LETTERS TO THE EDITOR

COMMENTS ON "SUPERCONDUCTIVITY—A CONSEQUENCE OF MAGNETIC INTERACTIONS?"

An important conclusion, that the pertinent pairing mechanism in the superconducting state of A-15 compounds such as Nb_3Ge, Nb_3Sn and Nb_3Si may be magnetic rather than phonon mediated, has been reached by Ekbote, Gupta and Narlikar[1] based on the following observation : The microwave resonance absorption (in the presence of a magnetic field) observed in thin films of these compounds ($T_c \sim 20$ K) in the temperature range 100 K–400 K (and attributed by them to conduction electron spin resonance and spin wave resonance) could not be observed in the experiments at 4·2 K.

We would like to point out that this conclusion should be carefully re-examined for the following reasons : (*a*) Quasiparticle tunnelling experiments[2,3], taken in conjunction with inelastic neutron scattering experiments[4], strongly suggest that the superconductivity in Nb_3Sn involves a phonon-mediated interaction, (*b*) normally one observes the spin wave resonance below the transition temperature in the usual antiferromagnetic systems, (*c*) the ESR signal strength could have fallen below the detection level for a variety of reasons such as (i) the decrease in the number of quasi-particles with temperature below T_c[5], (ii) saturation of the ESR signal because of long spin lattice relaxation times at low temperatures, (iii) the decrease in skin depth for microwaves at low temperatures due to the increased conductivity of thin films especially when they become superconducting, (iv) changes in the microwave configuration inside the ESR cavity due to changes in the dielectric properties of the samples at low temperatures. Therefore a failure to observe the microwave resonance absorption need not necessarily indicate an antiferromagnetic coupling betweeu conduction electrons in the superconducting state.

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REPLY TO "COMMENTS ON SUPERCONDUCTIVITY—A CONSEQUENCE OF MAGNETIC INTERACTIONS?"

Venkataraman *et al.*[1] have commented on our paper[2] that the disappearance of CESR of A-15 compounds need not necessarily indicate an antiferromagnetic coupling of conduction electrons in the superconducting state. In particular they have raised three specific points and have suggested that we should re-examine our conclusion. Although these points were well considered by us before publishing our note, we nevertheless answer them in the following :

(*a*) At present there exists no direct experimental support for the electron-phonon coupling in superconductors[3]. The quasi-particle tunnelling studies[4,5] carried out in conjunction with the inelastic neutron scattering experiments[6], where $G(\omega) = a^2 F(\omega)$ holds, provide no direct support but have to be stretched appreciably to the extent of speculation to justify the phonon mediation. The results pertaining to $G(\omega) = a^2 F(\omega)$ simply indicate that the phonon energy is affected in superconducting transition, though the former need not necessarily be the cause of the latter. The recent work of Kim[7] has shown that the phonon energy can be considerably affected by exchange enhancement in A-15s and therefore change in phonon energy is a property of superconducting state which might as well result from e change interactions. It may be pointed out that the failure of McMillan equation has led to other possible superconductivity mechanisms in A-15s[8].

(*b*) The antiferromagnetic systems referred by Venkataraman *et al.* are very different from the collective electron antiferromagnetic state envisaged by us. The spin waves reported in our studies are the fluctuations in the unstabilized SDW state in the conduction band. Below T_c, when the state is stabilized, the spin waves vanish. Like in usual antiferromagnetic systems, the spin waves can still be excited, but only with the application of much higher fields and frequencies, which necessarily would revert the superconductor to the normal state.

(c) The vanishing of CESR below T_c can not possibly be due to the reasons put forth by Venkararaman *et al.*

(i) Similar results were obtained for samples measured near their T_c. Moreover, the CESR results of Schultz *et al.*[9], where Al was in the forced normal state, provide a strong credence to our contention. In fact the reported Knight shift data of A-15s[10] and magnetic susceptibility measurements of Ekbote *et al.*[11] on Nb_3Sn and V_3Si single crystals are more readily explained in terms of our model.

(ii) The spin lattice relaxation time at low temperature, in superconducting state has been fully discussed by various theorists and they have shown that it is not much different from the normal state[10].

(iii) The skin depth in superconductor has been well discussed by Pippard[12] and others more than 30 years ago. The skin depth is of the same order as the penetration depth λ and our samples are approximately $\lambda/2$ thick. Thus, this satisfies the conditions given by the theorists[13,14] for observing CESR in superconductors.

(iv) The dielectric properties of the present materials are not altered at low temperatures so that the question of change in the microwave configuration inside the cavity does not arise.

In the light of the above we believe that the points raised by Venkataraman *et al.* are not responsible for the vanishing of the CESR. Finally we may mention that some of the other features, which we believe are important to the present study, are discussed in our comprehensive work on CESR and spin waves in various A-15 materials possessing a range of T_c values from non-superconducting to 22·65 K, which is being published elsewhere[15].

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A SIMPLE METHOD OF CALCULATING THE VOLUME OF ANY DISTORTED COORDINATION POLYHEDRON IN CRYSTAL STRUCTURES

Usually during the analysis of crystal structures, the shapes of the coordination polyhedra occurring in them are identified and the metal-ligand distances and related angles are listed. But very rarely are the volumes of such polyhedra calculated and their values presented. The volumes comprise additional information that is useful in many ways, for example, in explaining the relative stabilities among the different phases of some crystal structures and probably in explaining the occurrence of a particular polyhedron among the various possible polyhedra for a given coordination number.

In text-books on solid geometry, formulae are available for calculating the volume of many regular convex polyhedra. For distorted convex polyhedra, the volume can be calculated by dividing them into many tetrahedra and finding the volumes of the tetrahedra. This method, though not entirely new, is presented here for the simple reason that it is not found in ready reference books such as *International Tables for X-ray Crystallography.*

All convex polyhedra can be resolved into tetrahedra, one of the triangular faces of which becomes a face (or part of it) of the polyhedron. The volume of a tetrahedron OABC constructed with the origin O and the points A (x_1, y_1, z_1), B (x_2, y_2, z_2) and C (x_3, y_3, z_3) as the vertices is equal to one-sixth of the value of the determinant formed with the coordinates of the points A, B and C as the rows of the determinant. It should be noted here that the coordinates should be in Å referred to an orthogonal coordinate system and also that the volume of the tetrahedron thus calculated is always signed (either positive