Solution Deposition Planarization of Long-Length Flexible Substrates

Extended Abstract for Presentation

Chris Sheehan* and Vladimir Matias

Superconductivity Technology Center, MS T004

Materials Physics and Applications Division

Los Alamos National Laboratory, Los Alamos, New Mexico 87545

Flexible electronic applications, such as printed circuits, integrated circuits, displays and sensors, and advanced energy applications, such as photovoltaics, batteries and high temperature superconducting coated conductors (HTSCC) place high demands on substrate properties. Despite the difficulties in transitioning from rigid and bulk form factors, the cost and functional benefits of developing thin-film, web coating processes on flexible substrates are too great to ignore. Temperature stability, chemical compatibility, surface roughness and cost are among key factors in selecting a substrate and buffer layer (if required). In this presentation, we demonstrate an inexpensive method for preparing extremely smooth flexible substrates in long lengths with high temperature stability. This method utilizes multiple chemical solution depositions to planarize the substrate to a desired level of smoothness. We demonstrate 0.5 nm RMS roughness oxide coatings on metal tapes that start at 50 times higher roughness.

Traditional substrate smoothing techniques include coatings, such as atmospheric solution deposition of polymers, vacuum deposition of polymers (PML coatings[1]), spin on glass (SOG),[2,3] and removal processes such as electropolishing,[4] mechanical polishing[5] and chemical mechanical polishing. Polymer smoothing coatings are not suitable for the high temperatures required for many applications. SOG is not a web coating process. The removal processes are suitable for metal tapes and high temperatures, but are either impractical for web coating or generate significant waste.

We have recently developed Solution Deposition Planarization (SDP) as an alternative substrate smoothing method.[6] SDP uses multiple solution coatings of amorphous yttria to planarize the substrate and eliminates the need for three other processes (in our example). The metal tape is coated via atmospheric dip coating of an yttrium acetate/alcohol solution, dried and converted to yttrium oxide by heating to 575°C in air. Surface tension of the liquid solution planarizes the free surface. Subsequent drying yields thicker areas in the valleys and thinner area on the peaks. Shrinkage of the coating occurs upon converting to solid and thus only a fraction of the roughness is removed with each pass. The process is repeated to reduce the roughness further until the desired smoothness is reached, which is a function of the starting substrate roughness. SDP coatings on substrates with an initial RMS roughness of 3-4 nm and 20-50 nm require 3-4 passes and 10-15 passes, respectively, to reach less than 2 nm RMS roughness over a 5 x 5 µm area.

The SDP-prepared substrates were used for fabricating HTSCC. In this case a $YBa_2Cu_3O_7$ (YBCO) layer of 1-3 µm is deposited on an ion-beam aligned template. Ion-beam assisted deposition (IBAD) of MgO is used to create a crystalline-aligned template for epitaxial growth of superconducting YBCO layers.[7,8,9] IBAD-MgO requires very smooth surfaces for deposition, less than 2 nm RMS roughness.[10]

*Email: Sheehan@lanl.gov Phone: 505-663-5568 Fax: 505-663-5550

A number of different YBCO deposition techniques were used successfully on these templates, including pulsed laser deposition (PLD), reactive coevaporation (RCE), and MOCVD. For the PLD sample the critical current, J_c at 75 K in self field (SF) was measured to be 2.85 MA/cm^2. An RCE YBCO film of 1 µm was deposited on an IBAD/SDP template and the J_c at 75 K (SF) was 4 MA/cm^2 without a buffer layer.[11] These J_c values match or exceed the best undoped YBCO samples made by PLD on single crystal substrates.[12] Currently several HTSCC manufacturers are exploring the use of this SDP technology in fabrication of their products. HTSCC have potential applications in power transmission cables, electric motors and generators, and fault current limiters.

This work received an R&D 100 Award for 2010.

We would like to thank Paul Clem, Jon Ihlefeld, and Cynthia Edney from Sandia National Laboratories and Yehyun Jung, Terry Holesinger, Matthew Feldman, E. John Rowley, and Paul Dowden of Los Alamos National Laboratory for assistance in this work. This work was supported by the Department of Energy Office of Electricity Delivery and Energy Reliability. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

References

1. J.D. Affinito, P.M. Martin, M. Gross, C. Coronado, E.N. Greenwell, *Thin Solid Films* **308** 19 (1997)
2. S. Gnanarajan and J. Du, *Super. Sci. Techn.* **18**, 381 (2005).
3. R. Lu, R. N. Vallejo, D. W. Fisher, J.Z. Wu, *Appl. Phys. Lett.* **89,** 132505 (2006).
4. S. Kreiskott, P. N. Arendt, L. E. Bronisz, et al., *Super. Sci. Techn.* **16**, 613 (2003).
5. J.R. Groves, P.N. Arendt, S.R. Foltyn, Q.X. Jia, T.G. Holesinger, L.A. Emmert, R.F. DePaula, P.C.Dowden, L. Stan, *IEEE Trans. Appl. Super*. **13**, 2651 (2003).
6. V. Matias and Q. Jia, DOE Superconductivity Annual Peer Review 2009; http://www.htspeerreview.com/pdfs/presentations/day%202/strategic-research/9-Coated-Conductor-Template-Research.pdf
7. *MRS Bulletin* **29** issue (2004).
8. C. P. Wang, K. Do, M. Beasley, T. Geballe, and R.H. Hammond, *Appl. Phys. Lett.* **71**, 2955 (1997).
9. V. Matias, J. Hänisch, E.J. Rowley, and K. Güth, *J. Mater. Res.* **24**, 125 (2009).
10. V. Matias, J. Hänisch, E.J. Rowley, C. Sheehan, P.G. Clem, N. Kumasaka, and I. Kodaka, edited by P. Barnes, D. Lee, C. Park, N. Amemiya, J. Reeves (Mater. Res. Soc. Symp. Proc. Volume 1001E, Warrendale, PA, 2007), No. 1001-M04-02.
11. V. Matias E.J. Rowley, Y. Coulter, B. Maiorov, T. Holesinger, C. Yung, V. Glyantsev, B. Moeckly, *Super. Sci. Techn.* **18**, 381 (2010).
12. S. Foltyn, L. Civale L, J.L. MacManus-Driscoll, Q. Jia Q, B. Maiorov, H. Wang and M. Maley, *Nat. Mater.* **6,** 631 (2007).

Formatted: Space After: 0 pt

*Email: Sheehan@lanl.gov Phone: 505-663-5568 Fax: 505-663-5550