AFRL-PR-WP-TP-2006-226

SUBSTRATE PLANARIZATION STUDIES ON IBAD SUBSTRATES

Srinivas Sathiraju, John P. Murphy, Julianna M. Evans, Angela L. Campbell, Lyle B. Brunke, and Paul N. Barnes

MARCH 2004

Approved for public release; distribution is unlimited.

STINFO COPY

PROPULSION DIRECTORATE
AIR FORCE MATERIEL COMMAND
AIR FORCE RESEARCH LABORATORY
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433-7251

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
March 2004	Conference Paper Postprint	03/10/2003 – 03/10/2004

4. TITLE AND SUBTITLE
SUBSTRATE PLANARIZATION STUDIES ON IBAD SUBSTRATES

5a. CONTRACT NUMBER In-house
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER 61102F/62203F

6. AUTHOR(S)
Paul Barnes and Julianna M. Evans (AFRL/PRPG)
Srinivas Sathiraju (NRC)
John P. Murphy (UDRI)
Angela L. Campbell (AFRL/MLPJE)
Lyle Brunke (UES Inc.)

5d. PROJECT NUMBER 3145
5e. TASK NUMBER 32
5f. WORK UNIT NUMBER 314532Z9

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Power Generation Branch (AFRL/PRPG)
Power Division
Propulsion Directorate
Air Force Research Laboratory, Air Force Materiel Command
Wright-Patterson Air Force Base, OH 45433-7251

NRC

University of Dayton Research Institute (UDRI)

Survivability & Sensor Materials Division (AFRL/MLPJE)

UES Inc.
4401 Dayton-Xenia Dr.
Dayton, OH 45432-1894

8. PERFORMING ORGANIZATION REPORT NUMBER
AFRL-PR-WP-TP-2006-226

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Propulsion Directorate
Air Force Research Laboratory
Air Force Materiel Command
Wright-Patterson AFB, OH 45433-7251

10. SPONSORING/MONITORING AGENCY ACRONYM(S)
AFRL-PR-WP

11. SPONSORING/MONITORING AGENCY REPORT NUMBER(S)
AFRL-PR-WP-TP-2006-226

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Conference paper postprint for the 2003 Fall Materials Research Society Conference Proceedings.

 PAO Case Number: ASC 03-3098, 26 Nov 2003.

14. ABSTRACT
To achieve high critical currents in 2nd generation superconductors deposited on metallic substrates, substrate average roughness and texture of the buffer layer are key factors. This study is about planarization of IBAD substrates using an inductively coupled RF discharge operating at 13.56MHz. A pancake coil antenna was used to construct the inductively coupled discharge system. Exposure to an Ar plasma for varying Ar pressures and time 15 min to 1 hr created linearized substrates. Surface roughness was measured using AFM as well as surface profilometer. Unpolished Inconel substrates have been studied under varying RF plasma conditions, such as pressure, RF power, and etch time to determine effects on substrate roughness. AFM and KLA- TENCOR SP measured average surface roughness (Ra) of the planarized samples. The best Ra found on plasma etched substrate is 4nm under 240 mTorr pressure and 100 W RF power and 30 min time from AFM analysis. The Ra values for Inconel substrates vary between 35-51 nm under varying conditions. Our initial results suggest that there is a decreasing tendency in Ra with the increase of Ar pressure.

15. SUBJECT TERMS substrate, planarization, IBAD, YBCO, surface roughness

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT:	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON (Monitor)
Unclassified	Unclassified	Unclassified	SAR	10	Paul N. Barnes **19b. TELEPHONE NUMBER** *(Include Area Code)* N/A

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

Substrate Planarization Studies on IBAD Substrates

Srinivas Sathiraju[2], John P Murphy[1], Julianna M. Evans, Angela L. Campbell[3], Lyle B.Brunke[4], Paul N. Barnes.

[1]UDRI, [2]NRC, [3]MLPJE, [4]UES Inc.
2645 Fifth Street, Bldg 450, Propulsion Research and Power Generation Branch, Air Force Research Laboratory, Wright-Patterson AFB, OH 45433

ABSTRACT

To achieve high critical currents in second generation superconductors deposited on metallic substrates, substrate average roughness and texture of the buffer layer are key factors. This study is about Planarization of ion beam assisted deposition (IBAD) substrates using an inductively coupled radio frequency (RF) discharge operating at 13.56MHz. The inductively coupled discharge system was constructed using a pancake coil antenna. Linearized substrates were created by exposure to an Ar plasma for varying Ar pressures (8 mTorr – 1 Torr) and time 15 minutes to 1hr. Surface roughness was measured using atomic force microscopy (AFM) as well surface profilometer. Unpolished Inconel substrates have been studied under varying RF plasma conditions, such as pressure (8 mTorr to 1 Torr), RF power (50 Watts to 200watts) and etch time (15 to 60 minutes) to determine the effects on substrate roughness. Average surface roughness (*Ra*) of the planarized samples was measured using AFM and KLA-TENCOR surface profilometer (SP). The best *Ra* observed on plasma etched substrate is 4 nm under 240 mTorr pressure and 100 watts RF power and 30 minutes time from AFM analysis. The *Ra* values for Inconel substrates vary between 35- 51 nm under varying conditions. Our initial results suggest that there is a decreasing tendency in *Ra* with the increase of Ar pressure.

INTRODUCTION

For the deposition of oxide buffer layers using ion beam assisted deposition (IBAD), the substrate smoothness is important for obtaining good texture of the buffer layers. However, there are no systematic studies reported on the substrate planarization. So in this paper we report a systematic investigation of substrate planarization using RF plasma under varying plasma conditions.

EXPERIMENTAL

An inductively coupled discharge system was constructed using a pancake coil antenna. Cross sectional view of the experimental set up is shown in Figure1. The chamber is pumped using a Turbo pump prior to the etching. Plasma was created by ionizing ultra pure Ar gas at 13.56 MHz RF power (max. 200 Wats) in the chamber to treat the substrates. Linearized substrates were created by exposure to the plasma at different Ar

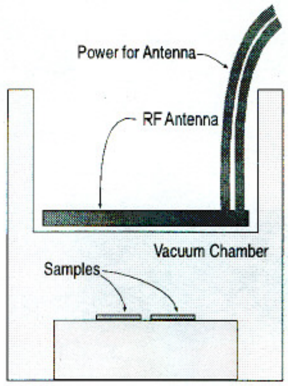

Figure 1 Cross sectional view of the experimental set up

pressures (8 mTorr – 1 Torr) and time (15 minutes to 1hr). We have also investigated the effect of magnetron plasma on the planarization at very low Ar pressures. Substrates were placed on the top of a circular magnetron. *Ra* of the sample, before plasma treatment and after plasma treatment determined using AFM as well as a SP.

RESULTS AND DISCUSSION

AFM surface analytical studies (10μm x10μm area over 30 positions) suggest that *Ra* is not affected from 30 to 120 mTorr pressure. However, a sudden increase in the Ra has been observed at 240 mTorr Ar pressure. The best fit for this graph is a Polynomial fit as shown in the Figure 2. The surface morphology of a planarized substrate at 30mTorr Ar pressure for 30 minutes with 100W RF power is shown in Figure 3. However, the *Ra* data (50μm x50μm) obtained from SP analysis shown in Figure 4 suggests that the trends are towards lower surface roughness with the increase of Ar pressure. Figure 5 suggests that there is no significant effect of RF power with time on the average *Ra*. However, a decreasing tendency in Ra with the increase in Ar pressure has been observed. More studies are in progress to explain the effects of Ar pressure or RF power or time of planarization on the substrate average roughness.

Table 1. Summary of AFM analysis for certain conditions of substrate planarization

Pressure mTorr	Power Watts	Time in mts	*Ra* (nm)	Mean	Median	Std Deviation	Variance	Best Ra (nm)
*0	*	*	9.1	8.7	8.3	2.71	7.4	5.9
30	100	30	9.6	8.9	8	3.41	11.7	4.1
60	100	30	8.1	7.5	6.8	2.95	8.7	4.4
120	100	30	8.6	8.2	8.04	2.6	6.76	4.3
240	100	30	15.2	15.2	8.6	10.1	101	5.1

0* Unpolished substrate

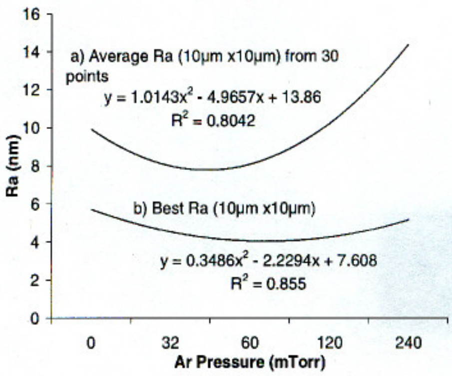

Figure 2

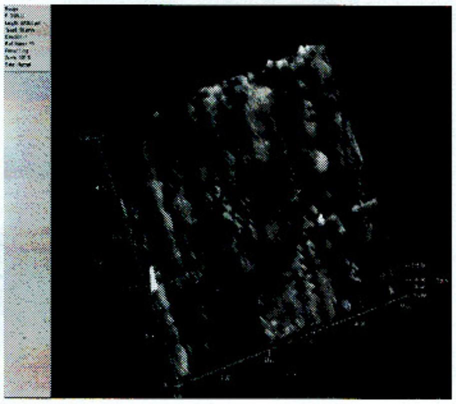

Figure 3

Figure 2. Affect of Ar Pressure on Ra of planarized Inconel (AFM analysis)
Figure 3. Typical surface morphology of the planarized Inconel substrate (SP micrograph)

Figure 4

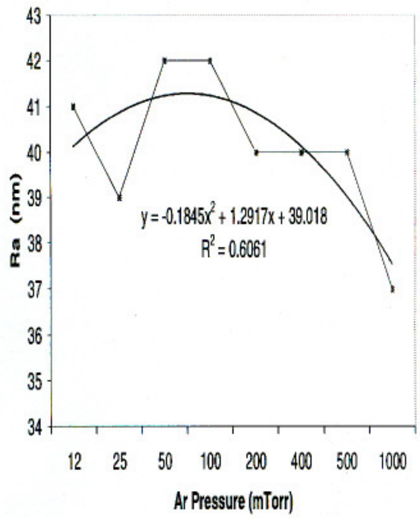

Figure 5

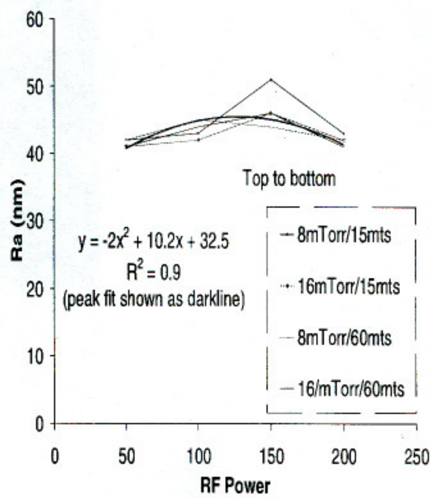

Figure 4. Affect of Ar partial pressure on *Ra* (from SP data analysis).
Figure 5. Affect of RF power on *Ra* (from SP data analysis)

ACKNOWLEDGEMENTS

Sathiraju acknowledges National Research Council (NRC), National Academy of Sciences (NAS), Air Force Office of Scientific Research (AFOSR), and the Propulsion Directorate of Air Force Research Laboratory (AFRL) for the award of SRA fellowship and research support.