A Presentation at DoE Nuclear Physics SBIR/STTR Exchange Meeting 13-14 September 2010

SIENNA TECHNOLOGIES® Inc.

providing solutions through advanced materials

Woodinville, WA

Web: http://www.SiennaTech.Com

Outline

- Who is Sienna Technologies, Inc.?
- Present an overview of our activities on High Performance Lossy Dielectric HOM Absorbers for SRF Cavities under DoE Grant Nos. DE-FG02-08ER85180 (SBIR Phase I) and DE-FG02-07ER84755 (SBIR Phase II).

Who is Sienna Technologies?

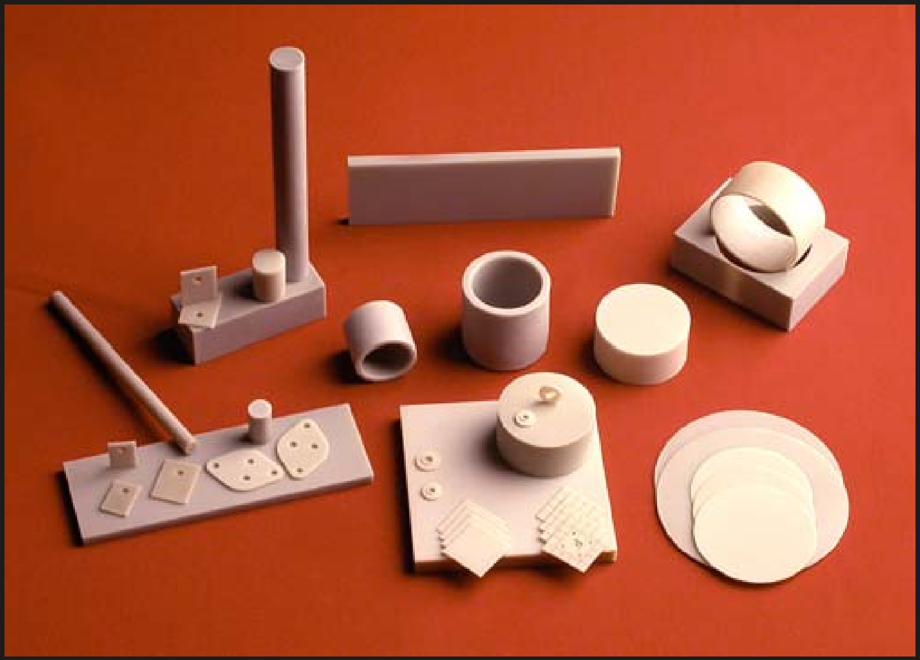
- Sienna Technologies, Inc. was founded in 1992 with a mission of developing new businesses by providing solutions through advanced materials technologies
- Today Sienna is the only US owned AlN manufacturer with integrated capabilities of:
  - shape forming
  - sintering
  - machining
  - metallization
  - brazing

What is Sienna's Business?

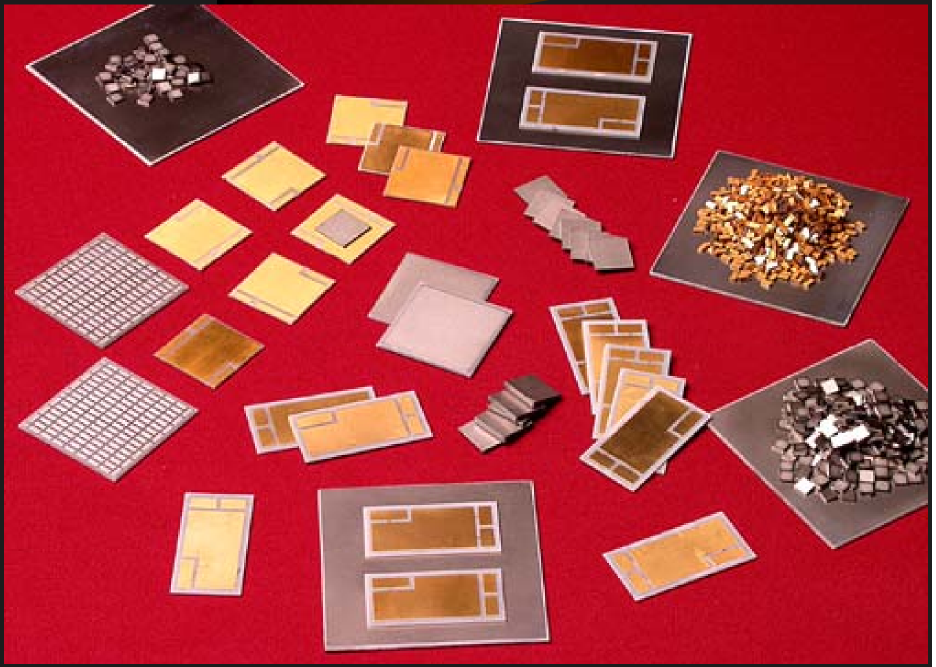
Sienna Technologies, Inc. is dedicated to the research, development, and manufacturing of:

- Bare and Metallized Aluminum nitride components for electronics and microwave applications.
- High temperature catalysts for Space Propulsion.
- Functional Materials for Electromagnetic interference shielding and Infrared warfare.

Aluminum Nitride Products

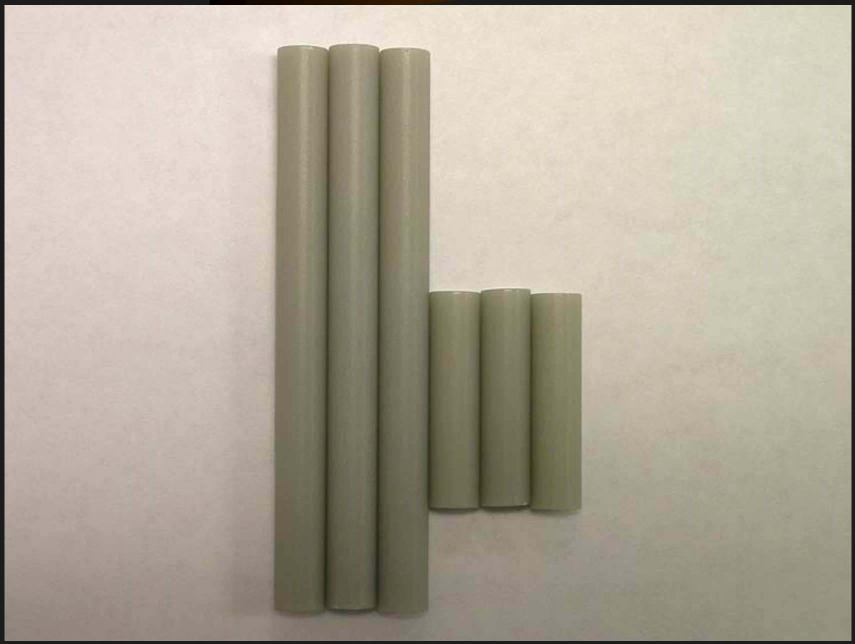


Bare AlN



Metallized AlN

MW Vacuum Windows and Collector Rods

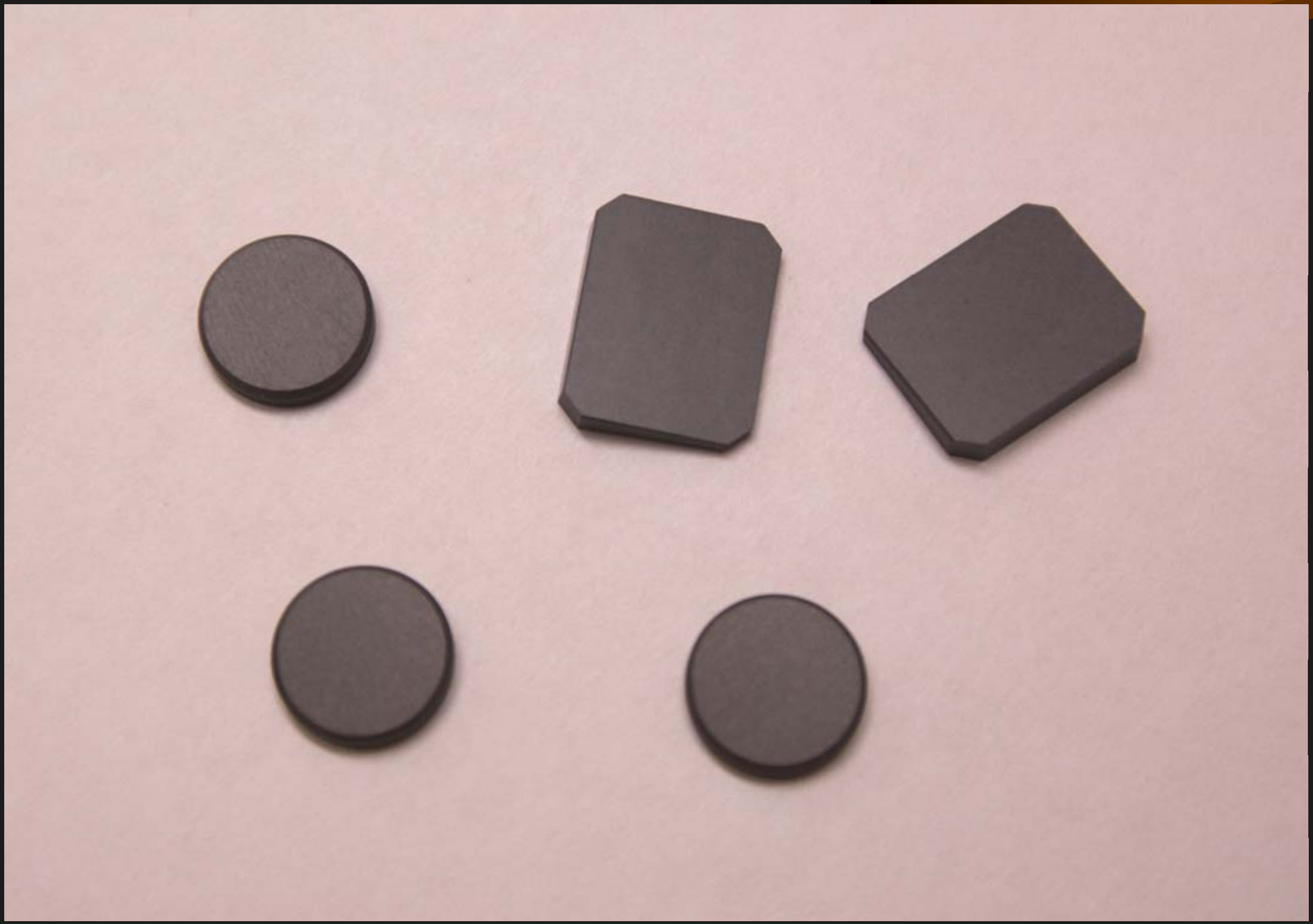


AlN-based Lossy Dielectrics as Replacements for the Obsolete BeO-SiC

	Ceralloy© 1370Y	Ceralloy© 137 CD1	Sienna STL-100-1	Sienna STL-100-1C	Sienna STL-100-2	Ceralloy© 2710
Composition	AlN-SiC	AlN Composite	AlN-SiC	AlN-SiC	AlN-SiC	BeO-SiC
Density, g/cm^3	3.19	2.99	3.26	3.24	3.28	3.02
Thermal Conductivity, W/m•K	53	95-105	76	90	115	130
Dielectric Constant, ε @ 10 GHz	21	31	43	40	39	23
Loss Tangent, tanδ @ 10 GHz	0.28	0.4	0.38	0.31	0.21	0.25
Thermal Expansion Coefficient, $10^{-6}/^{o}C$	5.1	5.1	5.5	5.5	5.5	7.0
Flexural Strength, MPa	300	190	558	393	489	

(DoE Grant No. DE-FG02-08ER85180)

AlN-based Lossy Dielectrics



Objective of SBIR Program

- To develop a family of vacuum compatible robust joining technologies to attach AlN-based lossy dielectrics to copper members for SRF cavities operating at cryogenic temperatures in ultra high vacuum, and for microwave tubes.

Justification of the Work

- Recently developed high thermal conductivity aluminum nitride (AlN) based lossy dielectrics can replace the toxic beryllia (BeO) based lossy dielectrics as high order mode (HOM) absorbers in superconductor radio frequency (SRF) cavities in linear accelerators and in microwave tubes.
- AlN-based lossy dielectrics must be joined to metallic copper members and tested in these applications.
- However, lack of suitable metallization and brazing technologies hampers the insertion of AlN-based lossy dielectrics into SRF cavities and other vacuum electron devices.

Issues with AlN-based Lossy Dielectrics

- Dielectric property match
- Mechanical strength
- Joining related failures

❖ The last two issues are closely related.

Relevance to NP Programs

- Lossy AlN components will provide environmentally friendly replacements for toxic BeO components as HOM absorbers in SRF cavities and in vacuum electron devices.
- The outcome of this project will most certainly lead to viable products for use by both Federal Government and commercial sectors in SRF cavities in linear accelerators and medium-to-high vacuum electron devices; x-ray sources for medical diagnostic and treatment devices; klystrons for direct broadcast satellites; gyrotrons for magnetic fusion based on electron cyclotron heating; microwave communication.

Joining Techniques

- Refractory Mo-Mn Metallization and Brazing
- Diffusion bonding
- Active metal brazing

Peel Strength Test sample

Peel Strengths of Ti-diffusion Bonded, Active Metal Brazed and Mo-Mn Metallized (STL-100)-Cu Joints

Material	Braze Alloy	Peel Strength (lb-f/in)
STL-100	Ti	> 56
STL-100-1	Ti	40
STL-100	CuABA	> 56
STL-100-1	CuABA	44
STL-100	CusilABA	> 56
STL-100-1	CusilABA	27
STL-100	Mo-Mn/Nicusil-3	> 56
STL-100-1	Mo-Mn/Nicusil-3	40

Peel Strengths of Ti-diffusion Bonded and Active Metal Brazed (STL-100)-Cu Joints after Thermal Cycling at -196ºC

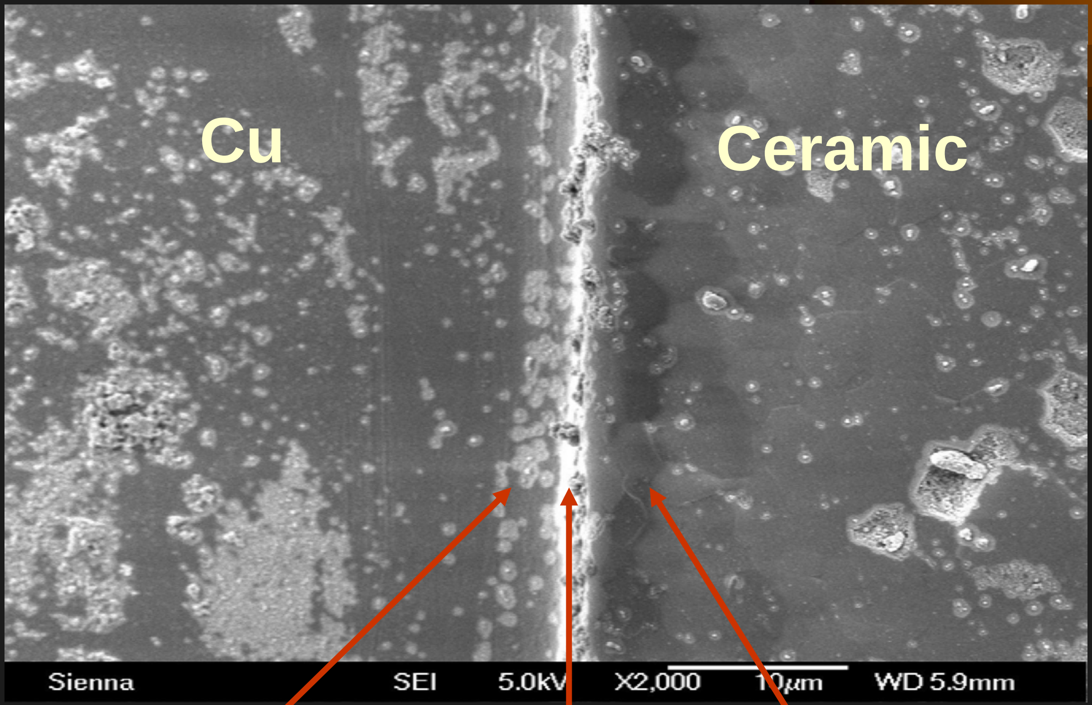
Material	Braze Alloy	Peel Strength (lb-f/in)
STL-100	Ti	> 56
STL-100-1	Ti	50
STL-100	CuABA	> 56
STL-100-1	CuABA	33
STL-100-1	CuABA	27
STL-100	CusilABA	> 56
STL-100-1	CusilABA	27

Peel Strength of CusilABA Brazed (STL-100C-Cu) Joints Before and After Thermal Cycling at RT to -196ºC

- 0 Cycles: 37 lb-f/in
- 2 Cycles: 48 lb-f/in
- 10 Cycles: 48 lb-f/in
- 20 Cycles: 41 lb-f/in

❖ Peel strength increases after few initial thermal cycles!

Scanning Electron Micrograph of STL-100 Lossy AlN-CuABA-Cu Interface

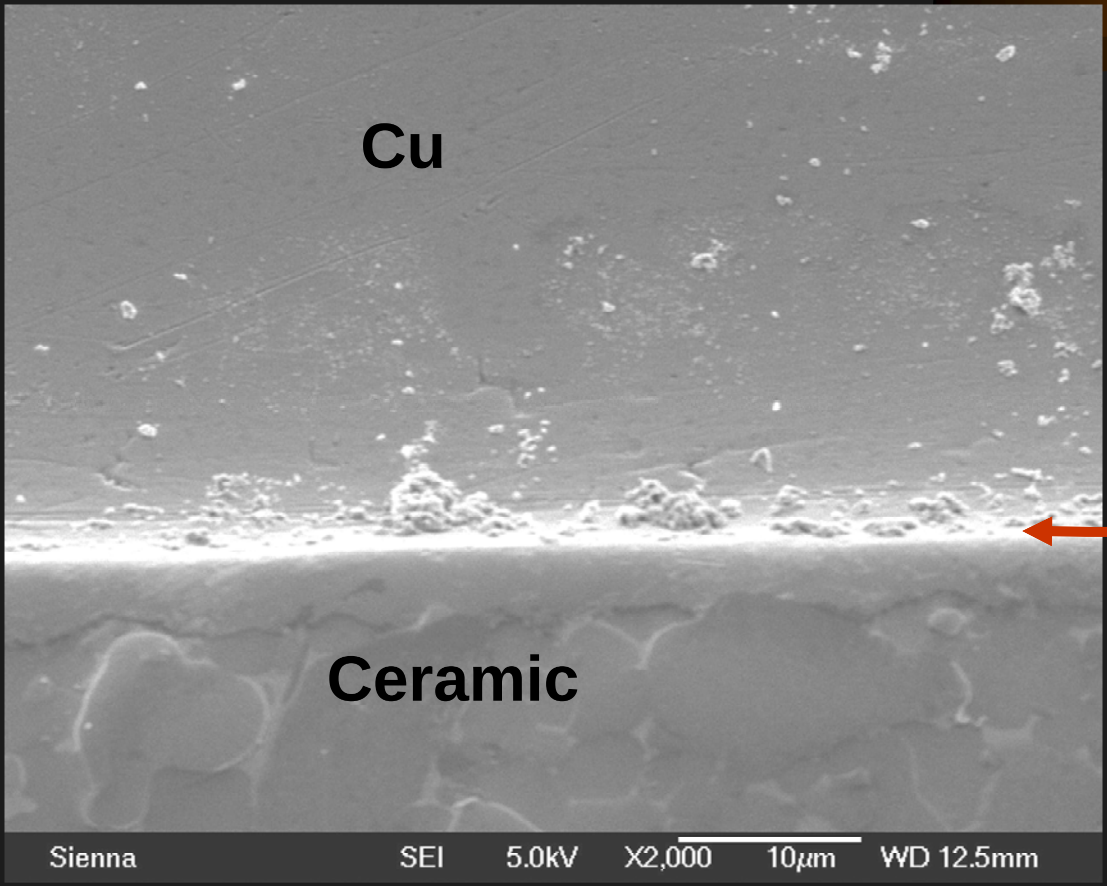


Atomic %
Al: 8
Si: 12
Cu: 60
O: 21

Atomic %
Ti: 18
Al: 14
N; 4.2
Si: 4.1
O: 43

Atomic %
Al: 52
N: 24
Si: 2.7
O: 21

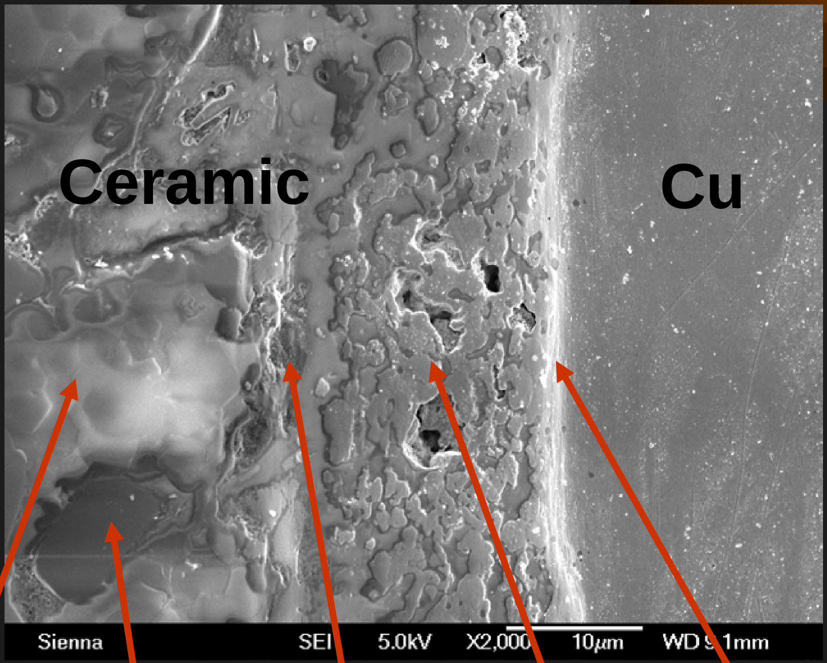
Scanning Electron Micrograph of Diffusion Bonded STL-100 Lossy AlN-Ti-Cu Interface



Atomic %

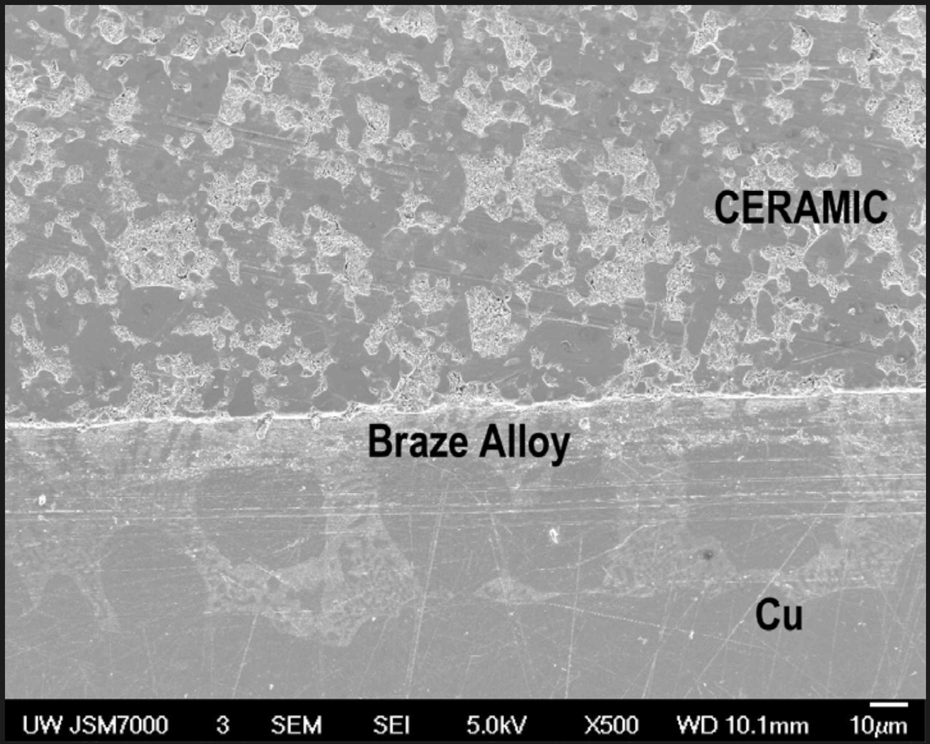
Ti: 25
Al: 10
Cu: 12
N; 46
O: 7

Scanning Electron Micrograph of STL-100 Lossy AlN/Mo-Mn/Ni/Cu-Au/Cu Interface

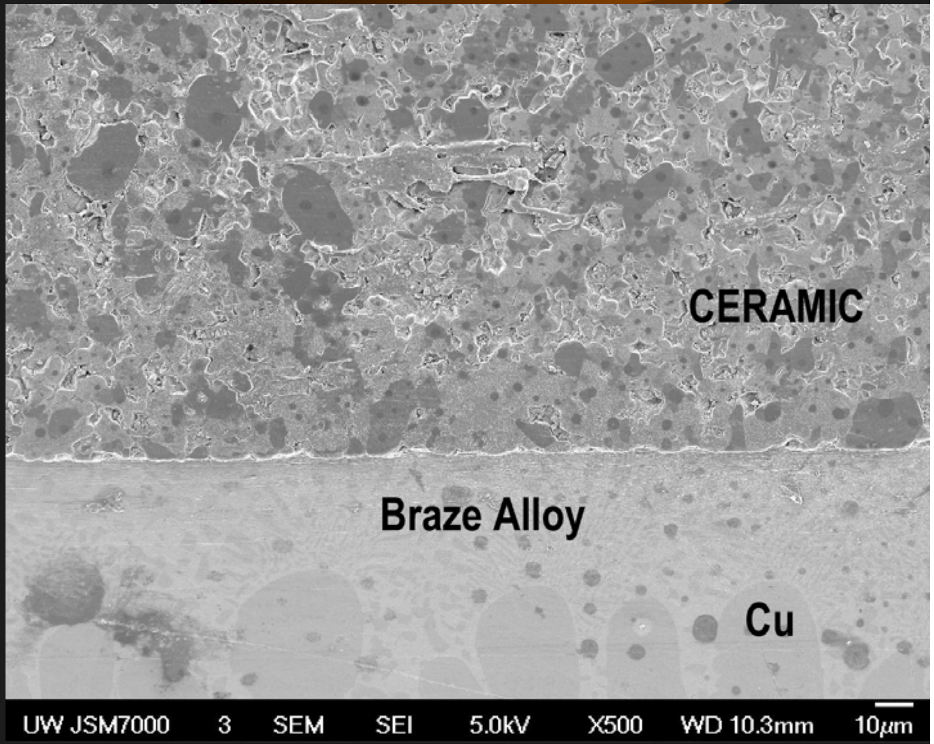


Atomic %	Atomic %	Atomic %	Atomic %	Atomic %
Al: 62	Ti: 12	Ti: 6.8	Ti: 2.85	Ti: 5.3
N: 35	Al: 48	Al: 65	Al: 33	Al: 2.5
O: 3	N: 18	Si: 0.5	Si: 4	Si: 10
	O: 2.5	Mo: 1.34	Mo:18	Mo:12
		O: 13.4	O: 32	O: 34

Images of CusilABA Brazed STL-100C-Cu Interface (a) before and (b) after thermal cycling between room temperature and -196ºC

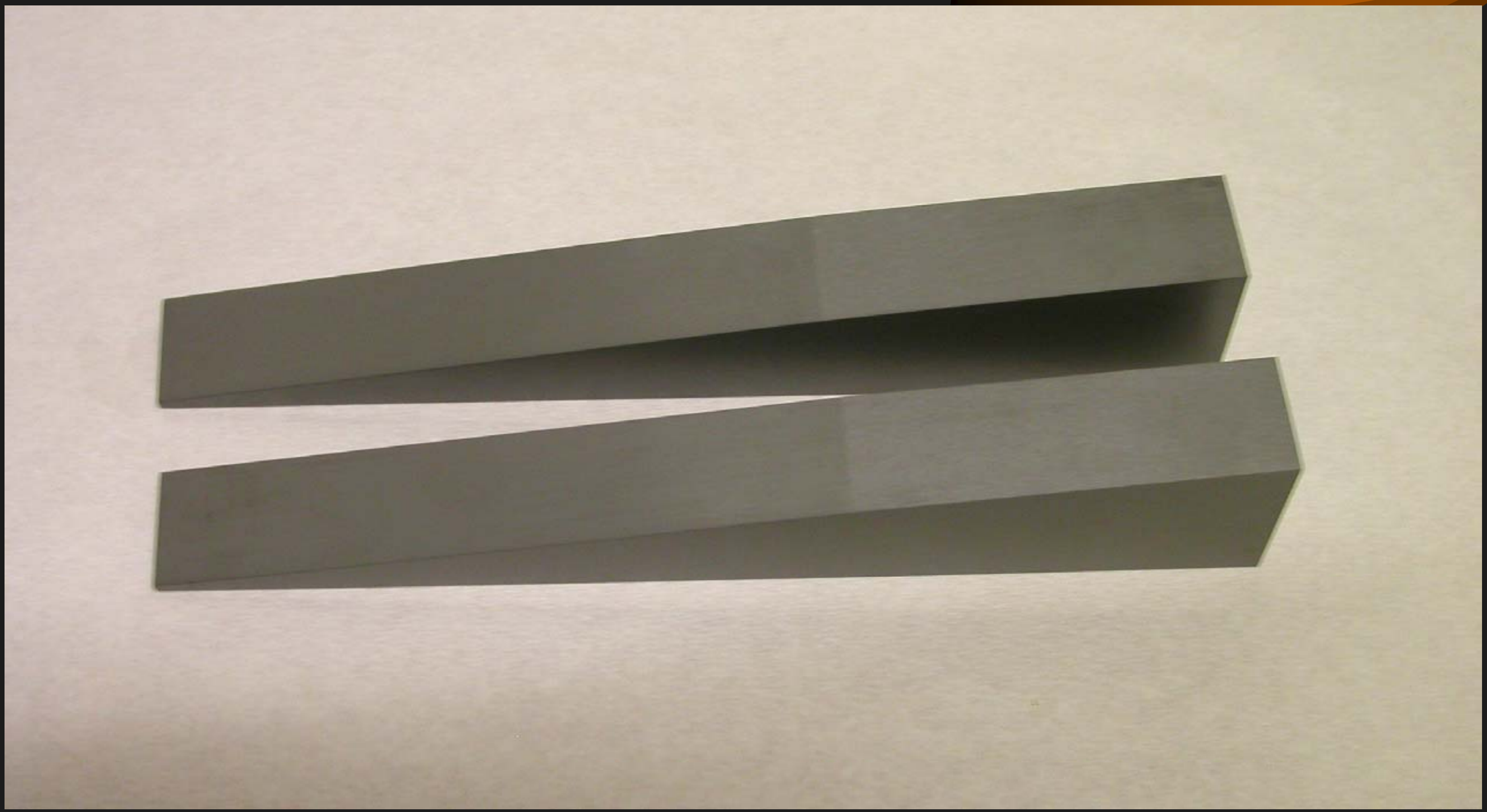


(a)



(b)

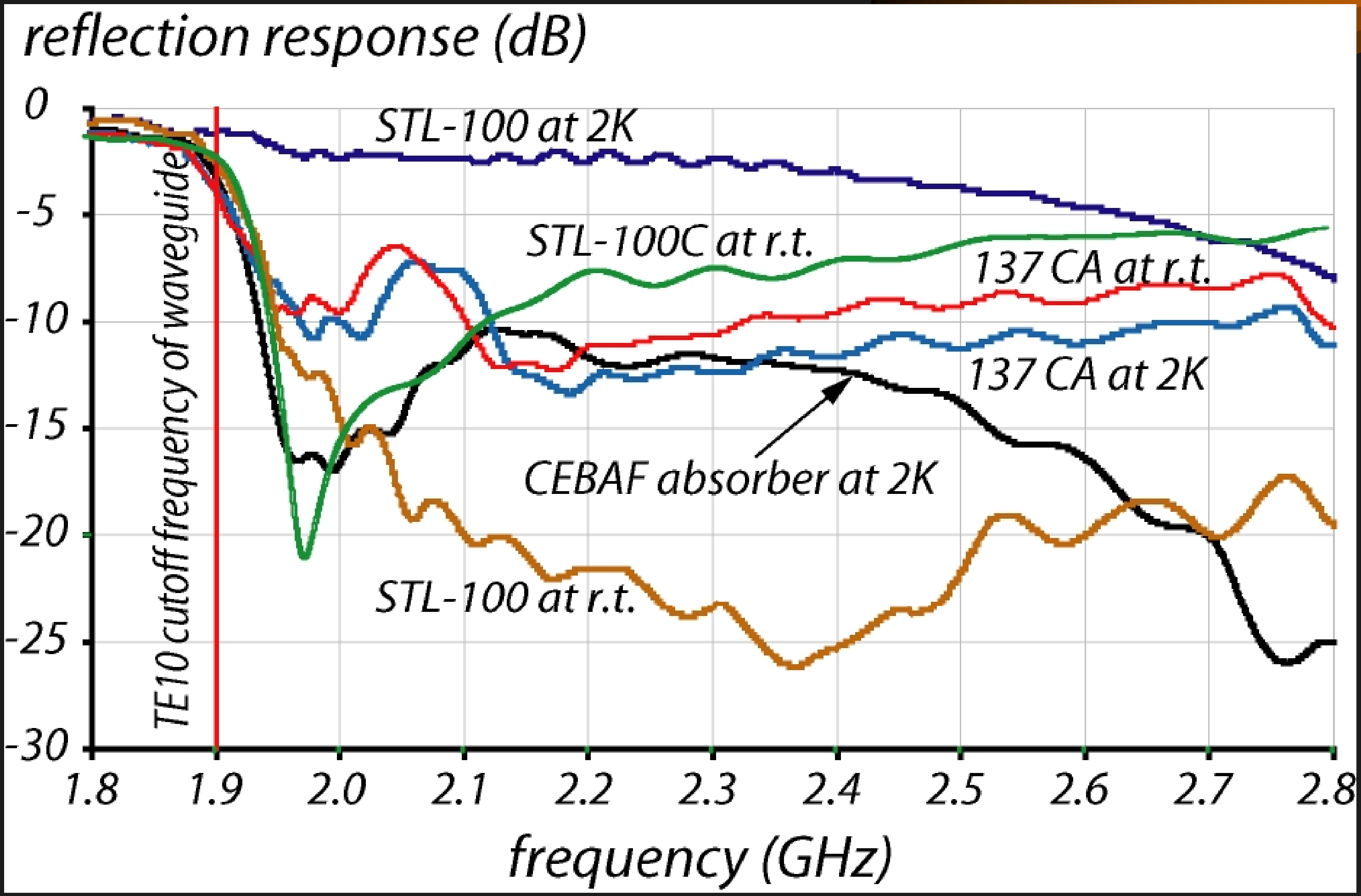
TJNAF HOM Loads



Brazed Absorbers on Copper Posts

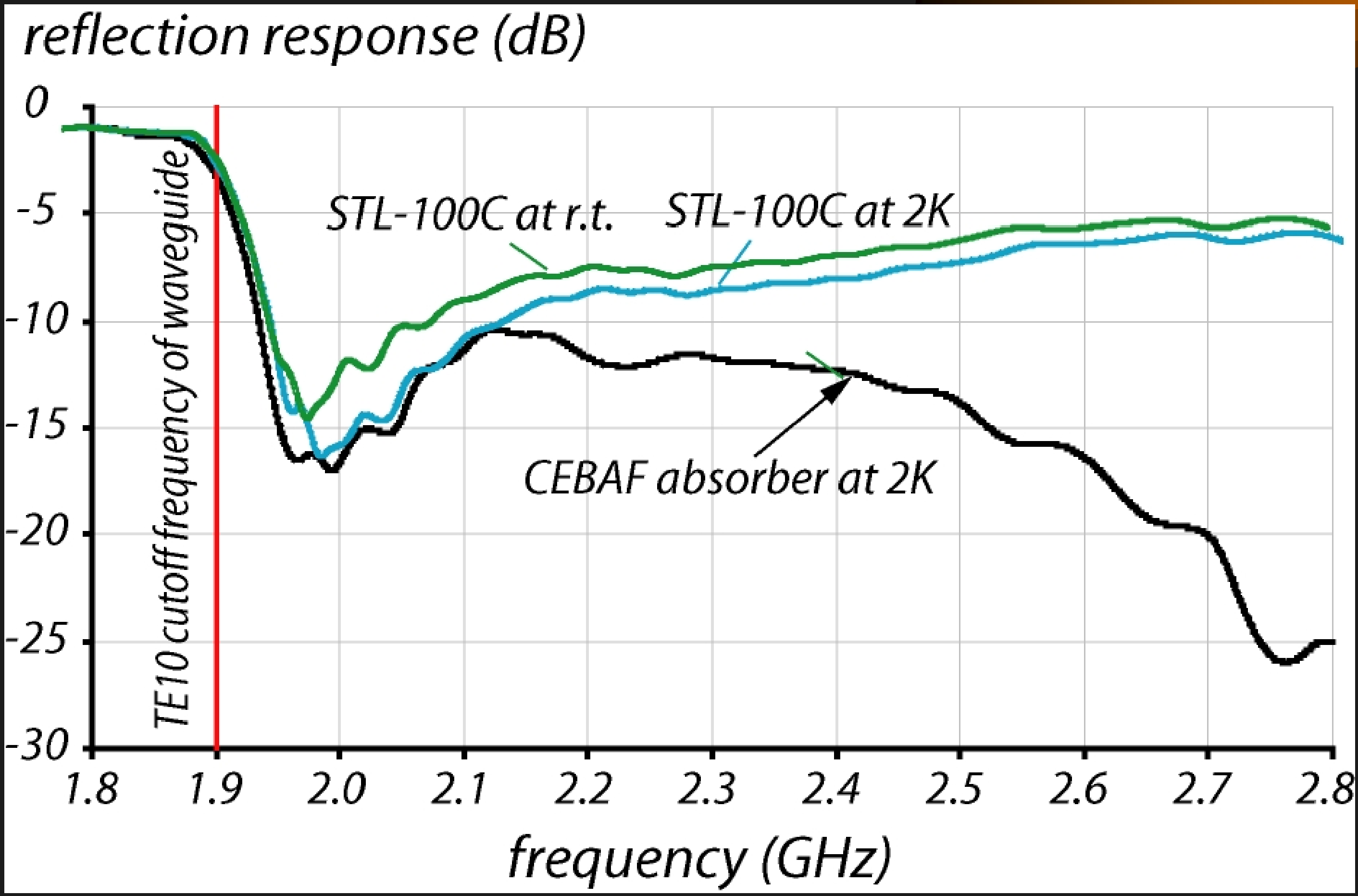
(Courtesy of Frank Marhauser, TJNAF)

Reflection Response of STL-100 and STL-100C Lossy Dielectrics and other Lossy Dielectrics at Room Temperature and 2 K



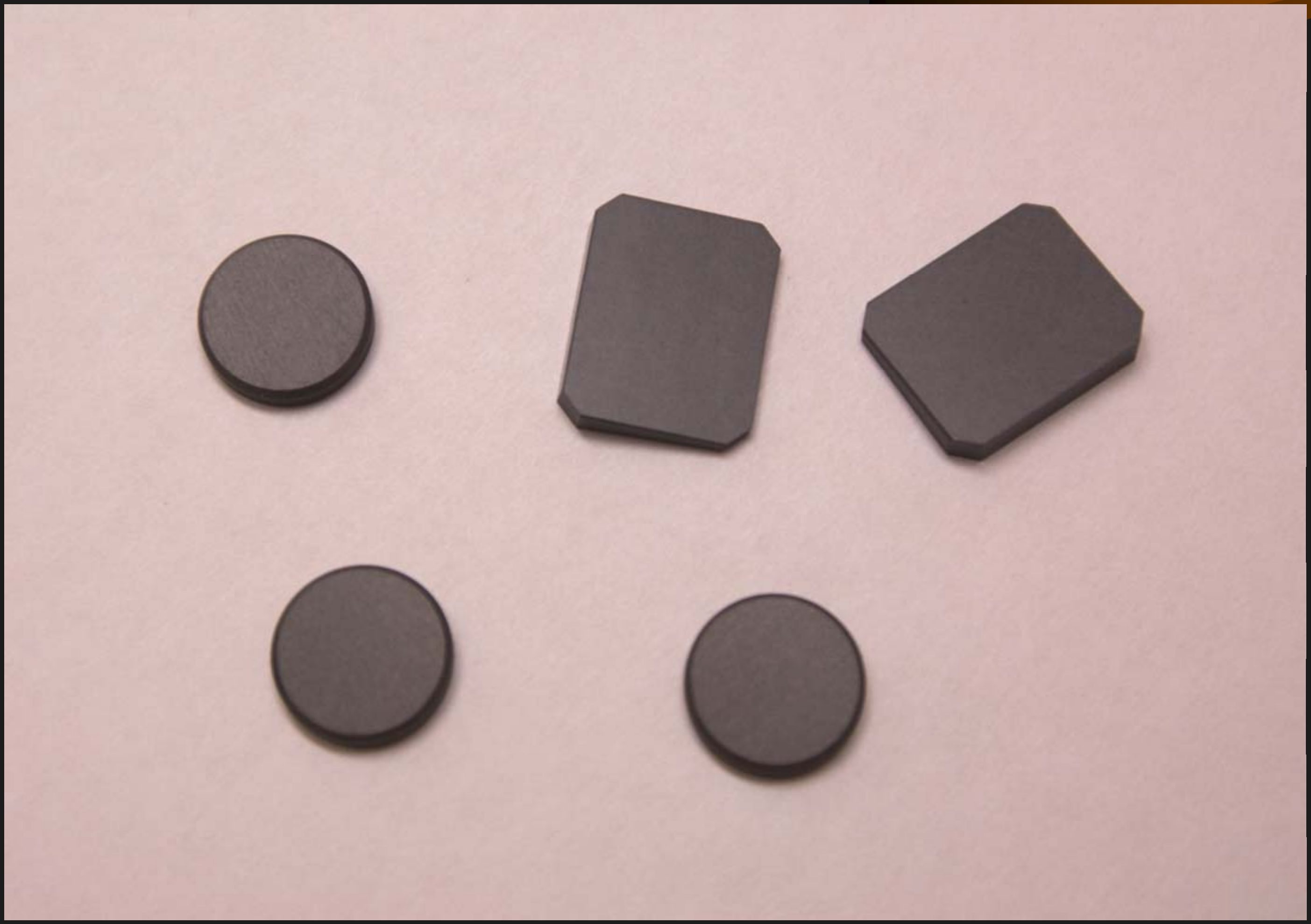
(Courtesy of Frank Marhauser, TJNAF)

Reflection Response of STL-100C Lossy Dielectric at Room Temperature and 2 K

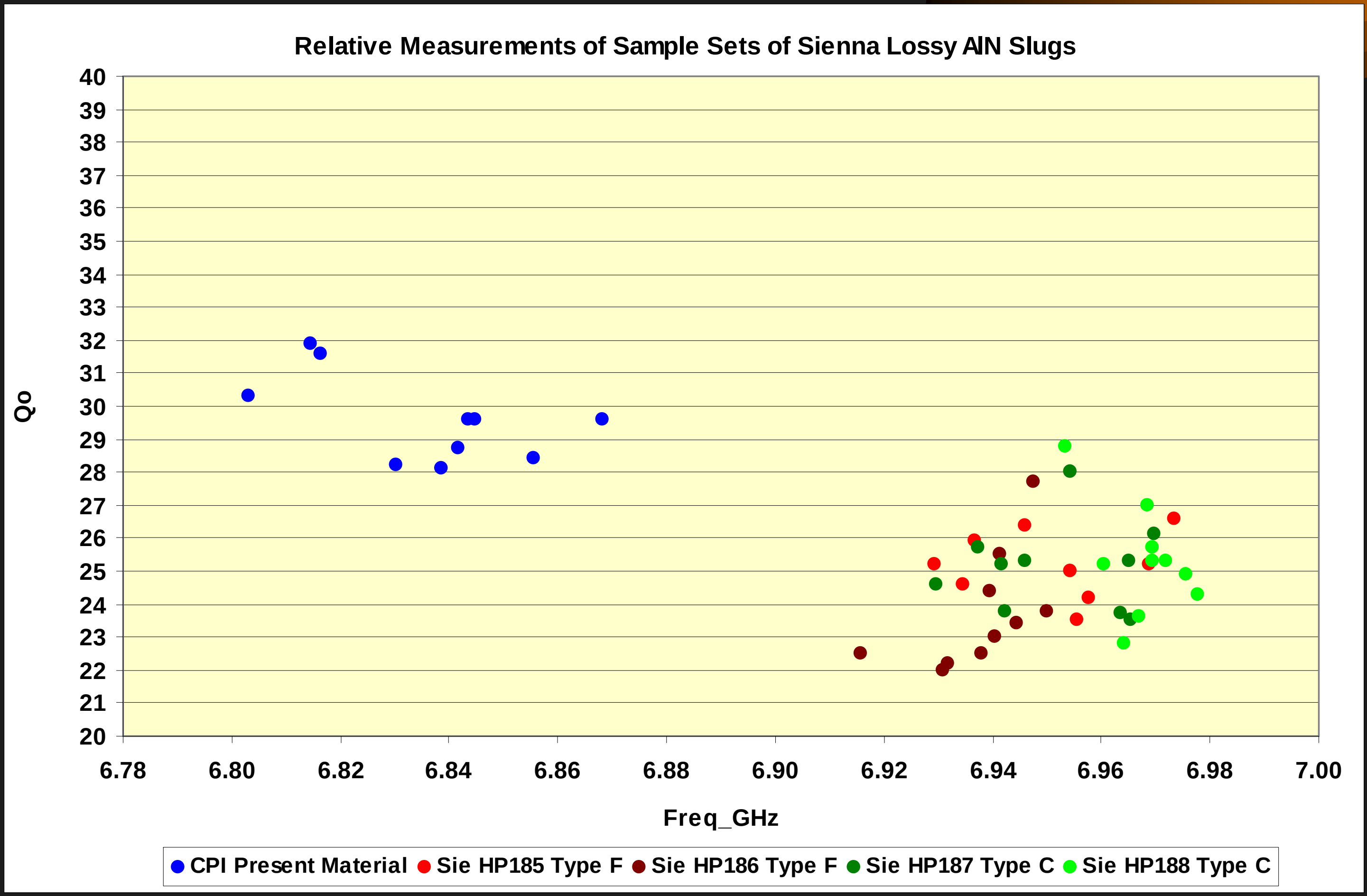


(Courtesy of Frank Marhauser, TJNAF)

Loss Buttons and Severes

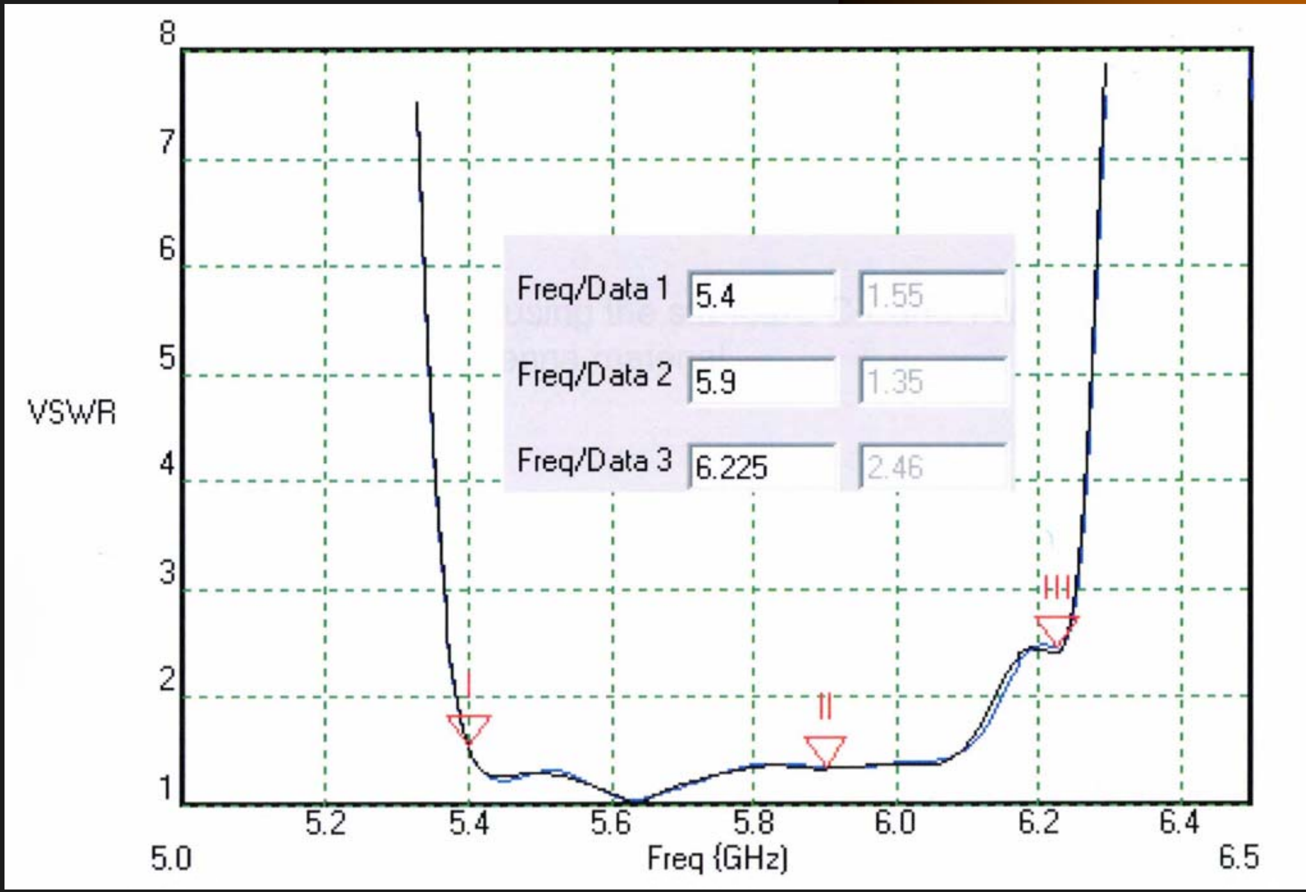


Cavity Q – Factor versus Resonant Frequency for STL-100 Lossy AlN Dielectrics
(DoE Grant No. DE-FG02-08ER85180)



(Courtesy of CPI-MPP)

Sienna STL-100 Lossy AlN Dielectrics are the Drop-in Replacements for the Toxic BeO-SiC Ones!



(Courtesy of CPI-MPP)

(DoE Grant No. DE-FG02-08ER85180)

Program Status / Future Plans

- Phase II Program was completed on 15 August 2010.
- Material and Joining Techniques Developed Passed the Qualification Tests at CPI-MPP.
- Tests are still ongoing at TJNAF.

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