

trons only perturb the vacuum impedance weakly, i. e., $|\sigma_{ij}/\omega\epsilon_0| \ll 1$.

In the calculation leading to Fig. 3, we have assumed a constant mean radiation time $T = (\gamma\omega_b)^{-1}$ for the electrons, as representative of the finite time spent in the cavity. The parameter $\beta = \gamma^{-1}(E_{\perp}/m_0c^2)$ where E_{\perp} is that part of kinetic energy in motion perpendicular to the magnetic field. For $\beta=0$, a conventional Lorentzian line is predicted; values of β greater than two lead to negative absorption at the lower magnetic field end of the line.

There are two possible explanations for the small inflections in our experimental traces, over those predicted by the theory outlined above. Due to a small misalignment of the cavity in the magnetic field, or due to the slight nonradial direction of Poynting's vector over the cavity volume perturbed by the electrons, it is conceivable that part of the effective wave vector is aligned along the magnetic field. In this case, another instability can come into play which feeds on the anisotropy of the distribution function.⁸ We tend to dismiss this as a possible influence since the first-order Doppler widths associated with this mode would be huge on the scale of Fig. 2(a). For this instability, in the case of a high ratio of transverse to longitudinal energy, negative absorption occurs for magnetic fields larger (not

smaller) than the line center. The second effect to which one can possibly attribute the added inflections is the fact that the assumption of constant radiation time is inconsistent with the fixed dimensions of the cavity. A constant radiation path length is more to the point, in which case we should take γ proportional to the velocity parallel to the magnetic field. Over some range of the parameters, this could have the effect of increasing the number of inflections.

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SUPERCONDUCTIVITY OF SOLID SOLUTIONS OF TaC AND NbC[†]

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The critical temperatures of superconducting intermetallic compounds can be empirically related to parameters such as crystal structure, composition, electron concentration, and lattice parameter, as shown by Matthias.¹ In a recent review paper, Roberts² clearly demonstrated that for a given crystal structure the critical temperature is related to the electron concentration per unit volume. It is not obvious, however, that similar correlations exist for another large class of superconductors, viz., the transition metal-nonmetal compounds of the cubic (NaCl) crystal structure. Although some of the highest critical temperatures reported have been for compounds of this class, the relevant literature is scarce and often contradictory. A pro-

gram to study systematically the carbides and the nitrides of the transition metals has been initiated at this laboratory.

The critical temperatures of solid solutions of TaC and NbC are reported in this paper. This system was chosen since Ta and Nb are in the same column of the periodic table and are, therefore, electronically similar; their sizes are identical in the elemental state; the interstitial element, carbon, is common to both compounds; both compounds are known to be superconductors; and they form a continuous series of solid solutions.

The powders of TaC and NbC, obtained from Fansteel Metallurgical Corporation, were ball-milled, leached with HCl to remove iron, and

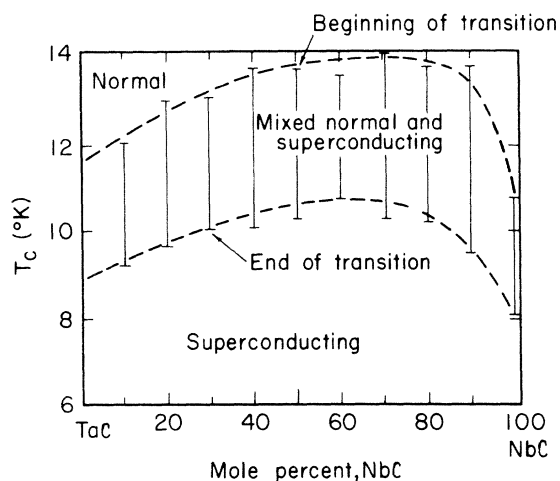


FIG. 1. The variation of critical temperature, T_c , with composition for the system TaC-NbC.

washed in distilled water to remove soluble chlorides. The powders were mixed by dry tumbling and extruded with polystyrene as a binder as rods of $\frac{1}{8}$ -in. diameter. The polystyrene was then volatilized in purified helium at 375°C and the samples were given an initial four-hour firing in vacuum at 1350°C . The rods were then sintered for 60 hours at 2100°C . Homogenization was verified by means of x-ray diffraction. Critical temperatures were measured by observation of an impedance change in a coil containing the sample. Samples of TaC and NbC, processed in the same manner as the mixed powders, exhibited the same critical temperatures as the original unsintered powders indicating that no significant contamination or change in carbon content occurred in the processing.

The variation of critical temperature with composition is shown in Fig. 1. The critical temperature has a broad maximum in NbC-rich solutions. Also, at a given composition, the transition from normal to superconducting behavior is spread over a range of three to four degrees. Giorgi *et al.*³ and Schröder⁴ have shown that the critical temperature of transition metal carbides or nitrides is dependent on stoichiometry to a degree in excess of that attributable to changes in electrons per unit volume. Giorgi, in a private communication, has suggested that the width of the transition zone at a given composition is also inversely related to stoichiometry. The possibility exists then that the maximum in critical temperature is a consequence of a variation in combined carbon. This is not the case, as

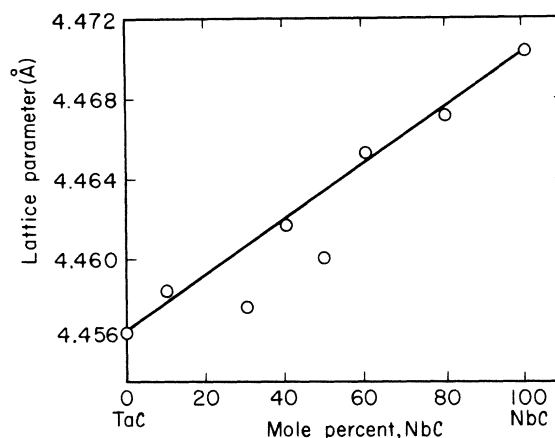


FIG. 2. The variation of lattice parameter with composition for the system TaC-NbC.

shown by the linearity of the lattice parameter composition plot, shown in Fig. 2. The lattice parameters^{5,6} and critical temperatures of the pure compounds correspond to the formulas $\text{TaC}_{0.98}$ and $\text{NbC}_{0.96}$. The agreement with Vegard's law for the solid solutions proves that the stoichiometry was not inadvertently changed during processing.

A maximum in critical temperature has been reported for the NbC-MoC system.⁷ Both NbC and MoC are superconductors forming cubic solid solutions up to 80% MoC.

In a system closely analogous to TaC-NbC, viz., HfN-ZrN, Giorgi and Szklarz⁸ have reported a linear variation of critical temperature and lattice parameter with composition. Both systems, TaC-NbC and HfN-ZrN, have metallic elements of the same size and electronic configuration, and a common interstitial element. Each system forms a continuous series of solid solutions which obey Vegard's law and each system is composed of superconducting compounds. Yet, one exhibits a maximum in critical temperature while the other does not. It can be concluded from the limited data available that the parameters so successfully applied to intermetallic compounds, i.e., electron-to-atom ratio or electrons per unit volume, are insufficient criteria in the case of solid solutions of transition metal-interstitial element compounds.

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OPTICAL ABSORPTION, ELECTROLUMINESCENCE, AND THE BAND GAP OF BP[†]

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In hopes of extending injection electroluminescence to III-V compounds with very high band gaps, we have studied the phenomenon along with other optical properties in cubic BP which is reported to have a band gap of 6 eV.¹ Injection electroluminescence, optical absorption, and the photoelectric response of an Au-BP surface barrier, however, lead us to conclude that cubic BP has an indirect band gap of only 2 eV. Our measurements were done at room temperature on small single crystals (0.1×0.1×0.01 cm) grown by crystallization from solution in nickel phosphides.²

Figure 1 gives the optical transmission, T ; the absorption coefficient, α , calculated for a reflectivity value of 0.31; and a typical electroluminous emittance, Φ , spectrum for a forward biased $p-n$ junction passing a current of 500 A/cm². The emission peaks at 1.97 eV, with sub-

secondary peaks on the low-energy side spaced about 0.1 eV apart. Although no conclusive identification could be made, this appears to be the energy of the LO phonon in accordance with a 12.1 μ lattice absorption band.¹ The external quantum efficiency is about 10⁻⁵ in agreement with that for a similar edge emission in GaP, another indirect band-gap material.^{3,4}

Owing to the presence of unavoidable pinholes in the single-crystal plates, the transmittance levels off for $\alpha > 180$ cm⁻¹. For lower values of α , i. e., $h\nu < 2.8$ eV, the transmittance is unaffected by the pinholes. The magnitude of α (190 cm⁻¹) on the high-energy side of the absorption edge agrees with that of GaP^{3,5} and SiC⁶ suggesting that the edge corresponds to indirect band-to-band excitation.

The case for a fundamental edge at 2 eV and

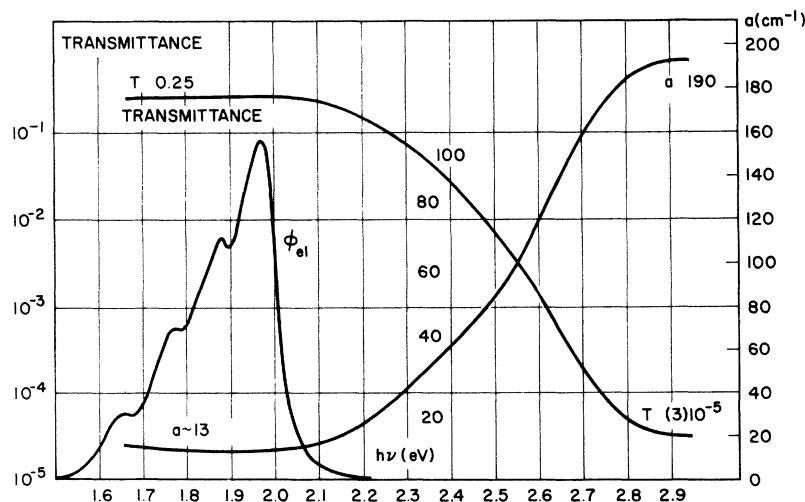


FIG. 1. Transmittance, absorption, and relative injection electroluminous emittance of BP at 300°C