SYNOPSIS

The era of high-$T_c$ superconductivity dawned with the discovery of superconductivity in ceramic cuprates La-Ba-Cu-O with $T_c \sim 30 - 40K$ by Bednorz and Muller in 1986. This was followed by the discovery of other cuprates with still higher transition temperatures like YBCO ($T_c \sim 90K$), BSCCO ($T_c \sim 110K$), TBCCO ($T_c \sim 130K$) etc. In all the cuprate superconductors there exist square-planar $CuO_2$ layers which are parallel to the ab-planes of the crystals and are sandwiched between metallic layers like the CuO chain layers in YBCO, LaO double layers in LSCO and TIO(BiO) layers in Tl(Bi) based compounds. It has been well established that the $CuO_2$ layers are the common features of these compounds and are the regions in the unit cell where superconductivity resides. These compounds are extremely type II superconductors and are characterised by high values of the critical temperature, very short coherence length, large anisotropy parameter and layered structure. Flux quantization and Josephson experiments indicate that the superconductivity in these materials result from pair formation, but there is still no consensus on the mechanism that enables the pairs to form. However, it does appear that whatever be the mechanism, the properties of these materials can be described by the Ginzburg-Landau concepts. But important changes arise from the extreme anisotropy, the extremely short coherence length and prominent fluctuation effects. The layered structure causes these materials to be highly anisotropic and in extreme cases to approach the two dimensional behaviour expected from a stack of decoupled superconducting film planes. A convenient model for the analysis of the consequences of layered structure in a superconducting material was proposed by Lawerence and Doniach and extensively
applied in the context of layered transition metal dichalcogenides. Several authors have employed modifications of the Lawrence-Doniach (LD) model to study the properties of layered high-$T_c$ cuprates.

Depending on the stoichiometry the crystallographic unit cell contains varying number of $\text{CuO}_2$ planes. Superconductivity appears when charge carriers are dopped into the $\text{CuO}_2$ sheets. The CuO chains in YBCO ($\text{TlO}$ and $\text{BiO}$ in Tl and Bi based compounds respectively) act as charge reservoirs which control the charge concentration in the $\text{CuO}_2$ planes. Several experiments point to the importance of the CuO chains in YBCO ($\text{TlO}$ and $\text{BiO}$ in Tl and Bi based compounds respectively) in enhancing the $T_c$ although they are not required to make the material superconducting. Thus it is natural to model a ceramic superconductor as a superlattice of two dimensional superconducting (SC) sheets with multiple $\text{CuO}_2$ planes sandwiched between nonsuperconducting (NSC) sheets consisting of multiple metallic planes like the CuO chain layers in YBCO. Experiments by Kleiner et al. and also by Briceno and Zettl indicate a scenario where the strongly superconducting layers induce a finite order parameter in weakly superconducting metallic layers through proximity effect. Thus we have differing order parameter on different layers. The spatial variation of the order parameter from layer to layer in materials where NSC layers are in the proximity of SC layers gives rise to many observed phenomena. These observations necessitates the modification of the usual LD formalism with the inclusion of the inequivalency of the layers to obtain a realistic picture of cuprate superconductors. This modification was done on the lines suggested by Bulaevskii and Vagner.

We have investigated the temperature dependence of the upper critical field $H_{c2}$ both parallel and perpendicular to the layers starting with the modified LD free
energy functional. Our calculations show a positive curvature for $H_{c2}(T)$ near $T_c$ as is observed in D.C. magnetization measurements on single crystals of YBCO. We have showed that the curvature of $H_{c2}(T)$ not only depends on the inequivalency of the layers but also on the mass anisotropy on the chain layers. The original LD model could not explain the positive curvature of $H_{c2}(T)$ near $T_c$. We have also studied using our model the temperature dependence of the first critical field $H_{c1}$ both parallel and perpendicular to the planes and also its angular dependence.

Thermal fluctuation effects in high temperature superconductors are much more pronounced than in conventional superconductors. Experimentally fluctuation contribution has been observed in conductivity, specific heat and magnetic susceptibility measurements in YBCO superconductors. The calculations based on modified LD model show that the fluctuation specific heat and parallel paraconductivity exhibit a dimensional cross over from a three dimensional regime near $T_c$ to a two dimensional regime further away from $T_c$. However it is found that the temperature dependence of the c-axis paraconductivity is different from that of either the paraconductivity parallel to the layers or the specific heat, but crosses over to OD fluctuation regime in the same temperature region. Fluctuation contribution to the London penetration depth both parallel and perpendicular to the layers and its temperature dependence has also been studied.