*A. Bianconi (ed.) Symmetry and Heterogeneity in High Temperature Superconductors, 213-216*
*NATO Science Series II Mathematics,Physics and Chemistry – Vol. 214*


# V.2

# OXIDE SUPERCONDUCTIVITY

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**Abstract**: The trio of ruthenate compounds, doped $Sr_2YRuO_6$, $GdSr_2Cu_2RuO_8$, and $Gd_{2-z}Ce_zSr_2Cu_2RuO_{10}$ all superconduct in their SrO layers, which is why they have almost the same ≈49 K onset temperatures for superconductivity. The sister compound $Ba_2GdRuO_6$, whether doped or not, does not superconduct, because the Gd breaks Cooper pairs. These fit in with the superconducting cuprates: the superconducting layers are SrO or BaO, not $CuO_2$.

**Key words:** Theories and Models of the Superconducting State; Type II Superconductivity; High-$T_c$ Compounds

## 1. RUTHENATES AND RUTHENO-CUPRATES

The ruthenates and rutheno-cuprates, including the superconductors (a) Cu-doped $Sr_2YRuO_6$, (b) $GdSr_2Cu_2RuO_8$, and (c) $Gd_{2-z}Ce_zSr_2Cu_2RuO_{10}$ and the non-superconductor $Ba_2GdRuO_6$ (whether Cu-doped or not) need to be explained by a successful theory of high-temperature superconductivity. All three of these superconducting compounds begin superconducting within a few degrees of ≈49 K, although full superconductivity, *e.g.*, of $Sr_2YRu_{1-u}Cu_uO_6$, does not become complete until $T_c$≈23 K, when Ru librations freeze out. Furthermore, whatever we propose for these ruthenates and rutheno-cuprates must also provide a suitable explanation of the cuprates and materials such as $Gd_{2-z}Ce_zCuO_4$ and $YBa_2Cu_3O_7$. The unified explanation which we propose is that the superconductivity is in the SrO or the BaO layers (or in the vicinity of interstitial oxygen) of all high-temperature superconductors.

## 2. DOPED $Sr_2YRuO_6$ SUPERCONDUCTS

$Sr_2YRuO_6$ superconducts when it is doped with only 1% Cu on Ru sites [1]. The superconductivity sets in at ≈49 K and becomes rather extensive at ≈30 K (when a spin-glass state appears) but does not become complete until ≈23 K when the Ru librations freeze out.

The interesting thing about the superconductivity is that all the sites are accounted for to better than 1%, and *the material contains no cuprate-planes* (at the >1% level). The material is layered (like most high-temperature superconductors) and so one must decide if the $(SrO)_2$ layers or the doped $YRuO_4$ layers actually carry the supercurrent. Because the Ru has a large magnetic moment, and the SrO has none, we select the SrO layer as the superconducting layer. The data for the material support this choice [2]. Obviously, a cuprate-plane model cannot explain these Cu-doped $Sr_2YRuO_6$ data, because there are no cuprate-planes in this material. The possibility that the superconductivity does not reside in the cuprate-planes of other high-temperature superconductors, but in the SrO, BaO, or interstitial-oxygen regions, must be considered very seriously.

## 3. DOPED $Ba_2GdRuO_6$ DOES NOT SUPERCONDUCT

Neither Cu-doped nor undoped $Ba_2GdRuO_6$ superconducts, although the material $Ba_2GdRuO_6$ is virtually the same as $Sr_2YRuO_6$ (and is in the same class as $Sr_2YRuO_6$) [3]. The main difference is that Y has L=0 and J=0, while Gd has L=0 and J=7/2. The lack of superconductivity in $Ba_2GdRu_{1-u}Cu_uO_6$ is due to Cooper pair-breaking in the BaO planes by J≠0 Gd.

## 4. $GdSr_2Cu2RuO_8$ AND $Gd_{2-z}CezSr_2Cu_2RuO_{10}$

The onset temperatures for superconductivity in the materials $GdSr_2Cu_2RuO_8$ and $Gd_{2-z}Ce_zSr_2Cu_2RuO_{10}$ are also near ≈49 K, and so it appears that doped $Sr_2YRuO_6$, $GdSr_2Cu_2RuO_8$, and $Gd_{2-z}Ce_zSr_2Cu_2RuO_{10}$ are all members of the same class of superconducting materials, and that they all superconduct in their SrO layers [4].

This viewpoint is bolstered by the facts that both of the ruthenate materials $GdSr_2Cu_2RuO_8$ and $Gd_{2-z}Ce_zSr_2Cu_2RuO_{10}$ show magnetism (associated with their cuprate-planes) at low temperatures, which strongly indicates that their superconductivity is not in their cuprate-planes, but in their SrO layers [5].

## 5. $Gd_{2-z}Ce_zCuO_4$ DOES NOT SUPERCONDUCT

$Gd_{2-z}Ce_zCuO_4$ does not superconduct, either because the size of Gd is too small or because Gd has $J\neq0$. The possibility that the problem with the superconductivity is due to Gd being too small can be eliminated by considering $(Gd_{1-u}La_u)_{2-z}Ce_zCuO_4$ which has a bond length that is long enough to superconduct, but does not superconduct. Therefore $Gd_{2-z}Ce_zCuO_4$ does not superconduct because Gd has $J\neq0$ and is a pair-breaker [6,7] --- much like in Cu-doped $Ba_2GdRuO_6$.

## 6. $GdBa_2Cu_3O_7$ DOES SUPERCONDUCT

$GdBa_2Cu_3O_7$ superconducts at around 90 K [8,9]. Since its $CuO_2$ planes are adjacent to its pair-breaking Gd ions, we can conclude that the superconductivity is not in its $CuO_2$ planes, but in other layers: the BaO layers are the only such layers that are generally available in other high-temperature superconducting compounds [10].

## 7. SUMMARY

The ruthenates and rutheno-cuprates are very similar to the cuprates: in both sets of materials the Gd compound does not superconduct, either in $Ba_2GdRu_{1-u}Cu_uO_6$ or in $Gd_{2-z}Ce_zCuO_4$. Also, once the superconductivity is located in the BaO or SrO planes (and not in the cuprate-planes) the superconductivity of $GdSr_2Cu_2RuO_8$ and $GdBa_2Cu_3O_7$ become easy to understand and consistent with the non-superconductivity of $Ba_2GdRu_{1-u}Cu_uO_6$ and $Gd_{2-z}Ce_zCuO_4$.

By placing the superconducting condensate in the SrO or BaO layers, and not in the cuprate-planes, we explain (i) why $Ba_2GdRuO_6$ does not superconduct, (ii) why $Gd_{2-z}Ce_zCuO_4$ does not superconduct, and (iii) why $Sr_2YRuO_6$ doped with Cu does superconduct - three facts that have been unexplained by cuprate-plane superconductivity.

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