Surface hardening of AZ31 Mg by PdCuSi thin film metallic glass coating

H. J. Pei, C. H. Huang, Y. C. Chang, B. Y. Chen, and J. C. Huang*
Department of Materials and Optoelectronic Science; Center for Nanoscience and Nanotechnology,
National Sun Yat-Sen University, Kaohsiung, Taiwan 804, ROC
*Corresponding author. Tel.: +886-7-5252000 ext 4063; fax: +886-7-5254099.
E-mail address: jacobc@mail.nsysu.edu.tw (J. C. Huang)

Abstract

The $Pd_{77}Cu_6Si_{17}$ (PCS) thin film metallic glasses (TFMGs) with high glass forming ability and hardness are selected as a hard coating for improving the surface hardness of the AZ31 magnesium alloy. Both micro- and nano-indentation tests are conducted on the specimens with various PCS thicknesses from 30 to 2000 nm. The apparent hardness and the relative indentation depth are integrated by a quantitative work-of-indentation model. The involved interaction parameters and intrinsic hardness values are extracted from iterative calculations. According to the results, surface hardness can be enhanced greatly by PCS TFMGs in the shallow region, followed by gradual decease with increasing relative indentation depth ratio. In addition, the specimens with thinner coating (for example, 200 nm) show greater substrate-film interaction and those with thick coating (for example, 2000 nm) become prone to film cracking. The optimum TFMG coating in this study is estimated to possess film thickness around 200-300 nm.

Equation

$$H = H_s + \frac{H_f - H_s}{1 + k\beta^X}$$

H_s and H_f are the estimated hardness for the substrate and coated film, respectively, k is a dimensionless hardness transition parameter, and X is the power exponent depending on the deformation mode and geometry.

Ref. J. R. Tuck, A. M. Korsunsky, D. G. Bhat, S. J. Bull, Surf. Coat. Tech. 139 (2001) 63-74.

Results and discussion

Table 1 The hardness of the PCS TFMGs deposited on the AZ31 substrate, obtained from the nanoindentation tests.

	Hardness (GPa) in specific thickness							
β	30 nm	50 nm	100 nm	200 nm	300 nm	500 nm	1000 nm	2000 nm
0.05	1.83±0.24	1.85±0.20	8.91±5.59	6.02±1.67	6.09±1.82	6.18±1.82	6.08±1.91	5.84±1.94
0.10	7.24±2.37	7.83±3.31	3.94±2.48	6.05±1.76	5.30±1.79	6.32±1.58	5.98±2.56	5.97±0.93
0.25	4.06±3.23	4.45±2.57	3.83±1.20	4.52±1.17	4.57±2.38	4.29±1.23	4.04±1.14	4.42±1.08
0.50	2.14±0.57	2.75±1.04	**3.18±0.47**	**3.30±0.43**	**2.85±0.35**	2.19±0.31	2.10±0.40	1.94±0.36
0.75	2.01±0.15	2.03±0.47	**2.33±0.21**	**2.39±0.19**	**2.12±0.19**	1.62±0.16	1.38±0.16	1.31±0.14
1.00	1.66±0.17	1.66±0.32	**1.96±0.21**	**2.00±0.16**	**1.73±0.13**	1.34±0.14	1.16±0.13	1.07±0.11
1.50	1.27±0.18	1.28±0.21	**1.52±0.13**	**1.53±0.15**	**1.30±0.06**	1.13±0.15	0.90±0.08	0.83±0.08
2.00	1.08±0.15	1.15±0.11	**1.31±0.13**	**1.37±0.13**	**1.17±0.03**	1.03±0.16	0.81±0.06	0.71±0.06

Table 2 The fitting parameters of the PCS TFMGs deposited on the AZ31 substrate obtained from the nanoindentation data.

Thickness (nm)	H_s (GPa)	H_f (GPa)	k	X
30	0.97±0.10	4.92±0.55	3.34	1.35
50	1.11±0.07	5.53±0.39	5.85	1.52
100	1.14±0.01	5.92±0.21	6.58	1.72
200	**1.20±0.05**	**6.59±0.14**	**7.08**	**1.76**
300	0.97±0.03	6.72±0.17	10.72	1.85
500	0.85±0.04	6.98±0.18	11.34	1.90
1000	0.70±0.02	7.38±0.26	14.36	1.92
2000	0.69±0.04	7.98±0.31	22.03	2.26

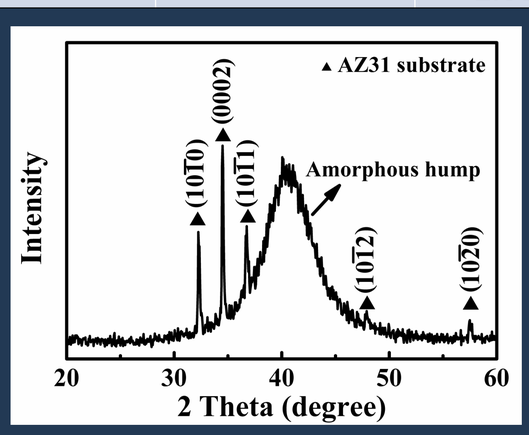

Figure 1 The XRD pattern of the PCS amorphous thin film deposited on the AZ31 substrate.

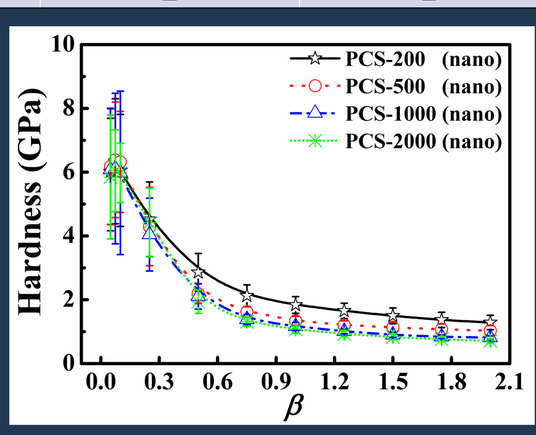

Figure 2 The hardness-β curves of the PCS TFMGs, measured by nanoindentaiton tests.

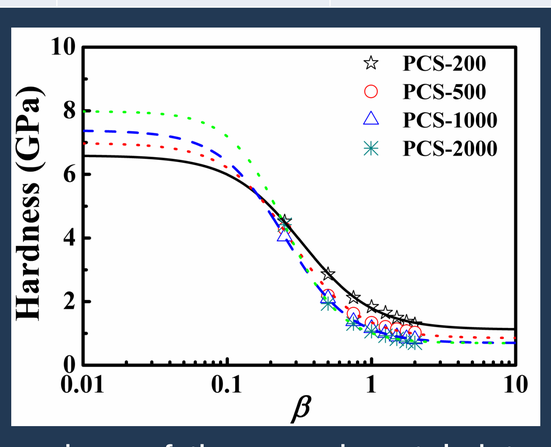

Figure 3 Comparison of the experimental data and the best fit predictions based on Equation for the PCS coated samples under nanoindentaiton. Note that the horizontal axis is presented in log scale.

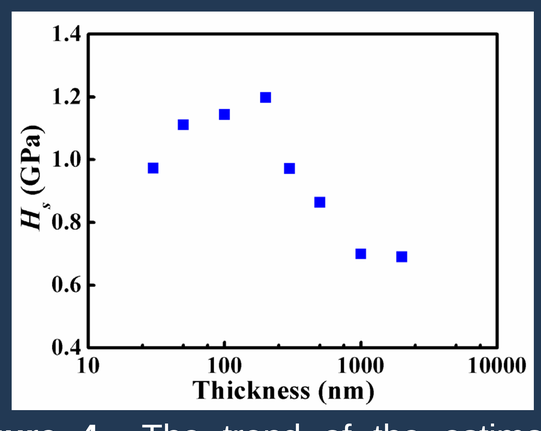

Figure 4 The trend of the estimated substrate hardness H_s. The optimum hard coating thickness might be around 200-300 nm.

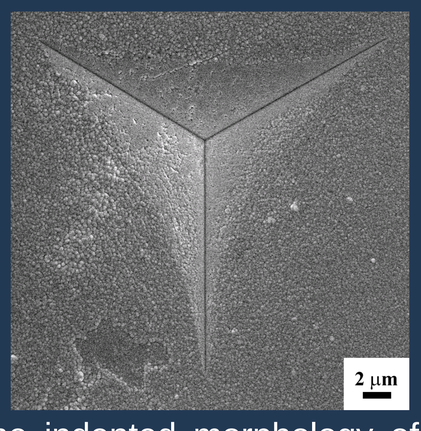

Figure 5 The indented morphology of the same PCS-2000 under nanoindentation loading at 257 mN and at β~2 is presented in Figure 5.

Conclusions

In this study, the PCS TFMG is demonstrated to be a promising protective film to enhance the hardness of AZ31 Mg alloy. With proper PCS coating, the apparent measured surface hardness, and likely the surface wear resistance, can be substantially enhanced. The evolution of shear bands in the TFMG coated layer provides a moderate deformation mode to prevent the film from cracking fiercely. The optimum extracted intrinsic substrate hardness H_s is estimated to locate at around 200-300 nm. This range appears the most promising TFMG coating thickness in considering all the factors related to hardness/wear improvement, more even load transfer distribution, and film cracking issues.