4. Experimental Objectives

1) Measure the hysteresis loop of soft magnetic ferrite material; acquire the coercitive force and residual magnetism of the material;
2) Measure the basic magnetization curve of soft magnetic ferrite and the relationship curve between magnetic conductivity and magnetic field strength;
3) Measure the Curie temperature of the ferromagnetic material

5. Precautions

1) Check the wiring is correct before turning on the power. After experiment, turn off the power before removing the wiring;
2) Turn on power and warm up for 10 minutes before experiment;
3) Do not short circuit the two ends of the AC power output directly to avoid damage to the power supply;
4) When the heating well is hot. Do not touch it to avoid burns.

6. Experimental Procedures

A. Observe and measure the dynamic hysteresis loop of soft ferrite

(1) Select a sample to be tested and connect the components according to the circuit shown in Figure 6.

(2) Adjust the oscilloscope light spot to the center of the screen. Adjust the magnetizing current ("A-Adj." knob) starts from zero and gradually increases until the magnetic induction strength B on the hysteresis loop reaches saturation (i.e. when the H value reaches a sufficiently high value, the curve tends to become flat, which is the state of saturation). Set the frequency of the magnetizing current to about $9000Hz$ ("F-Adj." knob). Adjust the X axis and Y axis divisions of the oscilloscope to appropriate values to make the hysteresis loop fill the entire screen as much as possible.

(3) Record the readings of vertices B_m and H_m of the hysteresis loop, the residual magnetic induction B_r and coercive force H_c (in units of voltage). Use formula (2) and formula (7) to convert these readings to the corresponding values of B_m, H_m, B_r and H_c. Plot Hysteresis loop of the soft ferrite sample.

B. Measure the basic magnetization curve of soft ferrite

Slowly reduce the magnetizing current from large to small and demagnetize to zero. Starting from zero, record the vertices of different hysteresis loops of current from small to large to make the basic magnetization curve ($B-H$ relationship) of ferrite and the relationship curve between magnetic permeability and magnetic field strength ($\mu-H$ curve), where $\mu=\dfrac{B}{H}$.

C. Measure the Curie temperature of ferromagnetic material samples

(1) Select a sample to be tested and connect the components according to the circuit shown in Figure 6. The voltage u_2 can be either connected to the oscilloscope *CH2* to observe its amplitude, or connected to the AC voltmeter on the apparatus panel to observe its effective value.

(2) Adjust the frequency of the magnetizing current to about $9000Hz$. Increase the magnetizing current until the magnetic induction intensity reaches saturation.

(3) Put the sample to be tested into the heating well (the hole of the Heater). Set the temperature to the expected value using Up/Down/Set/Reset buttons. When the temperature in the well is stable within 1 °C of the set temperature, record the effective value of voltage u_2 and the temperature t at that time. Increase the temperature gradually from room temperature, record multiple sets of data. Note to take more data points in the region where the slope changes rapidly.

(4) According to the data points, make a curve of voltage u_2 with temperature t, and take the temperature value at the maximum slope in the curve as the Curie temperature t_C of the sample.

7. An example of data recording and processing

Note: Following data are for reference only, not the criteria for apparatus performance:

A. Measure the dynamic hysteresis loop of soft ferrite

Sample number: B

Sample dimensions: inner diameter $2.8mm$, outer diameter $6.0mm$ and thickness $4.0mm$, we get:

Average perimeter of sample $l = 13.8mm$, cross-sectional area $S = 6.4mm^2$.

Frequency of magnetizing current: $f = 9036Hz$, $R_1 = 2\Omega$, $R_2 = 300\Omega$, $C = 1\mu F$

Table 1 Readings of u_1 and u_2 on the oscilloscope and corresponding *H* and *B*

u_1/mV	$H/(A/m)$	u_2/mV	B/T	u_1/mV	$H/(A/m)$	u_2/mV	B/T
23	8.3	0	0	-29	-10.5	-10	-0.047
29	10.5	10	0.047	-36	-13.0	-19	-0.089
36	13.0	19	0.089	-40	-14.5	-22	-0.103
40	14.5	22	0.103	-60	-21.7	-29	-0.136
60	21.7	29	0.136	-80	-28.9	-32	-0.150
80	28.9	32	0.150	-96	-34.7	-33	-0.155
96	34.7	33	0.155	-80	-28.9	-32	-0.150
80	28.9	32	0.150	-60	-21.7	-31	-0.145
60	21.7	31	0.145	-40	-14.5	-29	-0.136
40	14.5	29	0.136	-20	-7.2	-27	-0.127
20	7.2	27	0.127	0	0	-22	-0.103

0	0	22	0.103	6	2.2	-19	-0.089
-6	-2.2	19	0.089	16	5.8	-10	-0.047
-16	-5.8	10	0.047	23	8.3	0	0
-23	-8.3	0	0				

Make the hysteresis loop of the sample according to the data in Table 1, as shown in Figure 7.

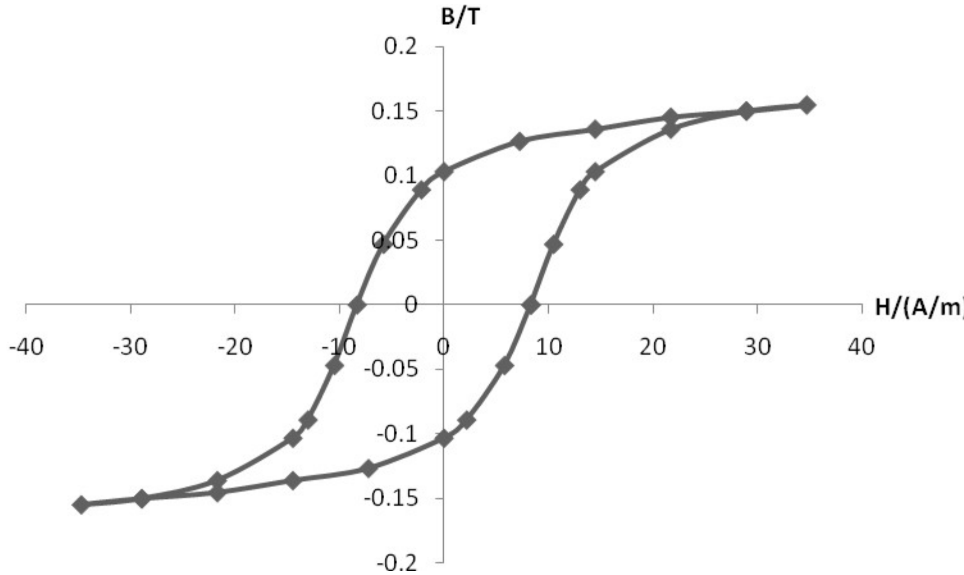

Figure 7 Hysteresis loop of sample B

From Table 1, we obtained the residual magnetic induction $B_r = 0.103T$ and coercive force $H_c = 8.3A/m$ for the sample B.

B. Measure the basic magnetization curve of soft ferrite

Sample number: B

Frequency of magnetizing current: $f = 9036Hz$

Table 2 Readings of u_1 and u_2 on the oscilloscope and corresponding H_i and B_i

u_1/mV	$H_i/(A/m)$	u_2/mV	B_i/T	u_1/mV	$H_i/(A/m)$	u_2/mV	B_i/T
0	0	0	0	40	14.5	24.5	0.115
4	1.4	1	0.005	44	15.9	26	0.122
8	2.9	2.5	0.012	48	17.4	27	0.127
12	4.3	5	0.023	52	18.8	28	0.131
16	5.8	8	0.038	56	20.3	28.5	0.134
20	7.2	11.5	0.054	60	21.7	29	0.136
24	8.7	15	0.070	66	23.9	30	0.141
28	10.1	18	0.084	70	25.3	30.5	0.143
31	11.2	20	0.094	80	28.9	31.5	0.148
32	11.6	20.5	0.096	90	32.6	32.5	0.152
36	13.0	22.5	0.105	100	36.2	33	0.155

Make the basic magnetization curve of the sample according to the data in Table 2, as shown in Figure 8.

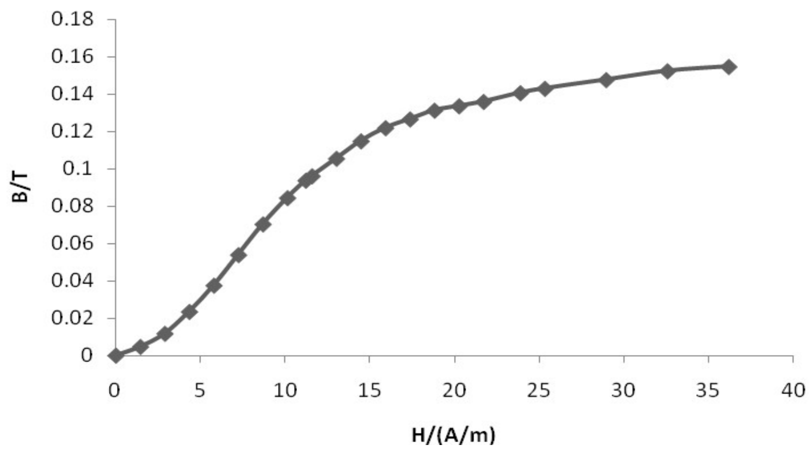

Figure 8 Basic magnetization curve of sample B

From the data in Table 2, the relationship between magnetic permeability $\mu = \frac{B}{H}$ and magnetic field strength H can be obtained, as shown in Table 3.

Table 3 data of permeability μ and magnetic field strength H

$H_i/(A/m)$	$\mu/(\times 10^{-3} H/m)$	$H_i/(A/m)$	$\mu/(\times 10^{-3} H/m)$	$H_i/(A/m)$	$\mu/(\times 10^{-3} H/m)$
1.4	3.24	11.2	8.36	20.3	6.59
2.9	4.05	11.6	8.30	21.7	6.26
4.3	5.40	13.0	8.10	23.9	5.89
5.8	6.48	14.5	7.94	25.3	5.65
7.2	7.45	15.9	7.66	28.9	5.10
8.7	8.10	17.4	7.29	32.6	4.68
10.1	8.33	18.8	6.98	36.2	4.28

According to the data in Table 3, make the relationship curve between the permeability μ and the magnetic field strength H of the sample B, as shown in Figure 9.

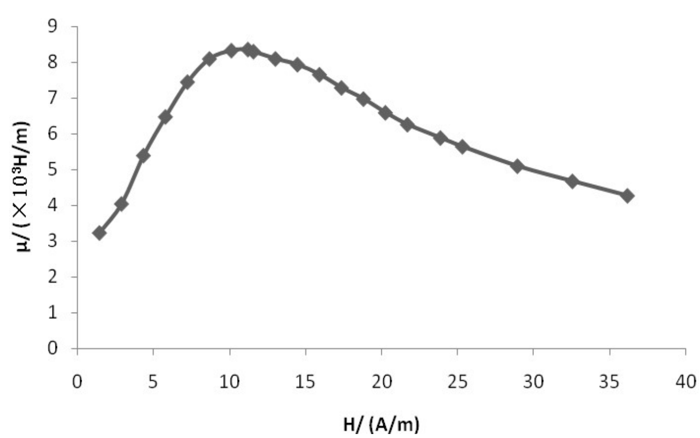

Figure 9 Relationship between permeability μ and magnetic field strength H of the sample B

C. Measure the Curie temperature of ferromagnetic material samples

Sample serial number: B

Frequency of magnetizing current: $f = 9036Hz$

Table 4 Data of temperature t and magnetic field strength (in effective voltage) u_2

t / ℃	25.8	30.9	35.8	39.7	41.9	44.0	46.1	48.0	49.9
u_2 (mV)	27.1	26.2	24.8	23.2	22.0	20.6	18.9	16.8	14.0
t / ℃	51.0	52.0	53.0	53.9	54.9	59.9	65.0	70	
u_2 (mV)	12.0	9.5	5.6	2.0	0.7	0.3	0.3	0.3	

According to the data in Table 4, the relationship between the temperature t and the effective value of the measured voltage u_2 (i.e. the magnetic field strength) is shown in Figure 10.

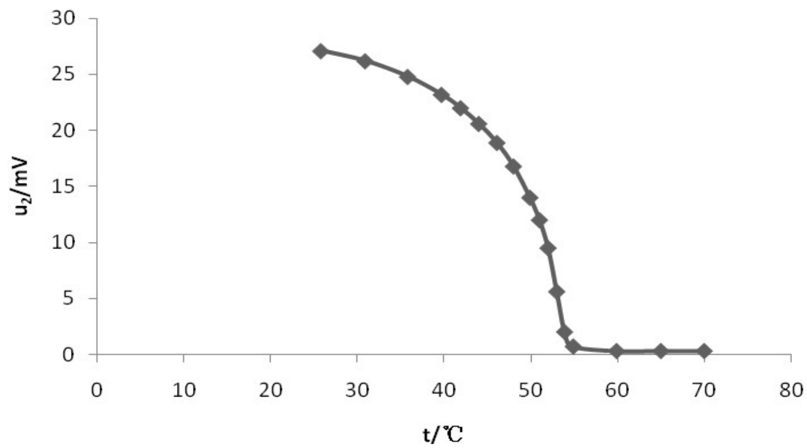

Figure 10 Curie temperature measurement curve of the sample B

It can be seen from Figure 10 that the Curie temperature t_C of the sample B is about 53℃ .