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Electron-fluctuating distortion interaction in the new high T_c superconductors

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Abstract. A mechanism involving interaction of conduction electrons with the distortion field and the phonon modes is considered for the newly discovered high T_c superconducting materials. This is capable of explaining the observed range of T_c.

Keywords. Structural distortion; superconductivity; Jahn-Teller polarons.

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Intense research activities have started at many centres in the world after the discovery of high T_c (36 K or more) superconductivity in doped lanthanum copper oxide systems, e.g. $La_{2-x}M_x CuO_4$, M = Ba, Sr, etc (Bednorz and Müller 1986; Uchida *et al* 1987; Chu *et al* 1987; Cava *et al* 1987). Regarding possible mechanisms, it is felt that the usual acoustic phonon-mediated processes may not give high enough transition temperatures. Accordingly, one should look for new mechanisms which may involve exchange of electronic excitations (Jagadish and Sinha 1987), bipolaronic mechanisms (Chakraverty 1979; Alexandrov and Ranninger 1981), interfacial excitonic mechanisms (Allender *et al* 1973; Ginzburg and Kirzhnits 1982), antiferromagnetic correlation as in the Hubbard model (Nozieres 1984; Anderson 1987) and mechanisms emanating from local distortions and structural instabilities in the system (Phillips 1976; Ngai and Reinecke 1977; Vujicie *et al* 1981).

At this stage it is desirable to note some special features of the $La_{2-x}M_xCuO_4$ systems. They have K_2NiF_4-type structure having planes of CuO_6 octahedra which share corners. These planes are separated by (La, M) layers. The structure of pure La_2CuO_4 (with copper in Cu^{2+} state, a Jahn-Teller ion) has a slight orthorhombic distortion. It is a semiconductor with low magnetic susceptibility (Rao *et al* 1985). $LaSrCuO_4$ is an insulator with Cu^{3+} ions in the diamagnetic state (Rao and Ganguly 1987). This low spin state appears to us to be stabilized by on-site bipolaron formation owing to strong electron-phonon interaction. It also leads to the splitting of e_g electronic states (at Cu^{2+}) leading to J-T polaron formation. The metallic behaviour of $La_{2-x}M_xCuO_4$ arises from the presence of Cu^{2+} and Cu^{3+} ions in the system wherein the J-T polarons become mobile and form a very narrow conduction band. It is confined to the two-dimensional planes of CuO_6 octahedra. Further, these oxide superconductors lie near the metal insulator transitions arising from the J-T polaron formation.