Development of New Transparent Conductive Material of Mg(OH)$_2$-C

Toshiro Kuji,* Takamitsu Honjo, and Masafumi Chiba
Course of Materials Science and Technology, Graduate School of High-Technology for Human Welfare,
Tokai University, Nishino 317, Numazu-city, Shizuoka 410-0395, Japan

Tohru Nobuki and J.-C. Crivello
School of High Technology for Human Welfare, Tokai University,
Nishino 317, Numazu-city, Shizuoka 410-0395, Japan

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New transparent and electric conductive material, Mg(OH)$_2$-C, was prepared by the sputtering Mg and C, and post-reaction of the Mg-C film with moisture in the air. The prepared film was composed of Mg, C, O, and H, and the lattice symmetry was identified to be Mg(OH)$_2$ structure (P-3m1) with slightly elongated c-axis compared with hexagonal Mg(OH)$_2$. The transmittance of the visible ray was 90% in the average. The electric resistivity of the film was on the order of $10^{-1}$ Ωcm. [DOI: 10.1380/ejssnt.2008.15]

Keywords: Sputter deposition; Electrical transport; Polycrystalline thin films; Graphite; Alkali metals; Mg hydroxide; Optically transparency

I. INTRODUCTION

Indium oxide doped with tin oxide, ITO has been widely used as a key material for liquid crystal display technologies because of its high transparency and electrical conductivity [1]. Recently, however, the scarcity of rare-metal indium has been strongly pointed out so that alternative transparent and electrical conductive materials have been actively studied over the last decade [2–4].

As mentioned above, most transparent conductive materials are based upon metal oxides. It is well known that the metal oxides are semiconductor so that in order to obtain high electric conductivity together with optical transparency, the consideration on a balance between the band gap and conductivity is very important.

Recently, Kondoh’s group reported very interesting results on the transparency for Mg-C compounds [5]. The structure of compounds was identified to be amorphous. The elemental composition was controlled by magnesium target area fraction. The colored glassy films were obtained.

II. EXPERIMENTAL

In this study, the depositions of Mg-C thin films were performed at room temperature in a pressure of 0.5 Pa during the Ar process gas atmosphere with the electrode using an RF-sputtering method. Magnesium and carbon were deposited on glass substrates. The experimental detail will be shown elsewhere [6].

III. RESULTS AND DISCUSSIONS

Appearance of as-sputtered Mg$_{80}$C$_{20}$ film was in somewhat between black and metallic color, as shown in Fig. 1(a). The as-sputtered film was not amorphous but crystalline. The crystal phase has not been precisely identified yet but existence of clear X-ray diffraction peaks implies that the film is in crystalline phase [6]. According to the calculated binary Mg-C phase diagram [7], Mg-C elemental couple is expected to be immiscible, expecting that the mixing enthalpy for alloying Mg and C is positive. The RF-sputtering could have created energy high enough to proceed alloying immiscible Mg-C couple.

However, the film of Mg-C gradually changing to be transparent with exposing into the air for appropriate time (15 min) and finally the film became fully transparent as shown in Fig. 1(b). We can see the university logo clearly through the film with thickness of approximately 3.5 μm. In order to look for the possible reactions during exposure to the air, after deposition nitrogen, dry-air, or oxygen were introduced into sputtering chamber but the optical transparency did not appear after these procedures. From the above results, it could be due to that the reaction of the film with moisture yielded the film transparent.

Figure 2 shows the X-ray diffraction (XRD) patterns of the transparent Mg(OH)$_2$-C film and Mg(OH)$_2$ film and powder. Mg(OH)$_2$ was prepared by immersing sputtered pure Mg film in water. Mg(OH)$_2$ powder was purchased from Soekawa Chemicals Co., Ltd. It can be seen that XRD peaks from the transparent film is well matched with those from crystal symmetry of Mg(OH)$_2$ structure (P-3m1) but the lattice was slightly elongated along c-axis of hexagonal structure. This elongation could be due

(a) as-sputtered
(b) transparent

FIG. 1: Appearance of (a) as-sputtered Mg-C film of 3.5 μm thick and (b) transparent film.

*Corresponding author: tkuji@wing.ncc.u-tokai.ac.jp

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FIG. 2: X-ray diffraction pattern of Mg(OH)\textsubscript{2}-C films. Inserted XRD patterns are from limited range of angle.

FIG. 3: Transmittance spectra of the Mg(OH)\textsubscript{2}-C film.

to the existence of C atoms in Mg(OH)\textsubscript{2} lattice structure, although at this present time it is not able to conclude that where C atoms are distributed over the lattice. Figure 3 shows optical transmission spectra for the transparent film. It is found that high transmittance was obtained over the wide range of wave length. It should be noticed that the transmittance of the visible ray (400–800nm of wave length) was sufficiently high.

Finally the electric resistivity of the transparent film is shown in Fig. 4. The resistivity started to be measured 15 min after full surface was confirmed to be transparent. The resistivity increased with time but minimum value was estimated to be $3 \times 10^{-1} \ \Omega \text{cm}$.

IV. CONCLUSIONS

Mg(OH)\textsubscript{2} is not an electrical conductor. However, the Mg(OH)\textsubscript{2}-C transparent film prepared in this work has surprisingly very low electrical resistivity. The electric conductivity is, therefore, definitely originated from the existence of C in the Mg(OH)\textsubscript{2} structure.

The further studies on the optimization of chemical composition and experimental conditions is essential. Moreover, information on the distribution of C atoms in the Mg(OH)\textsubscript{2} lattice is very important. The neutron diffraction work is now under review. However, it is believed that the film reported in this work is the first non-oxide type of transparent conductive material.

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