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# Investigation of thermal hysteresis near the Néel transition in chromium

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**Abstract.** The electrical resistivity and Young's modulus of several samples of chromium have been measured in the vicinity of the Néel transition. To within the accuracy obtainable, no thermal hysteresis was observable.

## 1. Introduction

Since the establishment of spin density wave theory as a means of interpreting the magnetic ordering in chromium, a vast amount of research has been devoted to studies of the Néel transition. These studies have involved the observation of anomalous behaviour in various physical properties (electrical resistivity being the most often investigated). Many of the studies have observed inconsistencies, non-reproducible effects or apparent hysteresis. Secondary anomalies in resistivity (Sabine and Svenson 1968), hysteresis (Arajs *et al* 1962, Stebler 1970) and relaxation effects (Stebler 1970, Weber and Street 1972) have been reported for both single crystal and polycrystalline samples. In general though, many of these effects appear to be non-reproducible from one experimental arrangement to the next.

Some of the observed effects have been successfully attributed to strain (Bacon and Cowlam 1969) and alloying (Arrott and Werner 1967), whilst experimental aberrations such as Peltier heating (Williams and Street 1980) or temperature non-uniformities may have had some perturbing effect. Nevertheless, hysteresis effects in resistivity have been reported several times. The magnitude of the maximum difference between heating and cooling cycles on polycrystalline samples has been reported to be as large as about 1%, whilst the temperature range of the effects appears to exist anywhere from 290 K to 350 K (extending both above and below $T_N$).

The object of this paper is to report measurements of the electrical resistivity and Young's modulus on annealed polycrystalline chromium in the vicinity of $T_N$.

## 2. Results

A sample of 99·999% polycrystalline chromium was spark cut to dimensions 2 mm × 3 mm × 30 mm and then annealed at 1200°C in vacuum for 24 hours. X-ray

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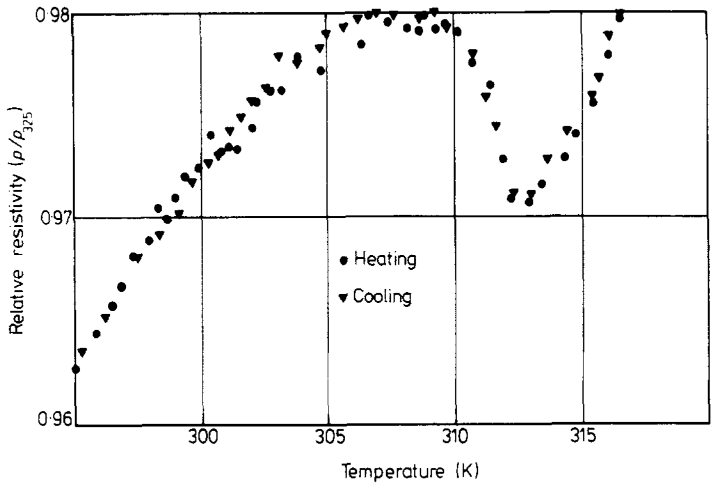


**Figure 1.** The electrical resistivity of annealed polycrystalline chromium in the vicinity of the Néel transition.

and resistivity analysis indicated only a low level of strain remaining after the anneal, with the sample having a very large grained appearance.

The sample was suspended in helium exchange gas by four copper wires, these being attached with silver conducting epoxy. The cryostat could be continuously heated or cooled at any desired rate. The temperature was monitored with two copper–constantan thermocouples attached to the sample with GE varnish. Resistivity was monitored with a data logging system, the current being reversed between consecutive measurements. No account was taken of Peltier heating effects (Williams and Street 1980), though these would have had no influence in the appearance or non-appearance of hysteresis.

The result of a 6 K per hour heating rate and 6 K per hour cooling rate between 280 K and 340 K is shown in figure 1. Both heating and cooling curves agree to within 0·1% and there is no evidence of any hysteresis.

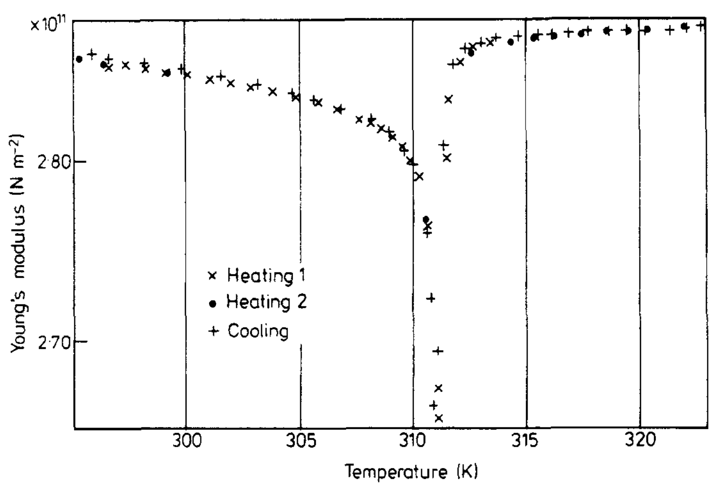


**Figure 2.** The Young's modulus of annealed polycrystalline chromium in the vicinity of the Néel transition.

The sample was next bonded to a 65 kHz quartz transducer with araldite epoxy. The assemblage was suspended by pivots in helium exchange gas, and heating and cooling at about 6 K per hour undertaken. The temperature was again monitored with a copper–constantan thermocouple. From the resonant frequency of the system, the Young's modulus of the chromium was determined (Munday 1968). Once again, heating and cooling cycles coincided to within the experimental uncertainty of 0·1% (figure 2).

Further measurements of resistivity using both DC and AC (eliminating Peltier effects) techniques were performed on a variety of strained and annealed samples; however in each case there was no evidence of thermal hysteresis about the Néel transition.

## 3. Conclusion

For both strained and annealed polycrystalline chromium, hysteresis effects were not observable in either resistivity or Young's modulus. Below $T_N$, large (approximately 1%) differences in resistivity have been observed as a function of $\boldsymbol{Q}$ orientation in single crystals (Muir and Ström-Olsen 1971, Akiba and Mitsui 1972). This could account for the previously observed hysteresis in single crystals below $T_N$; however it would appear to discount the possibility of hysteresis above $T_N$. Furthermore, neutron diffraction (Shirane and Takei 1962) and specific heat studies (Williams *et al* 1979) have indicated that ordering persists above $T_N$ only in heavily dislocated polycrystalline samples. Such highly non-uniform samples would be unlikely to have any preferred alignment of $\boldsymbol{Q}$ sufficient to account for the observed hysteresis above $T_N$.

The earlier observations of thermal hysteresis extending from 280 K to 340 K remain in contradiction with current results, and any solution may lie in the effects of $\boldsymbol{Q}$ alignment and strain.

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