Ultrafine-Grained Aluminum by Cryogenic Surface Mechanical Attrition Treatment

[1]K.Y. Wang, [2]J.C.Jiang, [1]C.G. Liu and [1]K.Lian

[1]Center for Advanced Microstructures and Devices, Louisiana State University, Baton Rouge, LA 70806

[2]Mechanical Engineering Department, Louisiana State University, Baton Rouge, LA 70806

Abstract

The LIGA technique occupies an important role in the arsenal of micromanufacturing technologies. The main impediment to commercial development of LIGA micromanufacturing is cost. The cost for synchrotron radiation is high, and the speed of electrodeposition is low. These two factors conspire to make primary metallic high aspect ratio microsacle structures prohibitively expensive as commercial devices. Recently, a very promising method about the microscale compression molding of Al with surface engineered LIGA insert was reported [1]. During this molding process, Al was heated to the temperature ~450^{o}C. Ni inserts conformally coated with a Ti-CH coating allow repeated Al micromolding with 100% transfer of microscale features from the insert to the molded Al plate. At this processing temperature, the crystalline grain of Al will coalesce and the mechanical properties such as microhardness and wear resistance will be deteriorated.

In MEMS application, the features generally fall in ten to hundreds micrometers ranges. The coalesced grains are detrimental to uniform mechanical properties because only few grains across the entire structure. Thus, there is great interest in surface hardening treatments for Al to improve its mechanical properties. In present study, commercial pure aluminum (AA 1100) was surface mechanical attrition treated in a cryogenic (liquid nitrogen (LN)) temperature. The initial grain size of Al was determined to be about 10 μm. The rod was cut into slices of 3.75 mm diameter and 2 mm thick. The sample was mounted in a vial that was vibrated by a SPEX 8000 mixer/mill. The liquid nitrogen was sprayed on the surface of the vial and the temperature of the vial was kept around -190^{o}C. The surface ultrafine-grained (around 300nm) was obtained by TEM after cryogenic surface attrition 10 minutes. The Knoop microhardness of the LN sample showed drastically increasing compared to that of the coarse-grained (CG) Al. For the different depth of the LN samples, the microhardness near the processed surface is higher than the depth far from the surface. The wear rate of the LN sample was decreased obviously compared to that of the CG Al. The friction coefficient of the LN sample is slightly lower than that of the CG Al. From the SEM results of the worn surfaces of the as-processed Al, we can suggest that the wear mechanism of the ultrafin-grained Al was micro-ploughing and delamination. The mechanism of formation of submicron grain under low temperature is also discussed.

[1] D.M.Cao and W.J.Meng, Microsystem Technologies, 10, 662-670 (2004)