# UNIVERSITI TEKNOLOGI MARA

# THE EFFECT OF Pr SUBSTITUTION AT Sr SITES IN 110K PHASE OF (Bi-Pb)-Sr-Ca-Cu-O SUPERCONDUCTING CERAMICS

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for the degree of
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# Candidate's Declaration

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the result of my own work, unless otherwise indicated or acknowledged as referenced work. The topic has not been submitted to any other academic institution or non-academic institution for any other degree or qualification.

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# ABSTRACT

The effect of magnetic Praseodymium (Pr) substitutional doping at varying concentration into the Strontium (Sr) site in the Bi-Sr-Ca-Cu-O (BSCCO) high temperature superconductor is investigated. The samples are prepared via solid state reaction method and underwent sintering, annealing and resintering process. The two measured properties are the electrical and the structural properties according to the stoichiometric formula $(Bi_{1.6}Pb_{0.4})$-$(Sr_{1-x}Pr_x)_2$-$Ca_2$-$Cu_3$-$O_\delta$ where $x = 0.0 - 0.5$. For all series of doping concentration, $x = 0.0 - 0.5$, $T_{C \, (onset)}$ decreased for $x = 0.1$, then slightly increased at $x = 0.2$. The $T_C$ then gradually decreased as $x$ is increased and approaches zero as $x > 0.5$. The onset of critical temperature $T_C$ and zero resistance critical temperature $T_{C \, (R=0)}$ as $x$ increases indicated the superconductivity destructive trend. Interestingly, at $x = 0.2$, the destructive trend was reversed, but as $x > 0.2$, critical transition temperature is lowered. Critical current density, $j_C$ was also optimised for $x = 0.2$ samples. Longer sintering and annealing also improves the $T_C$ and this is shown in $x = 0.2$ sample. At $x = 0.2$ sample, the $T_C$ (onset) for sintered, annealed (at 820 $^0$C) and resintered samples are nearly identical to pure sample. The best $T_C$ achieved for doping occurred for the sample annealed at 830 $^0$C for 30 hours at $x = 0.2$, where $T_{C \, (onset)}$ 109 K and $T_{C \, (zero)} = 80$ K, respectively. X-Ray Diffraction analyses were performed to determine the phase of the superconductor at varying concentration doping level, confirming that at starting composition $(Bi_{1.6}Pb_{0.4})$, the phases 2223 and 2212 (mixed phases) co-exist at $T_C \leq 110$ K. The 2223 high phase was dominant in Pr-free and $x = 0.2$ samples. Other doping concentrations were dominated by 2212 and 2201 phases. The crystallographic structure underwent transition from tetragonal to orthorhombic as doping concentration of Pr was increased due to contraction of $c$-lattice. Substitutional doping of Pr introduces impurities into the BSCCO compounds and this introduces extra electrons at the Sr site by $Pr_2O_3$. This may suggests that the contribution towards $T_C$ suppression comes mainly from the hole-filling effect. This is due to the loss of local superconductivity in the $CuO_2$ plane. The results from incremental Pr doping also indicated that hybridization has negligible effect on the deterioration of critical transition temperature. Instead, based on the rate of $T_C$ suppression, it is suggested that the hole-filling effect is the principal mechanism of $T_C$ suppression. This is also supported by the copper valence calculation, optimized level of doping for the 2223 phase, and c-axis length contraction due to higher concentration of Pr doping.

Keyword: Praseodymium, substitutional doping, BSCCO, $T_C$, $j_C$

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