temperature thermal expansion and magnetostriction of Kovar

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The temperature and magnetic field dependence of the thermal expansion coefficient and the magnetostriction of commercial Kovar, an Fe-Ni-Co glass-to-metal sealing alloy, has been measured below 50 K and well into the magnetic saturation region. The measured properties of Kovar show anomalous behavior similar to that found in other Invar-type alloys, and are markedly different from the properties of a pure alloy of about the same composition.

var[1-] is a commercial alloy designed to have a good ermal expansion match to certain hard glasses. a r-to-glass seals are used with increasing frequency emperatures down to 4.2 K and in high magnetic ds. It is important with regard to the integrity of the l to know the thermal expansivity and magnetostric- e behavior under such conditions. This paper reports the temperature and magnetic field dependence of the ermal expansion and magnetostriction of Kovar below K; comparison is made to an experimental Fe-Ni-Co loy of quite similar composition.

commercial Kovar sample of $\frac{1}{4}$-in.-diam bar stock s kindly provided by the Specialty Metals Division, estinghouse Electric Corp., Blairsville, Pa. Compo- tion of this commercial alloy is 29.10-wt% Ni, 17.29- % Co, 0.45-wt% Mn, balance Fe compared to the erimental alloy LM54 which is 30.30-wt% Ni, 17.70- % Co, balance Fe. Both alloys were cold reduced 75% area, sectioned, and annealed for 1 h at 1100 °C in dry drogen (dew point < – 50 °C).

cimen preparation and measuring techniques have en described previously.[2-4] The temperature dependence of the forced magnetostriction $h_0' = \partial l/l\partial H$ well into the paraprocess region ($H = 2.3$ T) was measured (Fig. 1). The saturation magnetostriction and the field dependence of the forced magnetostriction were measured at 20 K (Fig. 2). The thermal expansion coefficient $\alpha = \partial l/l\partial T$ was measured at $H = 0$ and $H = 2.2$ T. The temperature dependence of h_0' and the saturation magnetostriction should produce a change in α as previously discussed.[3,4] All length changes were measured between equilibrium states, and relative to an OFHC copper cell using a three-terminal capacitor dilatometer. This procedure is particularly important for these materials as their low thermal conductivity required over 1 h to achieve thermal equilibrium between the sample and the copper cell at 50 K. This long time set the practical upper temperature limit for the measurement apparatus used. Only very slight traces of any relaxation process following a change in magnetic field in the paraprocess region were found at 4.2 K.

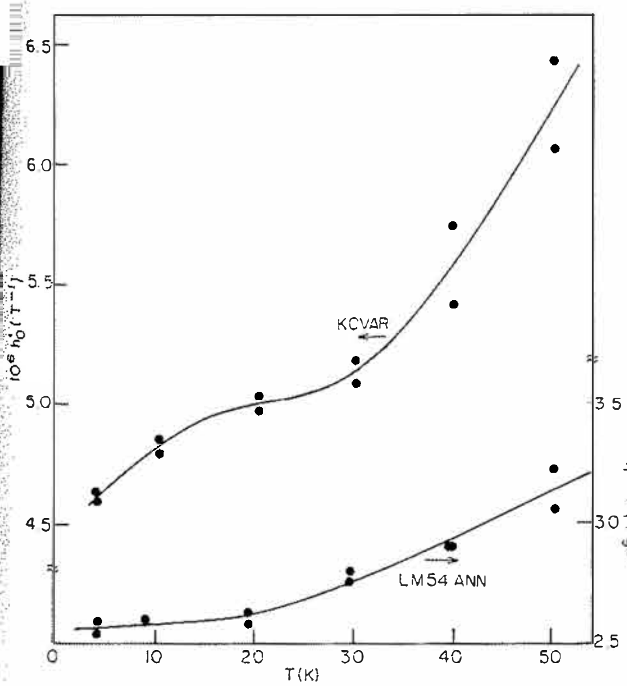

FIG. 1. Temperature dependence of the forced magnetostriction coefficient of Kovar and of the LM54 ANN sample.

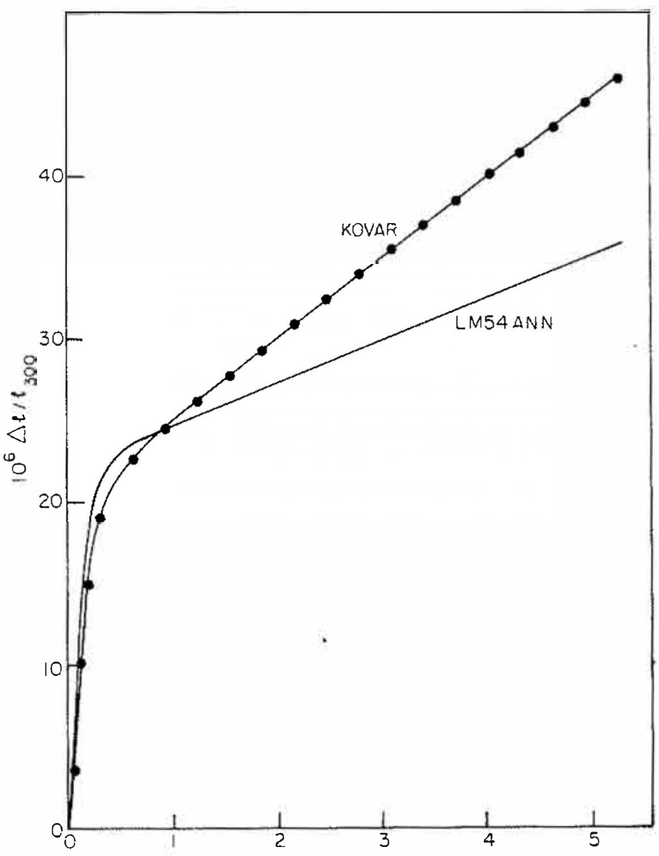

FIG. 2. Magnetic field dependence of the magnetostriction of Kovar and LM54 ANN at 20 K.

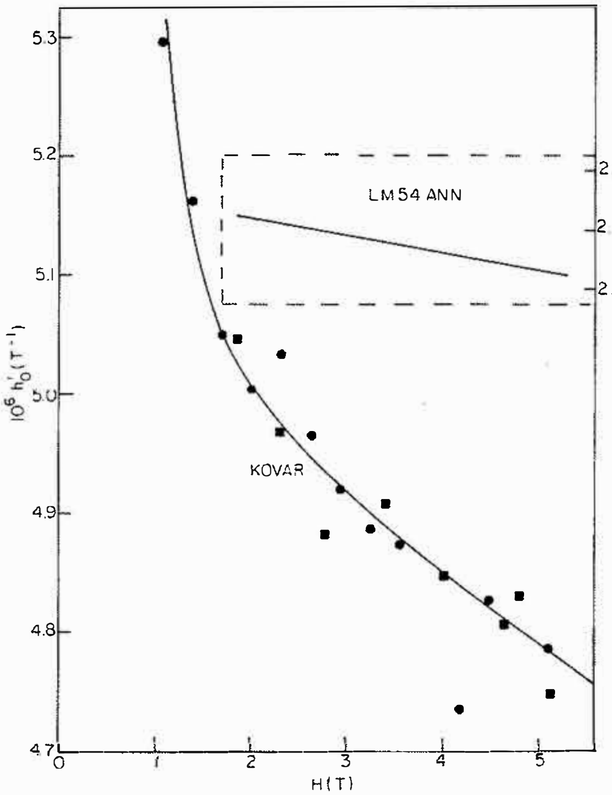

FIG. 3. Magnetic field dependence of the forced magnetostriction coefficient of Kovar and LM54 ANN.

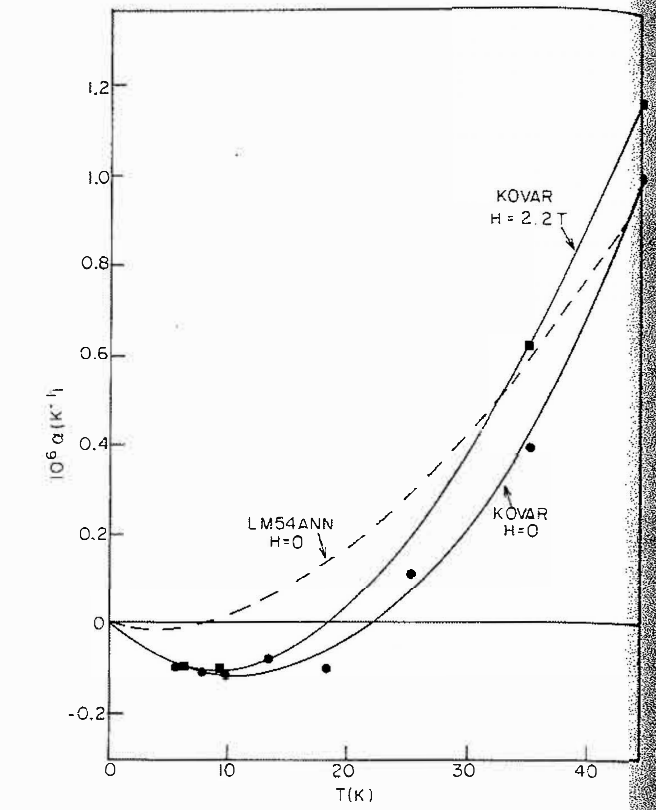

FIG. 4. Temperature and magnetic field dependence of the thermal expansion of Kovar.

The differences in the properties of the two alloys are quite striking, despite their very similar compositions. h_0' for Kovar is twice as large and has a temperature dependence that more closely resembles that observed for alloys nearer the Invar composition.[4] Also, it decreases below 20 K for Kovar, but not for LM54 ANN. The saturation magnetostriction for the Kovar sample is slightly less than that observed for LM54 ANN; h_0' is also more field dependent (Fig. 3). The thermal expansion $\alpha(H=0)$, for Kovar is less than $\alpha(H=0)$ for LM54 ANN (Fig. 4), consistent with the presence of a larger Invar anomaly. α for Kovar is negative below 22 K. Above 20 K, $\alpha(H=2\ T)$ is appreciably different from $\alpha(H=0)$, and in reasonable agreement with the temperature dependence of h_0', if the temperature dependence of the saturation magnetostriction is negligible. The large differences observed here between a commercial alloy and an experimental alloy of close composition point out the complexities of the Invar problem. We are still not able to account for the empirical methods used for control of properties of commercial alloys.

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[1]Kovar is the registered trademark of Westinghouse Electric Corp.

[2]G. K. White, Cryogenics 1, 151 (1961).
[3]W. F. Schlosser, E. Latal, P. P. M. Meincke, G. M. Graham, and D. A. Colling, *AIP Conference Proceedings No. 3, Thermal Expansion—1971*, edited by G. M. Graham and H. E. Hagy (American Institute of Physics, New York, 1972), p. 195.
[4] W. F. Schlosser, G. M. Graham, and P. P. M. Meincke, J. Phys. Chem. Solids 32, 927 (1971).