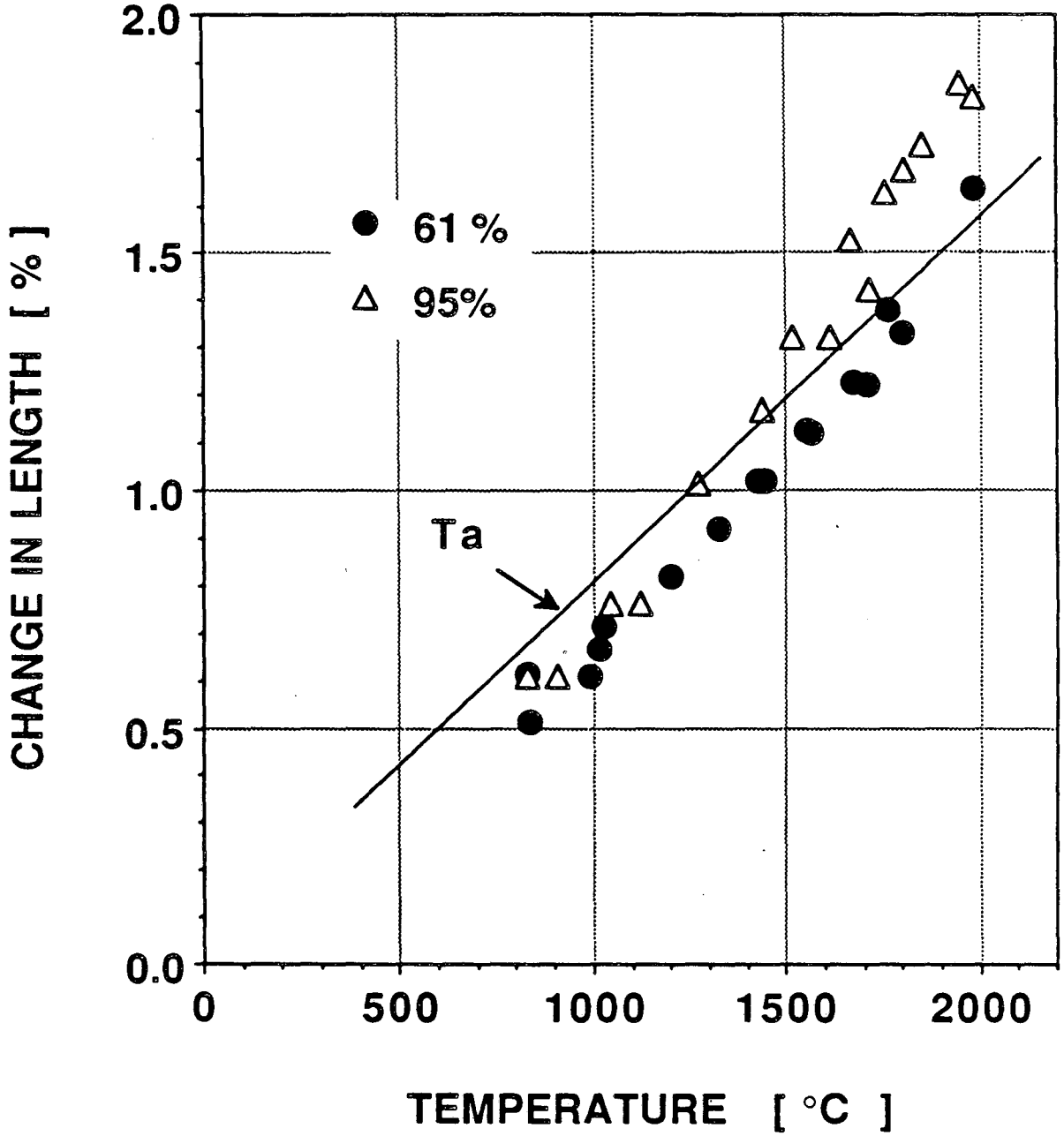

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Figure 3

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