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Effect of filler behavior on nanocomposite SU8 photoresist for moving micro-parts

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Abstract

The use of low-stress SU8 nanocomposites as a functional material for micro-parts and coating applications is described in this paper. It was found that the nanoparticles lower the internal stress and decrease the wear rate and frictional coefficient of the SU8 epoxy. The applicability of this technology is demonstrated on gear wheels configuration and coating multilayer capping technology on moving micro-parts.

Keywords: SU8; Stress; Nanocomposites; Photoresist; Wear; MEMS; Micro-parts

1. Introduction

The increasing interest in Micro-parts has raised the request for a new photoresist material with improved mechanical properties. One major problem is the internal stress and the lack of tribologically optimized surface for micro-parts. Due to the small forces at moving micro-parts and high pressures occurring in microfluidic, the R&D work is focused to minimize the friction and the internal stress during processing.

In this paper, we characterized the residual stress and the friction behavior of reinforced SU8 nanocomposite layers. The difference between pure SU8 and SU8 filled with silica nanoparticles was investigated by using thermal stress measurements and Sliding Friction Apparatus (SFA). This new SU8 based nanocomposite photoresist is expected to find applications in coating for moving parts and micro-electromechanical devices.

SU8 is a well-known thick photoresist used in fabrication of MST and MEMS systems [1–3]. However, it is hard to get fine patterns with high aspect ratio structures because of high internal stress [4]. The modification of the mechanical properties of the SU8 material is based on the use of inorganic nanoparticles. The goal of the study is to load the SU8 epoxy with different inorganic particle concentrations, in order to improve the tribological performance and the mechanical properties of the SU8 photoepoxy. The coefficient of thermal expansion of basic SU8 is high (50 ppm/°C) [5].

In this study we identified that SU8 nanocomposite material improves the stress behavior and the tribological properties of the layer and can be a candidate for moving applications such as solid lubricant, [6] 3D shape structures and coating layer.

2. Experiments and discussion

SU8 photoresist from Gersteltec and commercial silica particles from Nissan Chemical Ltd. were used. Nanocomposite test structures have been realized by photolithography process on silicon, Aluminum and quartz wafers. Stress measurement investigations have been carried out by determining the stress evolution on a SU8 and SU8

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nanocomposites cap layer as function of processing temperature conditions, as shown in Figs. 1 and 2. We observed that the main stress is generated as the cross-linked photoepoxy cools down, points A, B. The grater bowing measured after the curing at 200 °C point B Fig. 2 with a Tencor FLX-2900 device.

The stress response of the SU8 nanocomposites due to normal process is presented and the CTE coefficients of thermal expansion were calculated and found to be lower (27 ppm/°C) than for pure SU8 (50 ppm/°C).

Tribological tests were carried out using a sliding friction apparatus (SFA) [7]. During the friction test, the sample surface was rubbed in laboratory at room temperature and at a relative humidity of 50–60% against a C-Steel, or POM balls (6 mm diameter), for 12 min with an applied force of 2 N and a sliding velocity of 35 mm/s. During the test, the coefficient of friction (COF) increased initially with increasing the number of cycles, and after reaching a maximum slowly decreased (see Fig. 3).

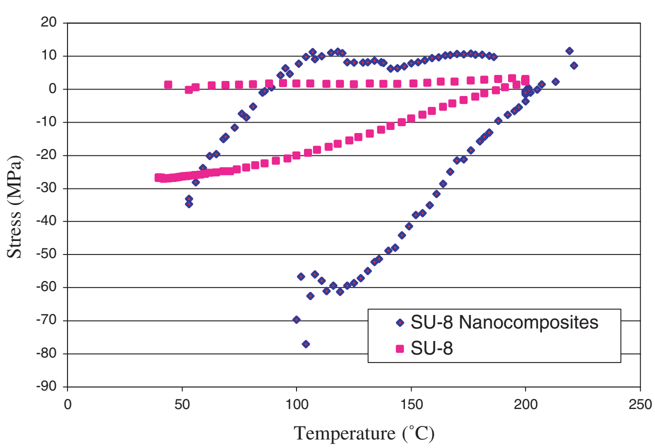

Fig. 1. Stress-temperature evolution for SU8 and SU8 nanocomposite.

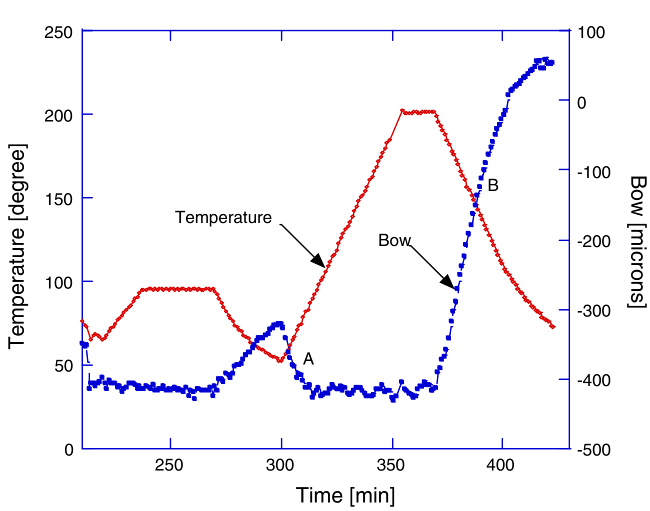

Fig. 2. Change of bow of a 410 μm thick Al wafer during program of curing of 70 μm SU8 nanocomposites resist.

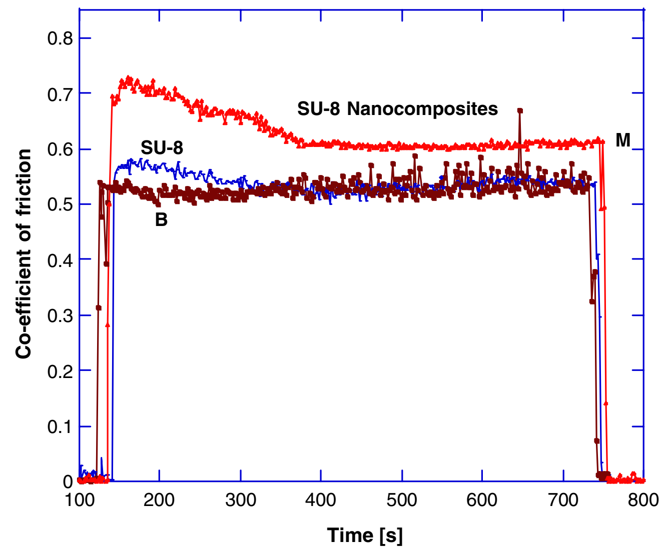

Fig. 3. Evolution with time of the coefficient of friction under a normal load of 2 N for Inox balls, B and M different concentration of silica filler in SU8.

Against POM balls, remarkably low dry COF values (around 0.05) were found for the couple nanocomposite photoresist/POM. No wear could be detected. Against steel the COF was higher (between 0.5 and 0.6) and was not significantly affected by the amount of abrasive particles incorporated into the composites (see Fig. 3). The abrasive particles reduced friction by a factor of 5 compared to the un-reinforced SU8 material (see Fig. 4).

To characterize the main nanocomposites surface features involved in the interphase debonding performance, we examined locally the surface roughness, by Atomic Force Microscopy (AFM). Two- and three-dimensional topographical images are shown in Figs. 5 and 6. The three-dimensional morphological characteristics of nano-

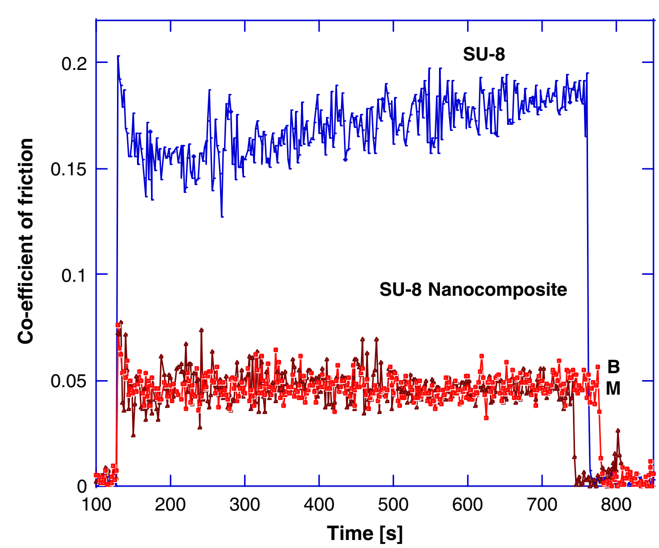

Fig. 4. Evolution with time of the coefficient of friction under a normal load of 2 N for POM balls, B and M different concentration of silica filler.

Fig. 5. AFM topographical scans of a nanocomposite surface after development.

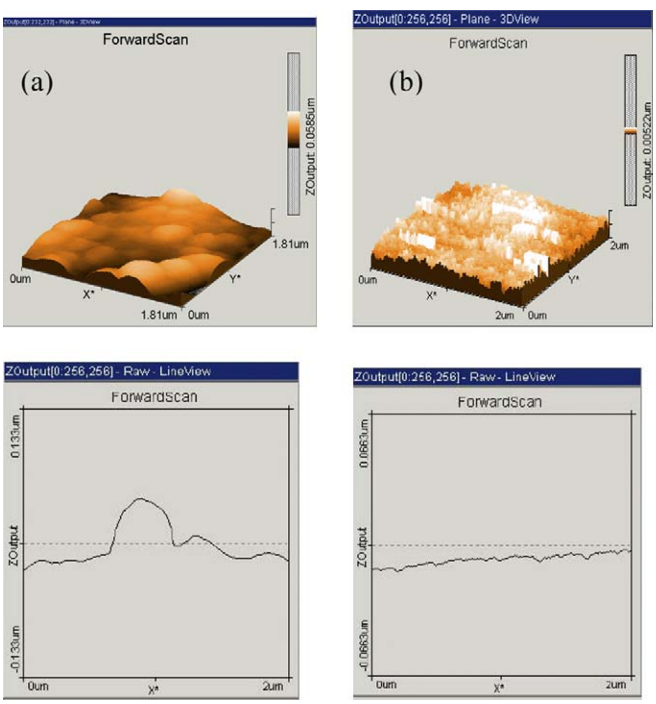

Fig. 6. Topographical scans of a nanocomposite surface after development (a) and after curing (b) showing the reduction in surface asperity obtained by curing.

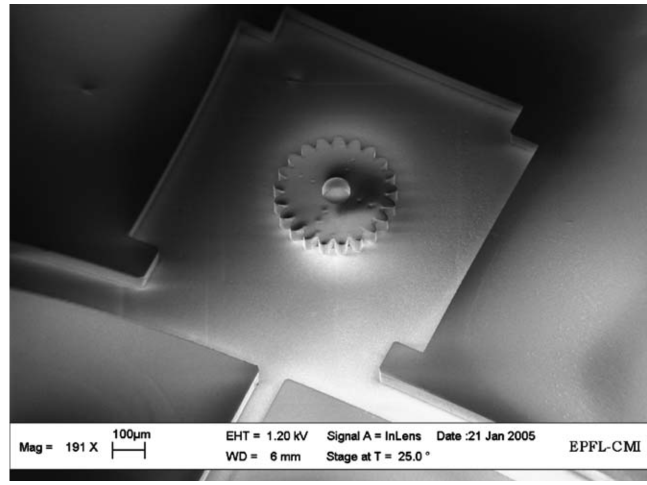

Fig. 7. SEM image of SU8 nanocomposite gearwheel.

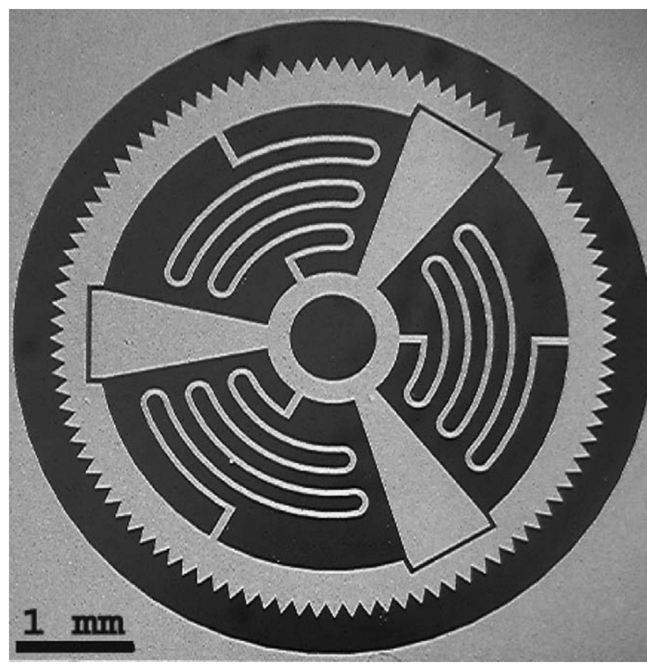

Fig. 8. Optical image of a 5 mm diameter wheel made out of SU8 nanocomposite.

composites after developement without curing and after curing are shown in Fig. 6.

We observed relatively neat, smooth and planar surface after curing with a value of Ra = 0.012 μm and a higher roughness value of Ra = 0.115 before curing (see Fig. 6a). We did not observe any micro crack on both surfaces.

The formulated SU8 structure is illustrated in Figs. 7 and 8. The gears were being manufactured by the UV-LIGA process. The photoepoxy is spin on the Si wafer surface followed by a pre-exposure bake of a few minutes on a hotplate at 95 °C to evaporate the solvent. The polymerization is effectuated by Mask Aligner, either in front side or backside mode. At last post exposure bake of 15 min is done followed the development of the structure by appropriate developer [8].

3. Conclusions

New SU8 nanocomposite materials have been developed. They are based on silica nanoparticles embedded in SU8 photoresist. The abrasive particles reduced stress and friction by a factor of 5 compared to the un-reinforced SU8 material.

Acknowledgments

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