CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF PROBLEM

Ever since the improvement of technology keeps on developing, various types of advanced ceramics have been made for different application in the industry. “Advanced ceramics” is defined as materials that have been modified in terms of its composition and internal structure in order to get the desired properties of ceramics such as superior mechanical properties, resistance to corrosion or oxidation, thermal, electrical, optical or magnetic properties to meet the demands of the industry. One of the most popular research conducted are research related to the application of advanced ceramics in electronic devices such as capacitors, insulators, substrates, integrated circuit packages, piezoelectric, magnets and superconductors (Glazer, 1972). Ceramics that are used in electronic applications are usually made from materials of oxides, nitrides, carbides and borides (Riedel and Chen, 2008).

Figure 1.1 Cubic perovskite structure of CCTO
Source Schmidt and Sinclair 2013
A material that can store energy when electric field is present is called dielectric material, therefore, a material with high dielectric constant is a material with the ability of storing large amount of energy and vice versa. Calcium copper titanate, CaCu$_3$Ti$_4$O$_{12}$ (CCTO) with body-centered cubic perovskite structure (Glazer, 1972) in Figure 1, is one the most popular ceramics among the researchers due to its high dielectric constant which is around 10,000 for bulk material at room temperature (Ab Rahman et al., 2014) with a good temperature stability in the range from 100 K-600 K (Subramanian et al., 2000) and almost frequency independent below $10^6$ Hz (Ab Rahman et al., 2014).

These properties make CCTO a possible candidate for making microelectronic devices as it can store large amount of energy due to its large dielectric constant, $\varepsilon'$; hence, a small size of devices for storing large amount of energy can be fabricated (Ab Rahman et al., 2014). The electrical properties of CCTO as reported by Sinclair group (cited by Sun et al., 2016) are said to be highly dependent on its internal barrier layer capacitors (ILBC) which relates to the insulating grain boundaries (GB) and semiconducting grain. From a study conducted by Pan & Bender (as cited by Yu et al., 2012), the dielectric constant of CCTO is found to be increased with the growth of grain and decrease of grain boundaries.

Even though CCTO have a very high dielectric constant, the dielectric constant, $\varepsilon'$ also comes with a drawback of a high dielectric loss, $\varepsilon''$ (>0.05) (Jumpatam et al., 2014) which becomes the limiting factor for CCTO to be used for industrial application (Ab Rahman et al., 2014). Due to the high value of dielectric loss, some methods have been developed in order to overcome the problem such as, doping. Doping is a process of adding a small amount of impurities to a material with the same atomic size to improve the properties of a material (Casiday & Frey, 2016).

In this case, magnesium oxide, MgO has been chosen as the doping material due to its ability to enhance the electrical properties of CCTO by increasing the dielectric permittivity and decreasing the dielectric loss (Thongbai, Yamwong & Maensiri, 2013). In addition, the substitution of Mg$^{2+}$ is reported to be causing the growth of grain, which leads to the increase of dielectric constant (Sun et al., 2016). The substitution of Mg$^{2+}$ into Cu$^{2+}$ is possible due to their close size of ionic radius as reported by Ni & Chen...
In this research, the effect of doping Mg\textsuperscript{2+} into Cu\textsuperscript{2+} site to the CCTO electrical and microstructural properties is observed.

1.2 PROBLEM STATEMENT

Due to its giant dielectric permittivity, much research has been made by researchers to determine the source of the giant dielectric constant and finding ways to reduce the large dielectric loss shown by CCTO. Having a large dielectric loss causes CCTO to be unsuitable for fabricating electronic devices (Xu et al., 2014). Some of the methods used by other researchers to enhance the dielectric properties of CCTO are doping CCTO with another compound, preparing CCTO at different temperature, sintering CCTO at different conditions, and preparing CCTO with different method.

Despite the variety studies conducted, the best element to be doped in order to enhance the dielectric properties without affecting much the microstructural properties of CCTO are still an unanswered question by the researchers. In order to overcome these limitations, method of doping CCTO at the copper, Cu\textsuperscript{2+} site with magnesium, Mg\textsuperscript{2+} has been proposed due to its ability to be substituted easily to Cu\textsuperscript{2+} site due to the close size of atomic radius, as well as the ability to increase the dielectric constant and reduce the dielectric loss by increasing the grain size of CCTO.

1.3 OBJECTIVES OF RESEARCH

The objectives of this research are:

i) To synthesis Mg-doped CCTO using the solid-state reaction technique.

ii) To study the effect of doping Mg\textsuperscript{2+} in Cu\textsuperscript{2+} site to the growth of grains in CCTO.

iii) To increase the dielectric constant and reduce the dielectric loss of CCTO by doping Mg\textsuperscript{2+} in Cu\textsuperscript{2+} site.