the anomalous effects reported here must await advances in the present level of understanding of current-induced flux flow and surface-barrier effects in thin superconductors.

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[1] The fact that the voltage across the microbridge (and therefore the resistance of the bridge) is zero on both sides of the voltage spike obviates the need for an analysis of the circuit which produces the current in the microbridge. The voltage spikes are definitely associated with the sudden appearance of resistance in the microbridge. If, on the other hand, the resistance had been nonzero before the voltage spike, it would have been necessary to explore the possibility that a change in the inductance of the superconducting circuit (Fig. 1) due to a transition of the film to the mixed state could have produced the voltage spike.

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PARAMAGNETIC-RESONANCE SPECTRUM OF Co^{1+} IN SINGLE CRYSTALS OF CALCIUM OXIDE*

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The paramagnetic-resonance spectra of two monovalent ions, Fe^{1+},[1] and Ni^{1+},[2] in CaO produced by gamma irradiation were reported recently. We wish to report the paramagnetic-resonance spectrum of Co^{1+} in single crystals of CaO. The Co^{2+} was converted into Co^{1+} by gamma irradiation of the crystals with a fuel element of the Israel Research Reactor, IRR-1. The spectrum of Co^{1+} was investigated at 3-cm wavelength and at various temperatures. The resonance results are given in Table I. For comparison we also list the available g factors and hyperfine-structure constants of the isoelectronic ion Ni^{2+}, and of Co^{1+} and Co^{2+} in both CaO and MgO.

The main features of the Co^{1+} spectrum are the following:

(a) The eight ($I=\frac{7}{2}$) lines of the normal $\Delta M=+1$ transition are not resolved and appear in the form of one broad line over 200 G wide. This is not surprising, since the smallest width observed of the isoelectronic Ni^{2+} line in CaO (the even isotopes of Ni have $I=0$ and a total natural abundance of 98.8%) is 88 G.[3] Since the hyperfine-structure constant of Co^{1+} in CaO is about 30 G, one cannot expect to resolve these lines. A calculation leads to a linewidth of the observed magnitude.

(b) Eight narrow hyperfine lines are superimposed on the above-mentioned wide line, with $g=2.2743\pm0.0008$, phase inverted and 5 G wide at 20°K, and with $g=2.2756\pm0.0008$, normal phase, and 1.5 G wide at 12°K. The linewidths of the individual components of the normal and phase-inverted octets are independent of the orientation of the crystalline axes with respect to the external magnetic field, within the accuracy of the measurements (±20%). The lines have a maximum intensity with the external magnetic field directed along the (100) direction and decrease slightly (20-40%) along the (110) and (111) directions. The phase-inverted line is equivalent to a hole burnt in the wide absorption line. It is likely that the main saturation effect will occur when the Zeeman splitting of the $M=1\rightarrow M=0$ and $M=0\rightarrow M=-1$ are exactly equal. The normal phase is obtained because of double-quantum transitions at low temperature and strong rf fields. The difference in the g factor between the normal and phase-inverted lines is probably caused by the Bloch-Siegert shift which is proportional to $(H_1/2H_0)^2$.

(c) Approximately halfway between the eight hyperfine lines, seven weaker lines are observed. The positions and the relative intensities of

Table I. Resonance results.

Configuration	Ion	Lattice	Temperature (°K)	g	$A\times 10^4$ (cm^{-1})	Reference
d^8	Co^{1+}[a*]	CaO	20	2.2743 ± 0.0008	31.6 ± 0.3	this paper
			12	2.2756 ± 0.0008	31.6 ± 0.3	this paper
		MgO	77	2.1728 ± 0.0005	54.0 ± 0.2	b, c
	Ni^{2+}	CaO	20 4.2	2.327 ± 0.001	...	d
		MgO	77	2.2145 ± 0.0005	8.3 ± 0.4	b
d^7	Co^{2+}	CaO	20	4.372 ± 0.002	132.2 ± 0.2	d
		MgO	20	4.278 ± 0.001	97.8 ± 0.2	e

[a] The values for Co^{1+} in CaO at 20 and 12°K were obtained by measurements made on the phase-inverted lines and on the double quantum transitions, respectively

[b] See reference 6.

[c] See reference 9.

[d] See reference 5.

[e] See reference 10.

the weak lines indicate that these are "forbidden" $\Delta M = \pm 1, \Delta m = \mp 1$ transitions. The intensities of these weak lines decrease approximately at the same rate as those of the stronger octet when the external magnetic field is rotated in the [100] plane from the H_{rf} perpendicular to H_{dc} to the H_{rf} parallel to H_{dc} position. We have also observed "forbidden" transitions of this type for Co^{2+} in CaO,[4] but here the "forbidden" lines increased and the "allowed" ones decreased when the above-mentioned rotation was performed, and reached a maximum and minimum, respectively, when H_{rf} is parallel to H_0 as expected from theory. It is clear that the effect of burning a hole corresponding to the "forbidden" septet is a direct result of the saturation of the octet.

(d) We did not observe the "forbidden" $\Delta M = \pm 2$ transitions at half-field for Co^{1+}, although these were reported for Ni^{2+} in CaO[5] and MgO.[6] This may be due to insufficient signal-to-noise ratio because of the increased linewidth.

It is interesting to compare the effective core polarization for these ions. In general, the hyperfine field can be written as

$$H^{\mathrm{hf}} = H_{\mathrm{spin}}^{\mathrm{hf}} + H_{\mathrm{orbit}}^{\mathrm{hf}} + H_{\mathrm{spin\ orbit}}^{\mathrm{hf}} + H_{\mathrm{core}}^{\mathrm{hf}}.$$

In our particular case $H_{\mathrm{orbit}}^{\mathrm{hf}}$ and $H_{\mathrm{spin}}^{\mathrm{hf}}$ are zero, whereas the $H_{\mathrm{spin\ orbit}}^{\mathrm{hf}}$ contributes considerably, as evinced through the deviation of the g factors. This field is given as[7]

$$H_{\mathrm{spin\ orbit}}^{\mathrm{hf}} = 2\beta\Delta g \langle 1/r^3 \rangle \ \mathrm{kG},$$

and is of the opposite sense to that of the $H_{\mathrm{core}}^{\mathrm{hf}}$, and therefore cancels partially. Assuming $\langle 1/r^3 \rangle$ values for the free ions as calculated by Freeman and Watson,[8] one obtains the values for the effective field caused by core polarization given in Table II. It is seen that core polarization for similar ions is nearly independent of the crystal host. This is seen strikingly for our case of Co^{1+}, where the observed hyperfine structure is nearly 40% smaller than in MgO, but the core polarization is about the same.

Table II. Core polarization in d^8 ions.

Ion	Host	Δg	$H_{\mathrm{obs}}^{\mathrm{hf}}$ (kG)	$H_{\mathrm{spin\ orbit}}^{\mathrm{hf}}$ (kG)	$H_{\mathrm{core}}^{\mathrm{hf}}$ (kG)	Reference
Ni^{2+}	MgO	0.2122	(−) 63 ± 3	+188	−251	a
Co^{1+}	MgO	0.1705	(−)160 ± 1	+114	−274	a
Co^{1+}	CaO	0.2720	(−) 93 ± 1	+182	−276	this paper

[a] See reference 11.

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THERMOELECTRIC POWER ANOMALY IN n-TYPE InSb AT LOW TEMPERATURES

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In n-type InSb at liquid-helium temperatures the concentration of electrons in the conduction band is independent of temperature, and the electrical resistivity is almost so. This behavior is analogous to that of a normal metal in the residual resistance region, and therefore the simplest theory of electron diffusion predicts that, as for a metal, the thermoelectric power (TEP) of n-type InSb should be proportional to the absolute temperature.[1]

We have found that this prediction is not fulfilled for n-InSb samples measured between 1.6 and 4.9°K. Instead, the measured TEP is much larger and has a different temperature dependence. A description of this anomalous TEP and a possible interpretation of it will be given in this Letter.

The samples measured were of single-crystal material purchased from Cominco Products, Inc. Their high quality was indicated by (1) good agreement between Hall effect and resistivity measurements made on different sets of contacts on a given sample, (2) uniform resistivity measured by traverses at 77°K, (3) high Hall mobilities at 77°K, and (4) low impurity content found by commercial mass spectrographic analyses by Bell and Howell Research Center (made on only two of the samples). The samples were undoped, or doped with Te, and ranged in carrier concentration from 6.9×10^{13} cm^{-3} to 5.4×10^{18} cm^{-3} and were about 2 cm in length and from 0.09 cm^2 to 0.13 cm^2 in cross section. Different cross sections were used to allow detection of possible size effects.

For the TEP measurements the samples were suspended in an evacuated copper can immersed in liquid helium. A heater coil was wound on the bottom end of the sample. Two germanium resistance thermometers were glued to the samples (with GE varnish No. 7031) at two points along the length of the sample, which were away from the ends by several sample widths. The thermometers were calibrated against the vapor pressure of the liquid-helium bath with exchange gas in the can (and no heater current flowing). The correctness of the temperature differences was indicated by the fact that the thermal-conductivity values[2] obtained by using them were apparently correct, since for samples which were comparable in concentration and size to those measured by other investigators,[3] there was good agreement between our and their thermal-conductivity values. The thermoelectric voltages were measured with a Keithley 148 Nanovoltmeter with an accuracy of 2% full scale. The correctness of the voltages were confirmed by TEP measurements we made between 12 and 24°K, since our TEP values are consistent with the results of Puri and Geballe.[4]

The results of our measurements in the liquid-helium range are presented in Fig. 1. From Fig. 1, we see that the TEP of each sample has a nonlinear temperature dependence and exhibits a maximum at some temperature. In order to interpret these results, we first calculated the diffusion TEP for the case of Coulomb scattering by ionized impurities, Q_I, since such scattering seems to account very well for the mobilities[2] of our samples at liquid-helium temperatures. The formulas used were

$$Q_I = -\frac{k_B}{|e|}\left\{\frac{r+\frac{5}{2}}{r+\frac{3}{2}}\,\frac{F_{r+\frac{3}{2}}(\zeta/k_BT)}{F_{r+\frac{1}{2}}(\zeta/k_BT)} - \frac{\zeta}{k_BT}\right\} \qquad (1)$$