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FINE SCALE MESOSTRUCTURES IN SUPERCONDUCTING AND OTHER MATERIALS

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ABSTRACT

We review experimental and theoretical literature on mesoscale features and structures in a variety of displacively transforming materials. These include twinning in martensites and the much finer scale tweed; both may have significant effects on both normal and superconducting properties. Elastic properties are particularly strongly affected. Recent x ray and neutron experiments suggest them in hi-Tc materials.

Introduction

Recently several experimental studies of superconducting oxide hi-Tc materials and their analogs have given strong evidence for a fine scale “buckling” modulation of the Cu-O octahedra in layer planes.1,2 This kind of behavior, certainly unrelated to critical fluctuations, appears over wide temperature ranges in both first order or second order displacive transforming materials.3,4 We review related observations in a number of other materials, notably martensitic systems, and propose that these new observations in oxide superconductors are not unexpected, similar behavior having been observed widely in metals, perovskites, and ferroelectrics, and given various names such as “tweed” and “transformation precursors.”5 The structural aspects are the main point of this review. Until recently almost the entire literature on the superconducting transition itself in oxides ignored details of the lattice structure and dynamics, probably because of early experiments on a few compositions which indicated an oxygen substitution isotope effect much smaller than (simple) BCS called for; that situation has changed significantly with the recent work of Crawford, et al.6 which showed that significant isotope effects occur in Ln2−εSrεCuO on the low-ε side of the Tc maximum. This and other observations suggest that special details of lattice structure and dynamics, particularly relating to the CuO octahedra, need to be included in theoretical models, whether through electron-lattice interaction or lattice-spin orbit interaction. We purposely use the word “lattice” rather than “phonon” since some important motions may be highly nonlinear.

The main body of this paper is not directed at oxide superconductors per se; rather it is intended to provide references to features found generally in materials undergoing structural phase transitions of the sort occurring in the oxide superconductors, indicative of the schizophrenic lattice instabilities of such materials. The extent to which these enter into a specific model of superconductivity is beyond the scope of this paper, and will only be commented on briefly.
Experimental Background

A. Fine Scale Structures

At the outset I want to express the opinion that by and large the physics literature on hi-Tc seems to be unfortunately disjoint from much related earlier work either on the physics of displacive transformations, or on work in other areas of materials science, notably ferroelectricity and metallurgy.

It is a circumstantial fact that almost all compound superconductors including the A-15s and oxides and numerous analogous compounds undergo martensitic structural transformations. These transformations are nearly all first order, ranging from almost second order (A-15 superconductors), through moderately first order (shape memory alloys), to very strongly first order (strong ferrous alloys). There are many features of physical and technological interest in these materials, but for present purposes the generic features are: (1) The transformations are solid-solid, from a high temperature phase (parent) to several possible equienergy (product) variants of a low temperature structure, with lower symmetry; (2) Because the lower temperature variants generally are misfits in the parent lattice (e.g. tetragonal in cubic, or orthorhombic in tetragonal) the production of only one variant would develop a large macroscopic internal strain within the parent phase. Thus, to relieve this large macroscopic energy, a mixture of “long” and “short” orientations of the variants is produced. In the limit of well-developed product phases of the variants, the intervariant regions are twin boundaries, and well-defined twin bands of alternating domains of the variants are found. As discussed by deGennes the patterns and competing driving forces have a close analogy with the behavior of real ferromagnetic systems. This “mesostructure” is easily observable and has been studied in metallurgy and ferroelectric materials for many decades. The same twinning patterns have been observed in high temperature superconducting oxides (see Figs. 1,a,b,c); (3) These transformations are essentially diffusionless, no long range motion of atoms (i.e., composition change) is involved, the structural changes coming about via elastic distortions and intracell motions or modulation waves. These can proceed with essentially the speed of sound and are nearly completely reversible topologically (e.g. shape memory alloys). Indeed, the configurations can be expected to respond (i.e., rearrange) to ultrasonic applied stresses in an essentially instantaneous manner, thus modifying measured elastic constants from the intrinsic values for a single crystal.

![Fig. 1 Martensitic Twinning patterns in several compositions of YBa$_2$(Cu$_{1-x}$Co$_x$)$_3$O$_{7+delta}$](image)
These physical ideas can apply to either first or second order solid-solid transformations (i.e., the parent phase imposes an elastic constraint) if the temperature is sufficiently far from the transition temperature that fluctuations are secondary; indeed, in clear first order transitions, transformation fluctuations are negligible anyhow. In cases where the parent phase has only one variant (e.g., cubic), above a transformation temperature $T_T$, and the multiple (e.g., tetragonal) variant phase is thermodynamically preferred below, the martensitic (twinning) structure, typically on a micron scale, should appear only below $T_T$. This well-defined martensitic habit pattern is indeed found only in the lower symmetry phase. But the story does not end here; there is an important further mesostructure.

As electron microscope capability advanced, in addition to the main martensitic structure an interesting criss-cross modulation on a much finer scale, typically 10–100 nanometers, was discovered. Remarkably, this structure appears tens to hundreds of degrees away from the transition temperature $T_T$. While at first this was argued to be an instrumental effect it is now quite well documented to be real. The appearance is like a “tweed” pattern, and that name was attached to it by Tanner, whose studies in alloys, and those of others, have now found many examples. Fig. 2, a,b,c shows this tweed in $YBa_2(Cu_{1-x}Co_x)O_{7-x}$ in the composition range such that $T_T$ is well below the imaging temperature. Within the martensitic regime (below $T_T$) the imaging conditions are not such as to see the tweed. Fig. 3 shows tweed as a precursor to the fcc-fct transition in $Fe_2Pd_{1-x}(x \approx 0.3)$. Fig. 4 shows tweed in the A-15 superconductor $V_3Si$, well above $T_T$. Characteristic streaked diffuse diffraction patterns indicative of the incipient product phase are found many tens of degrees above $T_T$. Tweed certainly is one possible source for the essentially elastic “central peak,” which is ubiquitous in neutron scattering studies of all these materials. Very high resolution imaging has demonstrated in the $Fe_{0.3}Pd_{0.7}$ system that the tweed is in fact a criss-cross of fct elastic distortion modulations of the fcc structure. This suggests analogy in oxide superconductors a pattern of criss-cross regions of oxygen octahedra rotated locally about one (110) axis next to regions of the other (110) variant, all in a tweed pattern of buckling. In short the recent observations in the oxide superconductors-

Fig 2 Tweed pattern in $YBa_2(Cu_{1-x}Co_x)O_{7-x}$ $T > T_{T_{damp}}$ so no twin boundaries are present. Above scale bar = 0.1 μm, the tweed pattern scale is 0 ($10^{-2}$ - $10^{-3}$ μm) (Figs. 1,d,e,f of Schmael et al., Ref. [1]).
Fig. 3. Bright-field image of tweed structure in Fe-30 at.% Pd alloy. T well above martensitic fcc-fct transformation temperature. Tweed scale $\approx 10^{-2} \mu$. (Muto et al., Ref. 12).

Fig. 4. Tweed in V$_3$Si at 40 K. The martensitic transformation occurs at $T_m \approx 19$ K; tweed persists up to $\approx 50$ K. (Oouchi et al., Ref. 4). The scale of the tweed is $\approx 0.5 \times 10^{-2}$ nm.

by Exami et al.$^1$ and by Sharma et al.$^2$ seem to be quite consistent with the presence of the tweed structures seen in many martensitic or ferroelectric materials. Just recently an elegant first principles simulation of a quench from the tetragonal phase of a $V_2BaxCu_2O_7$ shows the development of a transient tweed phase as the material finally cools into the low-temperature martensitic orthorhombic structure.$^{14}$ (Fig. 5.).

While the direct imaging of tweed provides graphic evidence for a fine scale mesostructure in fact there is a long history of investigation of the nature of structural transformation precursors. In fact, a series of particularly precise and controlled studies of precursors in perovskites by K. A. Müller$^4$ using magnetic resonance methods was itself the "precursor" for the discovery of the high $T_c$ oxide superconductors. One such report analyzed the transition in BaTiO$_3$, which transforms from a high temperature cubic paraelectric material by a first order transition to a tetragonal ferroelectric phase. The transformation is nearly
describable by a soft mode model. However, clearly before the mode can actually condense the first order transition occurs. The subsequent formation of electrically polarized domains in patterns is analogous to martensitic twin bands. While the soft mode idea and the critical fluctuation idea were invoked, if examined in detail, in addition to the magnetic resonance information there are disturbing inconsistencies: (1) Raman scattering shows evidence for the presence of distortions like the tetragonal phase for nearly 100K above the transformation, totally removed from the very weak fluctuations near the first order transition! (2) The Debye-Waller factor is inconsistent with elastic constant measurements in the same region. Müller concludes from experiment that, to varying degrees, in several structurally transforming perovskites, there can be spatially coherent fluctuating regions (microdomains) over wide temperature ranges preceding transformations. It seems likely that some inconsistencies in optical data on the oxide superconductors can be associated with similar fine scale mesostructures involving the tetragonal orthorhombic structural distortions. Müller finds evidence for dynamic, intrinsic fluctuating microdomains in highly
pure samples, but also great sensitivity to pinning by defects. As we discuss below, local composition variations can also provide a strong stimulus to stabilize static coherent structural distortions, such as twist.

**B. Elastic Properties**

If there is one generic feature among many structurally transforming martensitic materials, it is the startling decrease in the shear modulus, $C$, measured ultrasonically, for the elastic distortion which is associated with the transformation, for a wide temperature range above the transition temperature $T$.\(^{15}\) In general, phonon softening to "zero frequency" is not seen.\(^{16,17}\) In this respect the recent measurements\(^{18}\) which show a large decrease in $C$ (experimental) upon approaching the tetragonal-orthorhombic transition in La$_{1.86}$Sr$_{0.14}$CuO$_4$ fall into the same pattern. In fact a considerable body of literature is devoted to the use of ultrasonic measurements to study pretransformation phenomena. The standard explanation of this behavior is not as straightforward as it may seem, i.e., find the "soft mode" (e.g. neutron studies) which determines the appropriate shear modulus.

To set the stage for suggesting why there seems to be cause for questioning the common interpretations consider the very interesting InTl martensitic alloy series 15.5 to 31 at.\% Tl, which transforms fcc to fct. For, say 25 at.% Tl (Fig. 6), the (first order) transformation is at $T\approx 195K$; between room temperature and $T_c$ the modulus $C' = \frac{1}{2} (C_{11}-C_{12})$ falls by a factor of 10, at least.\(^{15}\) With this in mind Finlayson and Smith\(^{19}\) made a thorough survey by inelastic neutron scattering of an alloy with this composition seeking the "soft phonon;" the result was that over the entire accessible phonon zone there was no measured softening of phonon frequencies with decreasing temperature! This startling result demands an explanation unrelated to mode softening for the giant softening of the elastic modulus $C'$. At the same time it is known that these alloys are remarkably sensitive to nonuniform or applied stresses. It has now been more or less concluded that the softness is due not

![Fig. 6](image_url)

*Fig. 6* Temperature dependence of the modulus $C'$ for [110] tetragonal shear to produce twinned martensite in InTl alloys. Note the giant softening for $\sim 100 \text{ to } 200 K$ above $T_m$. Extensive neutron scattering measurements have not yet found any mode softening with temperature! (T. Finlayson, Ref. 15; T. Finlayson and H G. Smith, Ref. 19)
to any phonon but to the relaxation of a highly mobile microstructure in response to the applied ultrasonic stress. As noted in the introduction, diffusionless transitions can proceed with speeds not reaching the speed of sound, so this concept is not apriori unacceptable.

The InTl alloys are only one, albeit possibly most striking, example of great elastic pretransformation softening. The FePd alloys have been explored in detail; to quote Muto, Oshima, and Fujita\textsuperscript{12} (p. 692) "the enhancement of the tweed contrast is connected with the small elastic constant, C', whether or not the alloys transform to fct phase." Then there is another group of materials, the superconducting A-15... In Fig. 7 the temperature dependence of the (ultrasonic) measured C' is shown for V$_3$Si.\textsuperscript{21} The continuous decrease of the modulus C' from room temperature to the structural transformation temperature T$_t$ which is near but not directly related to the superconducting transition is clearly remarkable. In this case the cubic to tetragonal transition is so nearly second order that detection of a lattice constant discontinuity is beyond experimental resolution; thus, this system was an ideal candidate for a soft mode Ginzburg-Landau model. But, to quote Testardi, "a considerable softening of the high frequency phonons occurs in both V$_3$Si and Nb$_3$Sn, although this is appreciably less than for the long-wave sound waves discussed previously." So, alas, again there is a clear need to seek a non phonon explanation for the large elastic constant softening. In fact, Testardi was one of the first to point out the possibility of arrays of microdomains which could respond dynamically to applied stresses as the origin of elastic softening, though at the time the imaging techniques which detect tweed were not yet available.

There is one more strongly persuasive fact, also generic. In all cases where the large elastic softening of the C' mode occurs, long before the transition is reached ultrasonic attenuation rises so steeply that transmission measurements become impossible. This would not happen if the ultrasound were only propagation of a simple phonon; on the

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{Fig7.png}
\caption{Pretransformation elastic softening in V$_3$Si (L. R. Testardi, Fig. 4 of Ref. 21). Principle tweed can be seen in a system which does not quite transform.}
\end{figure}
other hand if at ultrasound frequencies there is a (quasi)reversible reorientation of coherent regions, with short range order in the low symmetry phase, one could expect considerable shake-off phonon emission as the density of these regions increases with lower T, leading to large attenuation. This anomalous attenuation appears in the A-15's, the shape memory alloys, and in the recent measurements of the 2,1,4 oxide superconductors.

In summary, the main ideas in this discussion of experimental observations is as follows:

(1) Materials in the perovskite, A-15, and shape-memory alloy classes undergo structural transformations to a twinned, banded mixture of product variants in a pattern called "martensite." Experimentally the mesoscopic twinned pattern is observable by light microscopy and parent phase diffraction spots are split (slightly) by the development of martensite. Bragg spots are either those of the parent or those of the product. The tetragonal-orthorhombic transitions in the hi-Tc oxides show this behavior.

(2) However, high resolution electron microscopy has disclosed a precursor structure of tweed-like criss-cross modulation mixtures in the high temperature phase of regions of the incipient phase. These are not well defined precipitates but a continuous intertwining of distortions in the (two or more) variants of the phase-to-be. They are on a much finer scale, and less distorted than the fully developed low temperature twinned structure. Unlike precipitates they will not lead to new Bragg spots; they will however produce diffuse diffraction streaks at reciprocal lattice points where the nominal lattice patterns should vanish. They could also lead to a small volume expansion of the lattice, but no macroscopic shear strain. Though not emphasized in the above discussion, tweed can in principle also exist as modulations in the low temperature phases, although experimentally this possibility has not been explored in any systematic way. The underlying physics is the same: the lattice is highly unstable to switching between equienergy variants of a structural modification of some parent lattice and this can occur either dynamically or elastically. There is a characteristic elastic coherence length which determines the range of short range order, and there may be some source of frustration that prevents settling into one variant or the other. One recent theoretical model for this structure will be discussed briefly in the next section.

(3) Many anomalous macroscopic properties, such as the experimental elastic constants and ultrasonic attenuation, can be affected by this highly unstable microstructure. In addition to the motion of domain walls in temperature regions where they are well defined, this fine scale microstructure seems to have large effects on "elastic" properties. Thus, the experimentally measured values are "effective" or ensemble averaged values, rather than single crystal values. The absence of twins alone is not sufficient to rule out the effects of this fine scale modulation, which in the case of the layered oxide materials would appear as a rocking, puckered, mixture of (110) and (110) rotations of oxygen octahedra.

The upshot is that structural, displacive, transformations have many subtleties which can even effect "normal" properties. To identify these subtleties requires careful control and characterization of the material structure at many levels. Speculations on which of these features, if any, are directly relevant to superconductivity per se is another matter, except for the circumstantial fact that all the superconducting materials, metallic or oxide, are nearly unstable structurally, and the various fine structures are indicators or probes of this property.
A. Theoretical Model For Tweed

Many of the questions raised by the experiments discussed above have faced theorists. One has been: What can drive, i.e. stabilize, a tweed pattern? Kartha, Castan, Setlina and I have recently\textsuperscript{23} put forth a model which is analogous to a "strain spin-glass." The ingredients are as follows:

(i) A characteristic of the structural transformations under discussion is that a change in relative concentrations in both alloy and oxide superconductors of a few percent can move the structural transition temperature \( T_t \) by tens, even hundreds, of degrees.

(ii) Most materials (to date) in which tweed has been seen are mixed oxides or alloys. It is intrinsic to these that there are local, statistical, composition variations, qualitatively proportional to say, \( \sqrt{c(1-c)} \) in a binary mixture.

(iii) Uniform phase transformations can be described in the framework of a Landau free energy. Here, to discuss non-uniform configurations, we use a spatially dependent Ginzburg-Landau free energy which is a temperature dependent coarse-grained local average determined by local composition. For a square to rectangular (tetragonal to orthorhombic) a suitable free energy is of the form\textsuperscript{23}:

\[
F = [\alpha_o(T) + \Delta(c)]\varphi^2 - \beta\varphi^4 + \gamma\varphi^6 + n \left(\frac{\nabla\varphi}{2}\right)^2 + \text{other elastic terms} \tag{1}
\]
Here \( \varphi \) is a strain which generates either of the two rectangular variants i.e. \( \varphi = \epsilon_{xx} - \epsilon_{yy} \). If \( \varphi \) is (+), the x axis is longer than y and vice versa for (-). (The cubic to tetragonal transition requires a z-component order parameter as well.)

(iv) The important feature added here is that in real materials the quadratic coefficient varies from place to place with concentration variations, in random fashion. Clearly, for a temperature and average composition such that the average bulk control parameter is above (in temperature) the transition condition, there can nonetheless be some regions below. In fact a gaussian distribution for \( \Delta(c) \) is a reasonable choice. There is a competition: local regions may want to transform, but elastic fields are nonlocal and impose a competing force from the surroundings.

(v) The resulting distortion pattern has been found by a Monte Carlo computer simulation, the results of which for one set of parameters are shown schematically in Fig. 8. Further details are given in Ref. 23. The degree of shading indicates the local distortion strength—white or black, fully developed variant 1 or variant 2; mid-gray are square (tetragonal) undistorted "parent" regions. While at this point the model and simulations are really not quantitative, an attempt was made to choose parameters representative of the Fe\textsubscript{3}Pd\textsubscript{1-x}. The resulting pattern has an appearance very similar to that seen experimentally.

(vi) In terms of further theoretical generalization it was noted that if one discretizes the distortions and represents the alloy states by spins up or down on 2 intersecting sublattices: \( \uparrow\uparrow \) or \( \downarrow\downarrow \) at any intersection corresponds locally to a distortion in variant 1 or 2, respectively; \( \uparrow\downarrow \) or \( \downarrow\uparrow \) corresponds to zero strain at that point i.e. square lattice. The rest of the development is too detailed to present here. The upshot is that the local statistical variation in the quadratic term of the G-L free energy yields a spin-glass-like Hamiltonian.
We have only begun to apply the model to other questions, such as the response of the system to an applied stress; this approach could provide a model for determining the effective elastic constants which are measured ultrasonically.

A closing comment: It is interesting that composition variations in mixed alloy or oxide systems, just in themselves, can drive the potentially unstable lattice even above the nominal bulk transition temperature so as to produce a fine scale, tweed-like modulation. Of course a distribution of defects or other impurities could also do so, but the key point is that it appears to be impossible to avoid tweed in mixed oxides or alloys.

Speculations on Superconductivity

As I indicated at the outset, the main purpose of this review was to show that many of the so-called microstructural "anomalies" recently seen in careful studies of the hi-Tc oxide superconductors should come as no surprise; they fit into common patterns found in many displacive, diffusionless structural transformations. What may be more remarkable is the seemingly almost total unawareness or concern on the part of the hi-Tc community with this extensively documented experience, in the physics literature of high temperature oxide superconductors. Indeed, whether theories be valence bond, Fermi liquid, Hubbard and variants, spin bags, etc. they all exist in a featureless, perfect, rigid or Debye phonon lattice. Early, the fact that for a narrow special series of compositions a very small oxygen isotope effect was observed was used to categorically throw out electron-phonon coupling mechanisms; now with the work of Crawford et al.\textsuperscript{6} it is obvious that that was a quite unwarranted generalization. Much more concern with lattice microstructures (e.g. tweeds) and instabilities, as well as the details of atom motions is obviously needed. Yet now there is clear evidence\textsuperscript{1,2,5} that lattice motions strongly affect the isotope shift, and change dynamically at Tc. Clearly, purely electronic theories are incomplete. In this respect we share the general philosophy which has been expressed by J. C. Phillips.\textsuperscript{24}
Nor need bringing the realities of textures and microstructural dynamics in real materials back into consideration be restricted just to superconducting properties; these fine scale structure "anomalies" may be the real origin of the "anomalous normal properties" (e.g., the long linear regime in $\rho(T)$). It seems to be ignored that many similar anomalies were seen in the A-15s in the normal regime, in electrical and thermal properties of the "normal" phase (cf. L. R. Testardi, Ref. 21). One thing to be said is that tweed is generally ubiquitous above $T_f$ in the high-$T_c$ superconducting oxides, where the "anomalous normal properties" have been observed. Though not much pursued, Horovitz et al. showed that twin boundary dynamics could lead not only to the long linear $\rho(T)$ regime, but also to anomalous low temperature thermal conductivity, which is not exponential in gap divided by inverse temperature. Tweed dynamics, probably more ubiquitous than twin dynamics should be added now in the vein of that theory.

Passing on to some heuristic proposals as to how these widely observed fine scale mesostructure might relate to the superconducting oxides, let us recap their main features. These seem to be random small (typically nanometer scale) regions of correlated lattice distortions alternating between two or more possible structural variants. On the average, the volume average distortion associated with them vanishes, so conventional (even precision) diffraction analysis is of no use in identifying their presence, yet they may have a profound effect on elastic properties, electrical resistance, and thermal conductivity, and superconductivity by coupling dynamically to electrons and phonons. Either special imaging or adequate analysis of diffuse scattering are needed to identify their presence. In addition, while seen in the very few transformations which are nearly second order-soft mode in nature, they are more often associated with weakly first order displacive transitions. Thus a soft mode theory per se, and particularly Ginzburg-Landau descriptions which do not include heterophase fluctuations simply miss this potentially important "microdomain physics."

![Fig 9](image_url)  
Fig. 9 Pretransion elastic softening of basal shear modulus $C_{66}$ in a crystal of La$_{1.6}$Sr$_{0.4}$CuO$_4$ for $1/T_\text{Ft}$, and reciprocal quality factor (Fig. 2 of Mglioni et al., Ref. 18).
How do these features relate to the hi-Tc oxide superconductors? From our viewpoint, the recent neutron scattering studies by Egami et al. are in striking accord with the characteristic features just described, as well as with similar behavior studied some time ago by K. A. Müller in non-superconducting perovskites. The focus is on the structural anomalies associated with the Cu and O atoms in the hi-Tc materials. These seem to be a general feature of hi-Tc, not restricted to the 214 compounds: Egami et al. studied Tl (2212), Tc = 110 K. Using a pulsed neutron source which provides neutrons with short enough wavelength to resolve features at less than a lattice constant, and performing suitable transforms of the scattering data including diffuse scattering they are able to obtain (as in liquids) an instantaneous pair correlation function (PDF) for the Cu-O distance. It clearly shows a double peak, while the fine averaged correlation shows only a single peak. Thus they conclude that there are regions of normal and anomalous Cu environments below Tc. Whether a spatial examination would show that this is another example of "twee!" or not is of secondary concern. What is important is that this correlated behavior changes significantly in the vicinity of Tc. It is not in the least surprising, as they point out, that such microdomains could have significant coupling to the electrons, and participate in a special way in driving superconductivity. For one set of proposals on the mechanisms Ref. 1 should be consulted. In summary, to the writer these experiments and proposals, centered around the concept of fine scale microdomains of local coherently distorted regions are not only reasonably expected for a wide class of high temperature oxide superconductors, but quite in accord with similar observations in many other materials. Now we know that they play some part in superconductivity.

Acknowledgments

I am indebted to Alan Bishop, not only for many discussions of these matters over the years, but for urging me to write this review, and for supplying many germane references on high temperature oxide superconductors. I wish also to acknowledge much help in developing these perspectives from past and current Cornell colleagues: Bob Gooding, Sivan Kartha, Teresa Castan and Jim Sethna, as well as from Lee Tanner on the subject of tweed.

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20. G. B. Olson, private communication; see also a review in ICOMAT89, "Maternal Science Forum," TransTech Publications (Sydney, Australia, 1989).


24. J. C. Phillips in "Workshop on Lattice Effects in high-Tc Superconductors," January 1992; Preprints: "Dopant Microdomains, Local Magnetic Moments, and Superconductivity in La$_{2-y}$Sr$_y$Cu$_{1-z}$Mg$_z$O$_4$ Alloys;" "Broken Crystal Symmetry and Microdomains in High-Tc Superconductors;" possibly models of the kind recently studied by Kartha et al.23 can be adapted to these specific ideas.