# Effect of Addition Mg and Na on Phase Formation and Crystallite Size of BPSCCO-2223 Superconductor

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Abstract: Superconductor samples based on BPSCCO-2223 have been prepared using solid state reaction. Precursor material (powder): $Bi_2O_3$, $PbO_2$, $SrCO_3$, $CaCO_3$ and CuO were mixed together using agate mortar for 2 h with twice grindings. Powder were then sintered at 300°C for 6 h with a rate of 10°C/min and 820°C for 20 hours at the same rate. MgO powder was added for 5%wt and 15%wt, respectively. The same amount as well as same procedure was applied for $Na_2CO_3$ powder addition. The powder was then put into palletising machine with 250 MPa before sintering at 850°C for 30 hours. Effect of addition Na and Mg on crystallite size and phase formation had been observed using XRD (powder method) type PAN analytical Empyrean. XRD-pattern was analysed with aid of Match v1.10 software. Results showed that crystallite size increased for 9.5% by addition of 5%wt Mg but decreased for 13.6% with 15%wt Mg. Addition of 5%wt Na decreased the crystallite size for 31.8%, whereas 15%wt Na decreased it to 14.2%. Maximum volume fraction of Bi-2223 (65.18%) was observed in non-doped sample.

## 1 INTRODUCTION

Superconductors generally classified as low temperature and high temperature depend on their critical temperature. Since the discovery of superconductor, many researches have been developing this kind of material around the word.

Superconductor materials Bi-based become an interesting and promising material since non toxic, inherently high critical temperature and multi phases. There are many techniques in preparation of Bi-based superconductor. The effective method is a method of solid state reaction, a mixture of oxide, peroxide and nitrate (R Abd-Shukor, 2004; R H Patel et al., 2005). Bismuth Strontium Calcium Copper Oxide or BSCCO (bisco) can be categorized as a high temperature superconductor with formula of $Bi_2Sr_2Ca_{n-1}Cu_nO_{2n+4+x}$. Many researches have been done for n=2, whereas for n=1 and n=3 are also interesting materials to develop. BSCCO is similar with YBCO superconductor.

BSCCO depends on number of its metallic ion. Thus, Bi-2201 is associated with n=1 ($Bi_2Sr_2 CuO_{6+x}$), Bi-2212 with n=2 ($Bi_2Sr_2CaCu_2 O_{8+x}$) and Bi-2223 for n=3 ($Bi_2Sr_2Ca_2Cu_3O_{10+x}$). Some system have been investigated such as: Bi-2201 (Tc=20K), Bi-2212 (Tc=95K), Bi-2223 (Tc=108K) and Bi-2234 (Tc=104K). Modifications have also been made with Pb substitution (Abbas et al., 2015). It was found that Pb stabilized the structure. MgO addition could increase Bi-2223 phase as reported by Lu (2016). Na could increase critical temperature (Kir Ebru, 2016). Effect of Sb doped Bi-based superconductor reported by Hermiz (2015).

It has been known that rare-earth elements improve the phase formation of the Tl-based superconductors (Syahrul Humaidi, 2019). In this brief paper we report on the effect of Mg and Na on the superconducting properties and phases formation of the BPSCCO-2223 phase.

## 2 EXPERIMENTAL

The samples were prepared using solid state reaction. To start with, powder with high purity of $Bi_2O_3$ (powder), $PbO_2$, $SrCO_3$, $CaCO_3$, CuO, MgO and $Na_2CO_3$. All oxides are in the powder preparation. The precursor BPSCCO was synthesized with two times grindings for 2h before sintering at 820°C for 20h. Mg and Na were added in final step of grinding. The next step was palletizing process at 70 ton to prepare



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pellet sample and followed by sintering process at temperature of 850°C for 30h. Characterization of samples cover: resistivity using cryogenics to obtain critical temperature, $T_{c\ zero}$ (four point probe method; XRD analysis using MATH computer program. Based on cryogenics and XRD analysis, crystallite size and critical temperature of the samples can be obtained as presented in Table 1.

Table 1: Critical temperature and crystallite size

| No | Sample | $T_{c\ zero}$ | d (nm) |
|---|---|---|---|
| 1 | Non-doped | 86K | 56.55571 |
| 2 | 5%MgO | 111K | 61.94372 |
| 3 | 15%MgO | 108K | 48.87306 |
| 4 | 5%Na | 80K | 38.59899 |
| 5 | 15%Na | 75K | 48.53214 |

XRD-pattern of samples are presented in Figure 1- Figure 5. Figure 1 shows XRD-pattern of non-doped $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_{10+\delta}$ sintered for 30h at temperature of 850°C. The occurrence of BPSCCO-2223 phase is around 66% denoted as (*) as presented in Figure 1. The rest phase is BPSCCO-2212 for 36%.

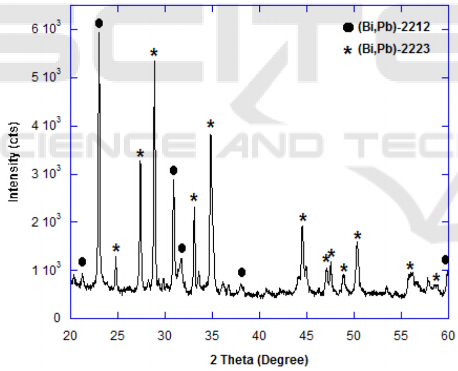


Figure 1: XRD-pattern for $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_{10+\delta}$.

Based on Figure 1, the space system of BPSCCO-2223 is orthorhombic with a=5.4056Å. In can be noted that no other impurity phase detected in this sample. The history of phase formation when 5%wt Mg was introduced can be seen in Figure 2. Based on XRD analysis, the lattice parameter a= 5.4056 Å, b= 5.4055 Å, c= 37.12, respectively. Phase formation of BPSCCO increases to 55% when the Mg content increase up to 15%wt as presented in Figure 3. XRD-pattern of 5%wt Na as shown in Figure 4. Like the addition of Mg, impurities have been detected in Na-doped as tabulated in Table 2. Phase formation of BPSCCO increases to 55% when the Mg content increase up to 15%wt as presented in Figure 3. Figure 4 and Figure 5 show the XRD-pattern of Na-doped BPSCCO.

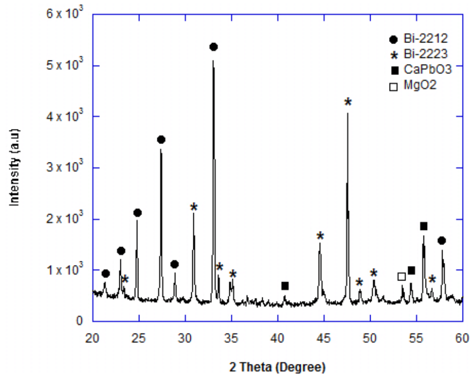


Figure 2: XRD-pattern of BPSCCO + Mg 5%wt

It is interesting to note that the phase formation affected the critical temperature of the samples.

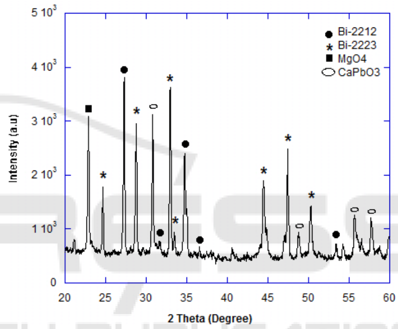


Figure 3: XRD-pattern of BPSCCO + Mg15%wt

Phase formation of BPSCCO increases to 55% when the Mg content increase up to 15%wt as presented in Figure 3.

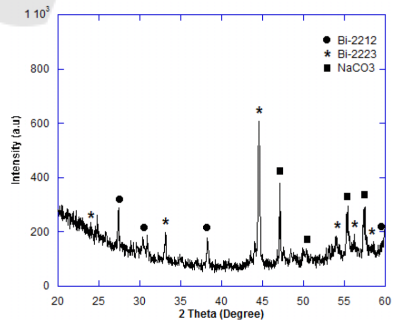


Figure 4: XRD-pattern of BPSCCO + Na5%wt

The effect of addition Mg and Na on phase occurrence can be summarized in Table 2.

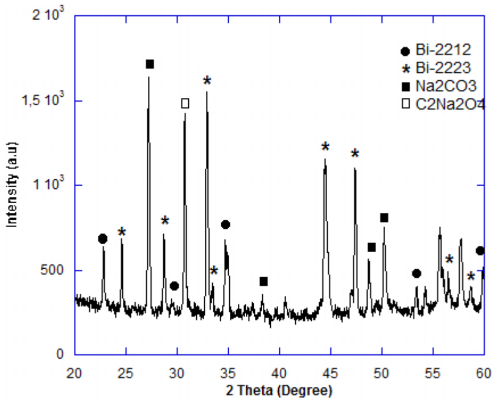


Figure 5: XRD-pattern of BPSCCO + Na15%wt

As it can clear be seen, no other impurity phase present in non-doped sample. However the content of impurities increases to 13% when 5%wt Mg was introduced to precursor material.

Table 2: Phase formation of BPSCCO

| No | $T_{sint}/t$ | Doped with | BPSCCO (2212) | BPSCCO (2223) |
|---|---|---|---|---|
| 1 | 850°C/30h | 0% | 34% | 65% |
| 2 | 850°C/30h | Mg5% | 46% | 41% |
| 3 | 850°C/30h | Mg15% | 24% | 55% |
| 4 | 850°C/30h | Na5% | 19% | 42% |
| 5 | 850°C/30h | Na15% | 11% | 45% |

The addition of 15% Mg increased the impurities content for 21%. The presence of impurities as a result of imperfection chemical reaction took place during the sintering. The same result can be noted in addition of Na. As it can be seen, impurities content increased for 31% and 39% when Na content 5% and 15%, respectively. It can be concluded that the effective doping level was in a small amount of Mg and Na.

## 4 CONCLUSIONS

Superconductor material Bi-based have been prepared with BPSCCO-2223 as major phase. Addition Mg and Na affect the superconductor parameters. Crystallite size as well $T_{c\ zero}$ decreased as Mg and Na content increase. Impurities occurrence decrease the zero critical temperature.

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