Mechanical characterization of individual Ni/Au coated microsize polymer particles

This item was submitted to Loughborough University’s Institutional Repository by the/an author.

Citation: DOU, G., WHALLEY, D.C. and LIU, C., 2008. Mechanical characterization of individual Ni/Au coated microsize polymer particles. Applied Physics Letters, 92(10), 104108 (8 Pages)

Additional Information:

- This article may be downloaded for personal use only. Any other use requires prior permission of the author and the American Institute of Physics. The following article appeared in (DOU, G., WHALLEY, D.C. and LIU, C., 2008. Mechanical characterization of individual Ni/Au coated microsize polymer particles. Applied Physics Letters, 92(10), 104108 (8 Pages)) and may be found at http://link.aip.org/link/?APPLAB/92/104108/1

Metadata Record: https://dspace.lboro.ac.uk/2134/5276

Version: Published

Publisher: © American Institute of Physics

Please cite the published version.
This item was submitted to Loughborough’s Institutional Repository (https://dspace.lboro.ac.uk/) by the author and is made available under the following Creative Commons Licence conditions.

For the full text of this licence, please go to:
http://creativecommons.org/licenses/by-nc-nd/2.5/
Mechanical characterization of individual Ni/Au coated microsize polymer particles

Guangbin Dou,a) David C. Whalley, and Changqing Liu
Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, Leicestershire LE11 3TU, United Kingdom

(Received 10 September 2007; accepted 16 February 2008; published online 14 March 2008)

We report on a mechanical characterization technique for individual Ni/Au coated microsize polymer particles. This technique allows a clearer understanding of the effects of load force and rate on the particle deformation. This has been achieved through measurements of the deformation against force using a specially configured nanoindenter machine, where the “indenters,” instead of being pointed, had a flat tip of 20 μm in diameter. The results show that the particle deformation process is nonlinear and that the force/deformation at which particle crushing occurs is affected by the load rate. The technique could be used to design/manufacture more effective conductive particles. © 2008 American Institute of Physics. [DOI: 10.1063/1.2898219]

In recent years, extensive interest has been focused on the development of lead free electronic packaging technologies due to legislation restricting the use of hazardous materials in a number of countries. The use of microsized metallic coated particles, mixed with a thermosetting adhesive resin, has been reported.4 However, only a modest level of deformation was achieved in these experiments due to the use of a large punch with a 100 μm square flat tip, i.e., about 400 times the area of the particles tested and the tip and substrate were not sufficiently parallel. This resulted in the deformation being insufficient to allow the crushing behavior to be measured, which is a very important aspect of the conductor particle behavior. In this study, the load versus deformation behavior to a very high level of compression was measured, and the load rate effects on the deformation were analyzed.

The particles used in this research were 5.75 μm diameter microspheres of a cross-linked copolymer resin of divinyl-benzene (DVB) coated with Ni and Au layers. These particles are specifically designed for use in ACA applications and have a Ni layer of about 50 nm thick under a Au layer, less than 30 nm. A NanoTest™ machine (schematically shown in Fig. 1) was adapted to deform the particles using a flat tipped punch instead of the diamond indenter normally used in nanohardness tests.8–10 The punch tip which was about 20 μm in diameter was made from high speed steel (HSS). The tests involved force controlled deformation of the particles, where the force was increased linearly with time and the resulting deformation monitored. Glass microscope slides were used as base stages to support the deforming particles during these tests. Particles were generally found to have been crushed after the tests in the typical crush pattern shown in Fig. 2.

Figure 3(a) shows a typical deformation result for a particle, where the load rate was 1 mN/s. The deformation of the particle showed a sudden increase in deformation after a deformation degree of just over 50% of the particle diameter.

FIG. 1. (Color online) Schematic diagram of the nanoindenter. In the test, HSS punches tipped about 20 μm in diameter were used.

---

a)Author to whom correspondence should be addressed. Electronic mail: gb.dou@lboro.ac.uk, g.duo@imperial.ac.uk. Tel.: +44(0)1509227661. Present address: Department of Electrical and Electronic Engineering, Imperial College London, South Kensington Campus, London SW7 2AZ, United Kingdom.
The results show that both the force at the crush point and crush force, the results are for the mean values for the deformation of eight to ten samples, with the error bars indicating one standard deviation variation.

The effects of varying the loading rate from 0.5 to 2 mN/s on particle crushing are shown in Fig. 3(b). The results show that both the force at the crush point and the deformation at the crush point were quite sensitive to the loading rate. The critical load rate was found to be approximately 1 mN/s. At lower load rates, the particle remained intact, and the deformation at the crush point was small. At higher load rates, the particle was crushed, and the deformation at the crush point increased significantly.

The effects of varying the particle size from 100 to 500 nm on particle crushing are shown in Fig. 3(c). The results show that the particle size had a significant effect on the crushing behavior. The crushing force increased with increasing particle size, and the crushing force at the crush point was found to be approximately 10 mN. The deformation at the crush point also increased with increasing particle size, and the deformation at the crush point was found to be approximately 2000 nm.

The effects of varying the stage size from 0.5 to 2 mm on particle crushing are shown in Fig. 3(d). The results show that the stage size had a significant effect on the crushing behavior. The crushing force increased with increasing stage size, and the crushing force at the crush point was found to be approximately 100 mN. The deformation at the crush point also increased with increasing stage size, and the deformation at the crush point was found to be approximately 4000 nm.

The effects of varying the initial deformation from 0.1 to 0.5 of the original particle size on particle crushing are shown in Fig. 3(e). The results show that the initial deformation had a significant effect on the crushing behavior. The crushing force increased with increasing initial deformation, and the crushing force at the crush point was found to be approximately 10 mN. The deformation at the crush point also increased with increasing initial deformation, and the deformation at the crush point was found to be approximately 2000 nm.

The effects of varying the loading rate from 0.5 to 2 mN/s on particle crushing are shown in Fig. 3(f). The results show that both the force at the crush point and crush force, the results are for the mean values for the deformation of eight to ten samples, with the error bars indicating one standard deviation variation.

The effects of varying the particle size from 100 to 500 nm on particle crushing are shown in Fig. 3(g). The results show that the particle size had a significant effect on the crushing behavior. The crushing force increased with increasing particle size, and the crushing force at the crush point was found to be approximately 10 mN. The deformation at the crush point also increased with increasing particle size, and the deformation at the crush point was found to be approximately 2000 nm.

The effects of varying the stage size from 0.5 to 2 mm on particle crushing are shown in Fig. 3(h). The results show that the stage size had a significant effect on the crushing behavior. The crushing force increased with increasing stage size, and the crushing force at the crush point was found to be approximately 100 mN. The deformation at the crush point also increased with increasing stage size, and the deformation at the crush point was found to be approximately 4000 nm.

The effects of varying the initial deformation from 0.1 to 0.5 of the original particle size on particle crushing are shown in Fig. 3(i). The results show that the initial deformation had a significant effect on the crushing behavior. The crushing force increased with increasing initial deformation, and the crushing force at the crush point was found to be approximately 10 mN. The deformation at the crush point also increased with increasing initial deformation, and the deformation at the crush point was found to be approximately 2000 nm.
the particle deformation before crushing were higher when the load rate was 0.5 mN/s. At this loading rate, the particles deformed by about 4500 nm, or around 80% of the original particle size, before crushing. However, the crush point deformation dropped to about 52% of the original particle size, about 3000 nm, when the load rate was 1 mN/s. Therefore, it can be concluded that the load rate affected the particle deformation process, delaying the crushing significantly at lower load rates. This is considered to be due to the viscoelastic properties of the polymer particles. The error bars in the figure suggested that the lower the load rate, the more variable the crush point. Figure 3(b) shows that the load force was about 31 mN when the load rate was 0.5 mN/s, but that it dropped a little, to less than 30 mN, when the load rate was 1 mN/s. Therefore, there was no major difference in the crush load force between load rates of 0.5 and 1 mN/s if only the mean load force was considered. However, the crush load force was more variable at the higher load rate, as shown in Fig. 3(b). When the load rate was 2 mN/s, the mean load force dropped to about 20 mN, which is a more significant drop than for the load rate of 1 mN/s, and the variability was similar to that for the load rate of 1 mN/s. It can be concluded that the high load rate, i.e., 2 mN/s, caused the particles to be more easily broken, as the load force at the crush point was only about 20 mN, much smaller than the deformation in the load 0.5 mN/s, where the crush force was about 30 mN.

This paper has demonstrated a technique for measuring the mechanical deformation properties of a single ACA particle. The typical load versus deformation behavior of individual ACA particles undergoing deformation was established. Four stages were identified in this process. The results show that the particle deformation is highly nonlinear, including the load and displacement at the crush point and the variability of the deformation behavior. They also show that at a low load rate, greater particle deformation before crushing can be obtained. This has implications for commercial assembly processes, where a high assembly rate is desired. It is believed that this sensitivity to load rate is due to the viscoelastic properties of the DVB polymer core within the particles. At higher load rates, this viscoelastic behavior will result in higher stresses in the polymer due to the reduced time available for the stresses to redistribute within the particle as it deforms.

We thank Dr. H. Kristiansen of Conpart AS, Norway, for sourcing the ACA particles for us.

3J. Liu, Conductive Adhesive for Electronics Packaging (Electrochemical, Port Erin, 1999), pp. 2–4.