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**14. ABSTRACT**  The grant supported research effort to understand factors limiting current-carrying capabilities in coated conductors (CCs). Three new operating modes of scanning laser microscopy (SLM) were developed under this grant, and total of five SLM modes were utilized for the research. The research found that the increased local-current density (current-crowding) was the main cause for the dissipation and the limiting factor for the current-carrying capacity. It was found in striated CCs that the current-crowding was caused by scratches from sample-handling, localized damages during striation process, or current flow configuration due to specific striation patterns. The other aspect of the research was to understand superconducting dissipation from various YBCO-family films on bicrystal grain boundary (GB) junctions. The samples on 24° [100]-tilt GB showed that the dissipation appeared like "hot-spots" along GB. There was no significant difference in the size and/or the pattern of hot-spots for different YBCO-family samples (regardless of nanoparticle additions, doping, and multi-layering) even though the current-carrying capability varied widely among the samples. The results implied that SLM features were determined by the GB angles not by the property of YBCO films when the dissipation began and the hot-spot appeared on GB.  

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Title of Project: Characterizing Coated Conductors with Variable Temperature Scanning Laser Microscopy (SLM)
2. Abstract

The grant supported research effort to understand factors limiting current-carrying capabilities in coated conductors (CCs). Three new operating modes of scanning laser microscopy (SLM) were developed under this grant, and total of five SLM modes were utilized for the research. The research found that the increased local-current density (current-crowding) was the main cause for the dissipation and the limiting factor for the current-carrying capacity. It was found in striated CCs that the current-crowding was caused by scratches from sample-handling, localized damages during striation process, or current flow configuration due to specific striation patterns. The other aspect of the research was to understand superconducting dissipation from various YBCO-family films on bicrystal grain boundary (GB) junctions. The samples on 24° [100]-tilt GB showed that the dissipation appeared like “hot-spots” along GB. There was no significant difference in the size and/or the pattern of hot-spots for different YBCO-family samples (regardless of nanoparticle additions, doping, and multi-layering) even though the current-carrying capability varied widely among the samples. The results implied that SLM features were determined by the GB angles not by the property of YBCO films when the dissipation began and the hot-spot appeared on GB.

3. Technical Summary

Experimental Set-up

There are four different modes of SLM operations we have used for this program; variable-temperature SLM (VTSLM), low temperature SLM (LTSLM), thermoelectric SLM (TE-SLM), alternating current SLM (AC-SLM), and pulsed-current SLM (PC-SLM). These modes share the basic experimental set-up shown in Fig. 1.

PC-SLM uses different experimental set-up shown in Fig. 2. More detailed information about the operating procedures of different modes can be found in MS theses listed later in the report.
Summary of Accomplishments

One of our major accomplishments is to recognize the signature of critical current ($I_c$) restricting areas. By comparing VTSLM and LTSLM images, we find that (1) lower $T_c$ areas do not necessarily have lower $J_c$; and (2) the increased local-current density is the main cause for the dissipation in superconducting states and $I_c$ limiting factor. The signatures of increased local-current density (current-crowding area) can be detected in VTSLM images. Our results in striated CCs show that the current-crowding is caused by scratches from sample-handling, localized damages during striation process, or current flow pattern due to specific striation patterns. Our results are reported in the list of publications and the M.S. theses at the end of this report.

We have studied grain-boundary (GB) characteristics of the family of YBCO with 211-nanoparticles, Ca-doping, and multi-layering. TE-SLM worked beautifully in identifying the location of GBs for all samples, and the magnitude of TE-SLM signal was proportional with the grain boundary angles.

We find that the flux-flow in YBCO film is responsible for the dissipation for a lower angle GB. The pattern observed in SLM indicates that the $6^\circ$ vicinal-cut in the substrate (from YBCO on $6^\circ$ [100]-tilt boundary SrTiO$_3$ substrate) generates easy path for flux-flow dissipation. Due to the strong dissipation in the film, $6^\circ$ GB does not appear to be contributing much for the dissipation.

From larger grain-boundary YBCO samples, on $24^\circ$ [100]-tilt boundary SrTiO$_3$ substrate, GB dominates dissipation in all of them. The emergence of voltage in I-V characteristics is related with the appearance of "hot-spots" along GB in LTSLM images. In some cases, we have
observed step-like I-V characteristics, which may be explained by Fisk steps. Strong correlation is noted between the steps in I-V characteristics and the hot-spot patterns along GB.

So far we have not observed any significant difference in the size and/or the pattern of hot-spots for different YBCO samples from 24° [100]-tilt boundary. This suggests that the superconducting dissipation is similar regardless the addition of nanoparticles, doping, and multi-layering when the sample process is optimized.

Another important aspect of this program was the development of new SLM modes. We demonstrated the feasibility of AC-SLM and PC-SLM. Using AC-SLM, we could obtain images equivalent to regular VTSLM and LTSLM. At this point, we have not found any additional loss/dissipation using AC due to the lower signal-to-noise ratio in AC-SLM and PC-SLM. However, future investigation and development are needed for AC-SLM and PC-SLM.

Summary of M.S. Thesis

1. P. H. Shelby, “VTSLM reveals current distribution around features in striated YBCO”.
3. S. Yoo, “Investigation of Current Percolation Characteristics in YBa2Cu3O7 Coated Conductor IBAD Samples with Scanning Laser Microscopy”.
4. J. L. Young, “New Operating Modes in Scanning Laser Microscopy”.

4. Personnel Supported

PI: Chuhee Kwon, Ph.D.
Graduate student: S. Yoo, Jeremy Young, (C. M. Khanal, P. H. Shelby, K. R. Barraca)
Undergraduate student: Jeremy Young, Ryan James, Meguimi Yamamoto, Samuel Pottish, and Michael Guerrero.
* Students in the parenthesis were not directly paid from the grant, but performed the research as a part of M.S. Thesis

5. Publications

Peer-Reviewed Publications


6. Interactions/Transitions

a. Participation/presentation at meetings, conferences, seminars, etc.


6. Poster at Southern California Conference for Undergraduate Research (SCCUR) held at University of California – Riverside, J. L. Young. “Enhancing the Capabilities of the Scanning Laser Microscope”. (Nov. 19, 2005)


7. New Discoveries, Inventions, or patent disclosures

None
8. Honors/Awards

None