AgMgAl thin film metallic glasses for electric contact applications

Y. T. Lin[1], Y. L. Chung[2], and J. C. Huang[1]

[1] Department of Materials and Optoelectronic Science, National Sun Yat-Sen University, Kaohsiung, Taiwan 804, ROC

[2] Metal Industries Research & Development Centre, Kaohsiung, Taiwan 811, ROC

Correspondent author: Tel.: +886-7-525-4070; Fax.: +886-7-525-4099., Electronic mail: jacobc@mail.nsysu.edu.tw

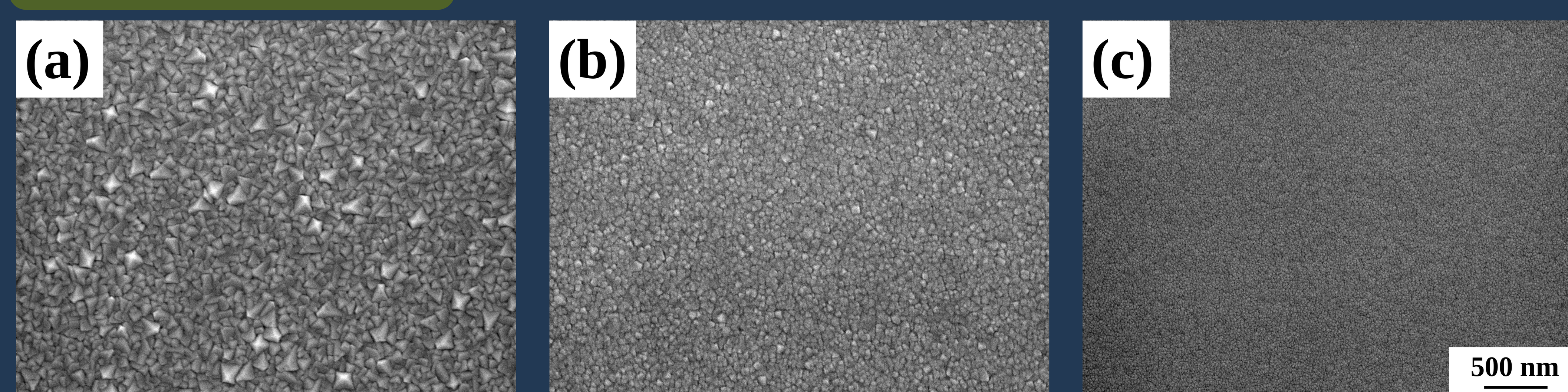
Abstract

The AgMgAl thin films, in an attempt in replacing the expensive pure Au contact film, are prepared by co-sputtering. The surface morphology, roughness, amorphous or crystalline atomic structure, grain size, and electric resistivity are systematically examined. Depending on the film compositions, the films can be fully amorphous or fully nanocrystalline, or a composite with the mixture of nanocrystalline phases dispersed in the amorphous matrix. Under the as-sputtered condition, the crystalline group has the lowest resistivity, ranging from 27 to 37 mΩ.cm, the composite group lies in the middle, 31 to 70 mΩ.cm, and the fully amorphous group possesses the highest resistivity, 87 to 122 mΩ.cm. Appropriate short thermal annealing of the amorphous films can drastically lower the resistivity down to as low as 9 mΩ.cm, already compatible to pure Au (3-7 mΩ.cm). This study demonstrates the feasibility of the AgMgAl films in replacing the pure Au.

Structure	Film material	Film thickness (nm)	Ra (nm)	Resistivity (mΩ.cm)
C	$Ag_{65}Mg_{22}Al_{13}$	1335	16.3	31
C	$Ag_{63}Mg_{22}Al_{15}$	1090	12.7	27
C	$Ag_{62}Mg_{22}Al_{16}$	1130	12.2	29
C	$Ag_{59}Mg_{24}Al_{17}$	1115	9.3	37
C	$Ag_{55}Mg_{30}Al_{15}$	890	6.6	33
A+C	$Ag_{69}Mg_{18}Al_{13}$	1475	8.8	35
A+C	$Ag_{68}Mg_{15}Al_{17}$	1025	9.9	31
A+C	$Ag_{67}Mg_{13}Al_{20}$	1100	9.1	33
A+C	$Ag_{63}Mg_{17}Al_{20}$	800	2.6	43
A+C	$Ag_{56}Mg_{25}Al_{19}$	920	1.3	70
A	$Ag_{60}Mg_{17}Al_{23}$	860	0.9	87
A	$Ag_{55}Mg_{24}Al_{21}$	890	1.0	101
A	$Ag_{52}Mg_{27}Al_{21}$	1010	1.7	108
A	$Ag_{48}Mg_{32}Al_{20}$	945	1.2	117
A	$Ag_{31}Mg_{42}Al_{27}$	750	1.6	122

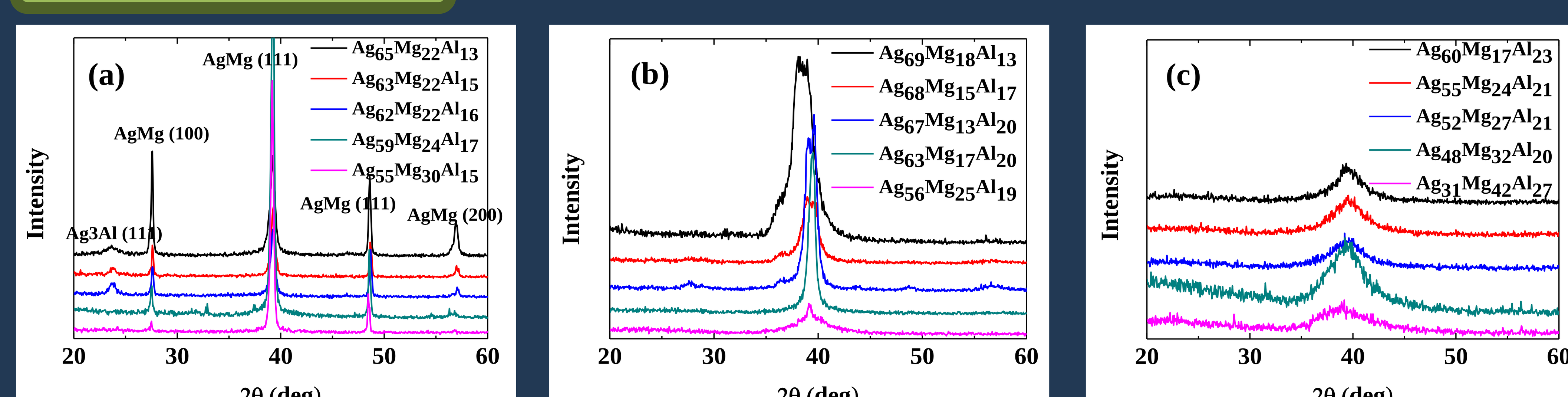
The resistivity, the surface roughness (Ra) of the Ag-Mg-Al thin films. C represents the crystalline structure, A the amorphous phase, and A+C the composite structure.

SEM Observation



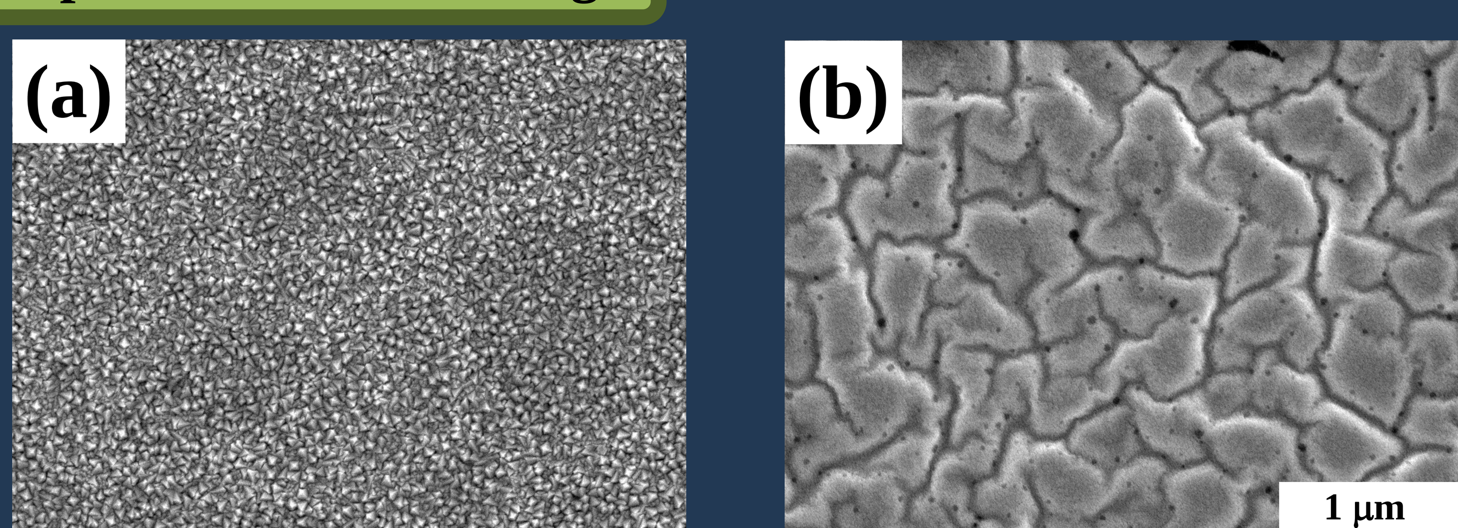
nanocrystalline $Ag_{55}Mg_{30}Al_{15}$ composite structured $Ag_{63}Mg_{17}Al_{20}$ fully amorphous $Ag_{48}Mg_{32}Al_{2}$

XRD patterns

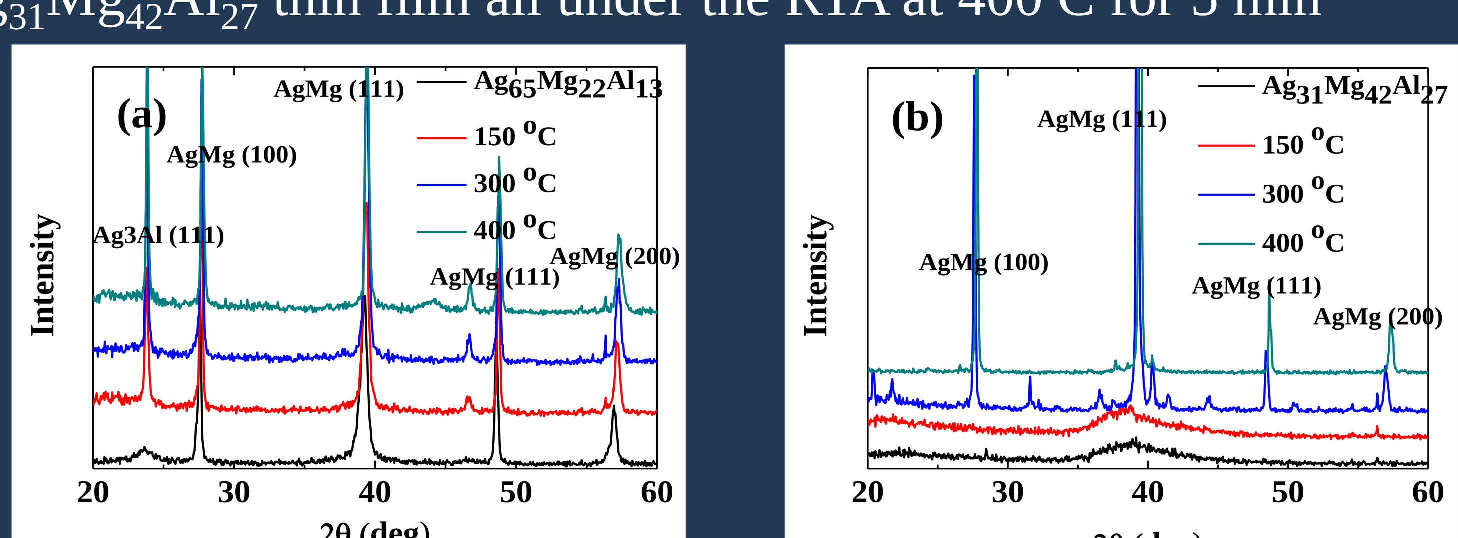


crystalline structure composite structure amorphous phase

Rapid thermal annealing



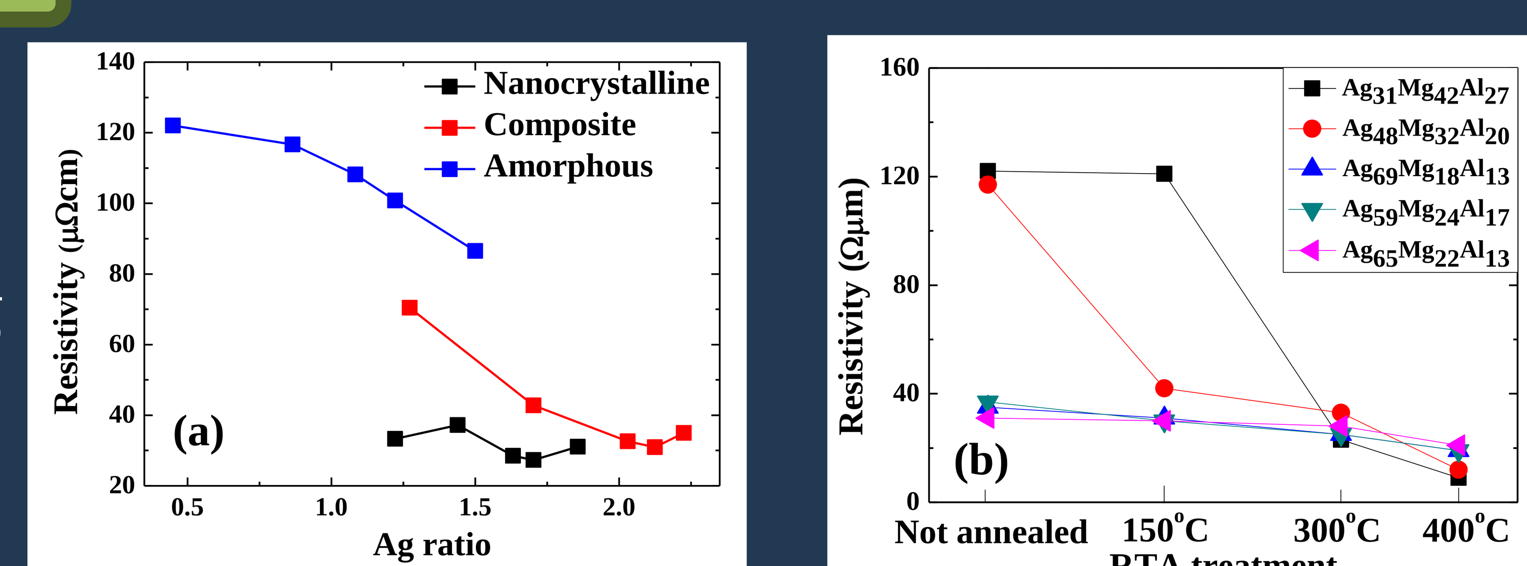
The (a) crystalline $Ag_{65}Mg_{22}Al_{13}$ thin film and the (b) amorphous $Ag_{31}Mg_{42}Al_{27}$ thin film all under the RTA at 400°C for 5 min



(a) The $Ag_{65}Mg_{22}Al_{13}$ crystalline film evolve slightly upon RTA treatments at 150, 300 and 400°C for 5 min. (e) The $Ag_{31}Mg_{42}Al_{27}$ amorphous film changes to crystalline upon RTA treatments at 150, 300 and 400°C for 5 min.

Resistivity

$$\text{Ag ratio} = \frac{Ag\ at\%}{Mg\ at\% + Al\ at\%}$$



The dependence of (a) resistivity of various multi-component AgMgAl thin films as a function of Ag ratio and (b) as a function of different RTA annealing conditions.

Conclusions

The 1 μm thick AgMgAl sputtered thin films, after proper RTA treatment, could exhibit a satisfactory low resistivity of 9 mΩ.cm and a much higher hardness of about 4.0 GPa. Since the films have been annealed treated at 400°C, they are thermally stable and possessing reasonable environmental resistance against corrosion, oxidation and humility during prolonged service. Also, the AgMgAl films would be much cheaper than the pure Au films, favorable for industry applications.