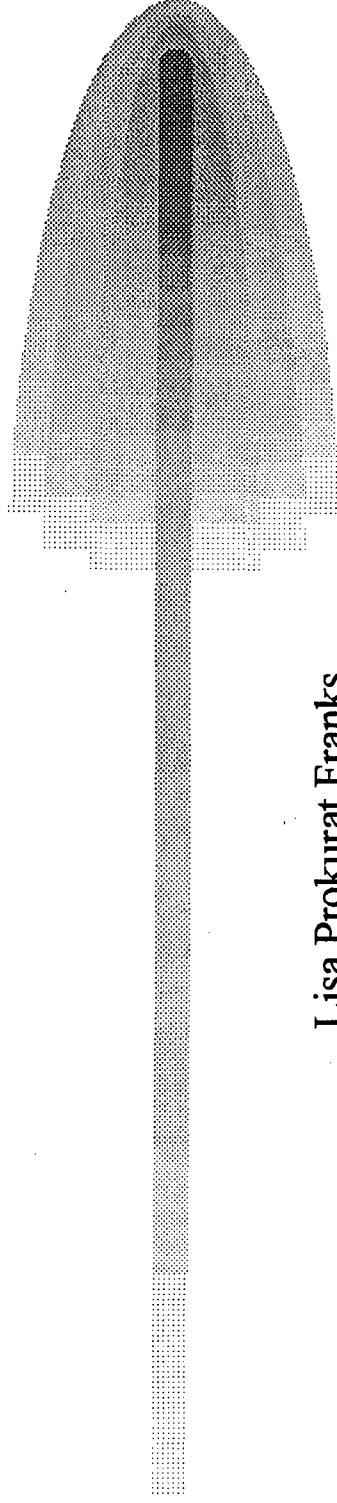


*The Effects of Colloidal Processing on
the Densification of Titanium Diboride
(TiB₂) - Alumina (Al₂O₃) Composites*



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Abstract

Titanium diboride/Alumina ($\text{TiB}_2/\text{Al}_2\text{O}_3$) powders produced using self-propagating high-temperature synthesis (SHS) can be hot pressed into armor tiles that exhibit superior resistance to penetration as compared to TiB_2 , SiC , B_4C or Al_2O_3 .¹ As with other advanced ceramics² however, difficulties in processing $\text{TiB}_2/\text{Al}_2\text{O}_3$ arise from the inability to reproduce specimens having identical microstructure and properties. Since the SHS powders are available commercially, the interactions between TiB_2 and Al_2O_3 have been analyzed with respect to their colloidal properties, as measured by their respective zeta potentials, density, volume fraction, and particle size. A comparison of colloidal properties, green and sintered densities and microstructure of Composite SHS $\text{TiB}_2/\text{Al}_2\text{O}_3$ and SHS TiB_2 with commercially available Aluminas has been completed. Although *SuspensionStability*® predicts the colloidal behavior of SHS TiB_2 in Alumina, the SHS Composite powders seem to be insensitive to colloidal processing, and the continuous microstructure associated with penetration resistance is predominantly characteristic of SHS Composite $\text{TiB}_2/\text{Al}_2\text{O}_3$ starting powders.

References

- [1] K.V. Logan, "Elastic-Plastic Behavior of Hot Pressed Composite Titanium Diboride/Alumina Powders Produced Using Self-Propagating High Temperature Synthesis," Georgia Institute of Technology, September 1992
- [2] B.A. Wilson and M.J. Crimp, "Prediction of Composite Colloidal Suspension Stability Based upon the Hogg, Healy, and Fuerstenau Interpretation," *Langmuir* 1993, 9, 2836-2843

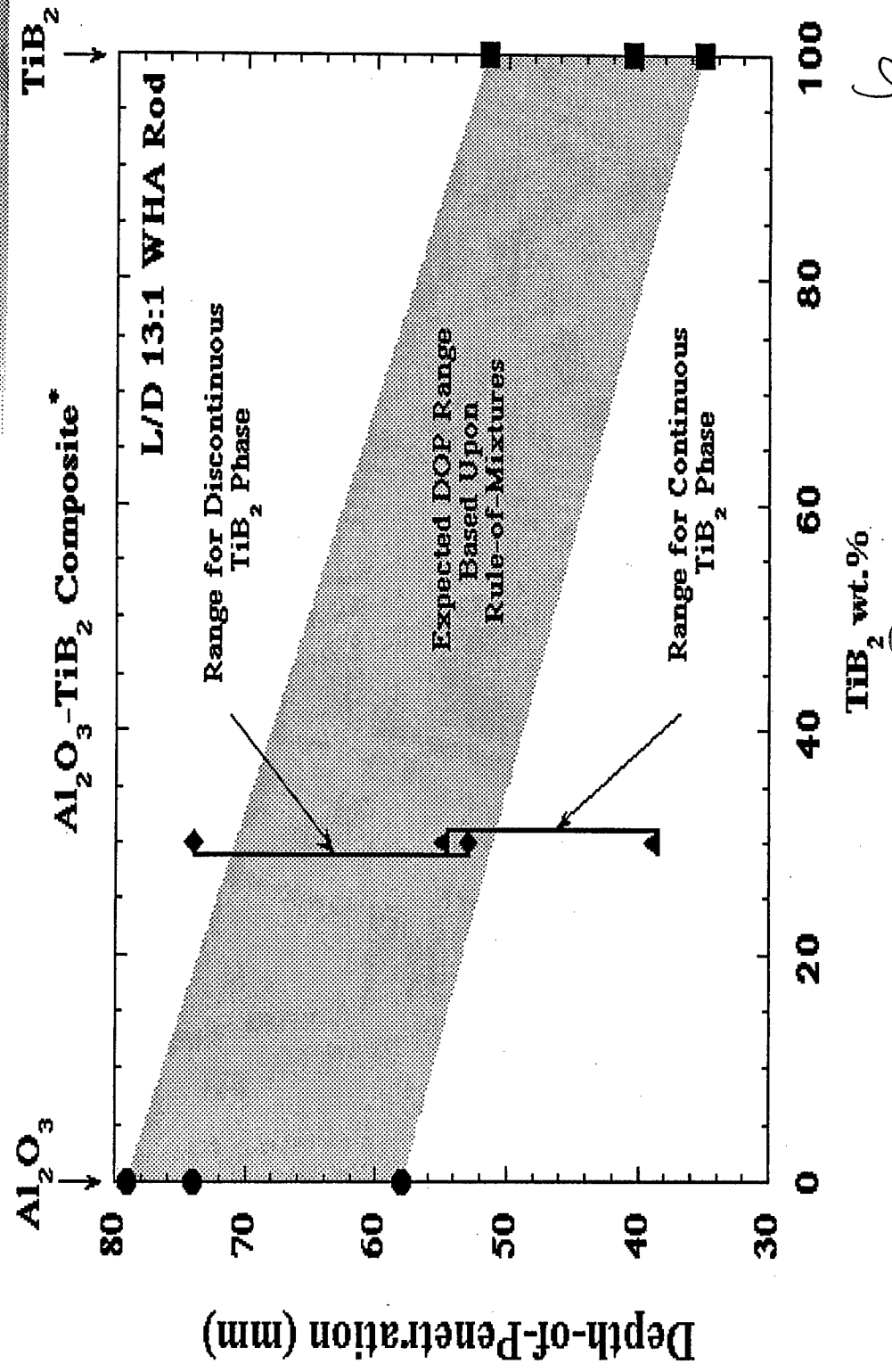
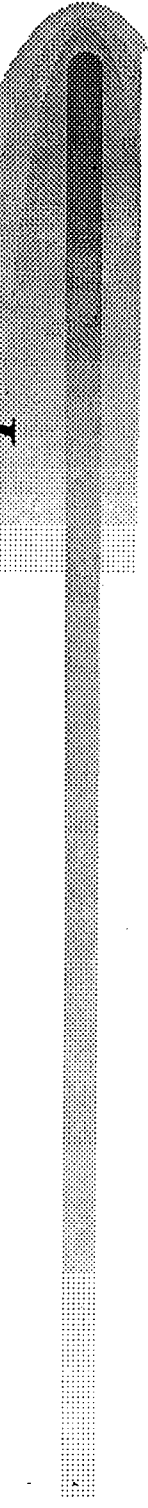
Why Investigate the Titanium Diboride - Alumina Ceramic Composite System for Vehicle Protection?

- Penetration resistance similar to pure TiB_2 at lower cost
- Performance better than expected by Rule-of-Mixtures suggesting unique, exploitable failure mode(s)
- Opportunity to optimize microstructure to decrease range of variation in performance and increase penetration resistance
- Commercial availability of SHS powders enable investigation of other processing routes

Future Work

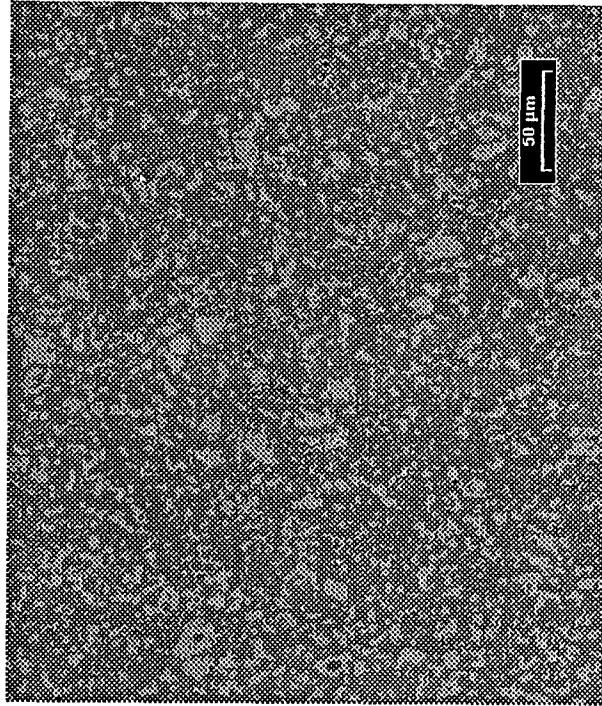
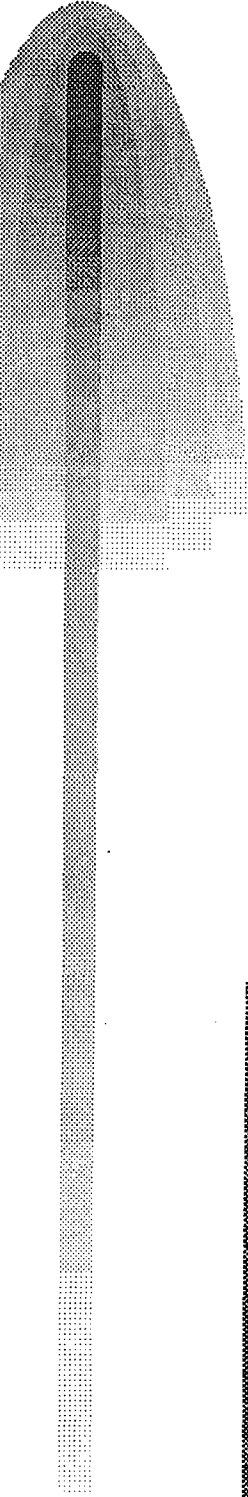
- Quantify the sintering parameters that optimize microstructure
- Evaluate and scale-up processing to produce armor targets for evaluation against small and medium caliber threats
- Shots on 4" targets scheduled to begin 9/00

Depth of Penetration Vs. Composition



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Microstructures



Discontinuous



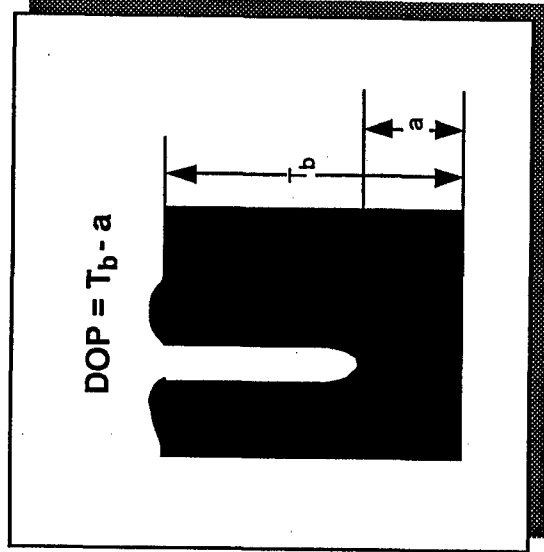
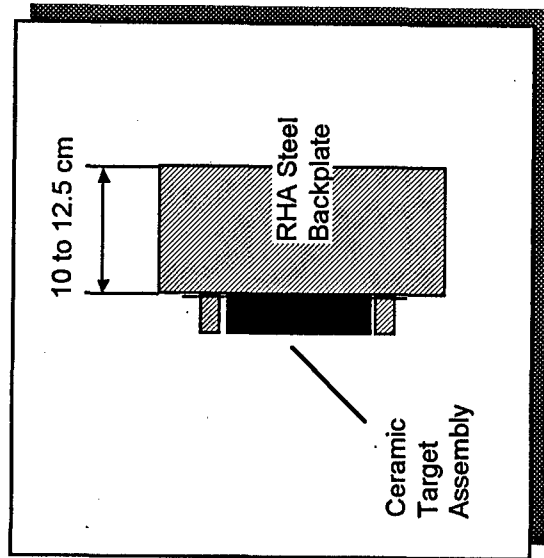
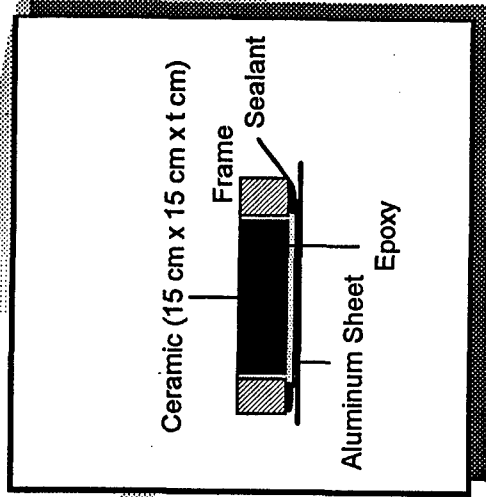
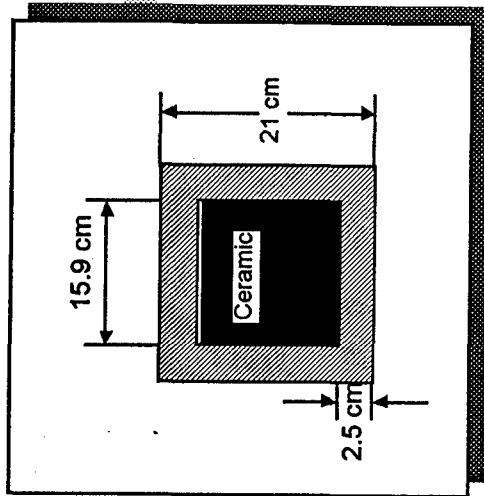
Continuous

Superior Penetration Resistance

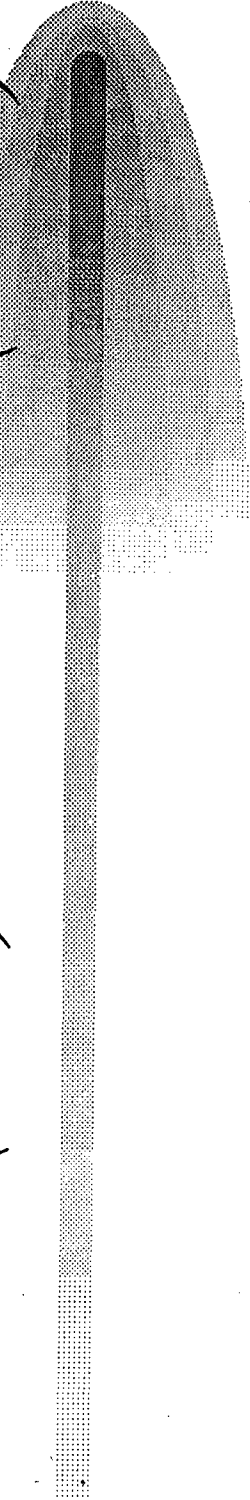
TiB₂ (light areas)/Al₂O₃ (dark areas)

7

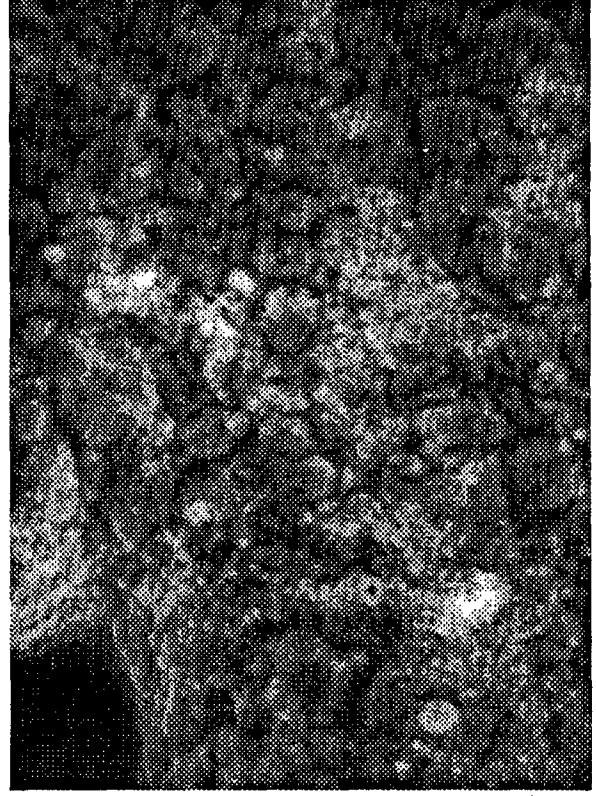
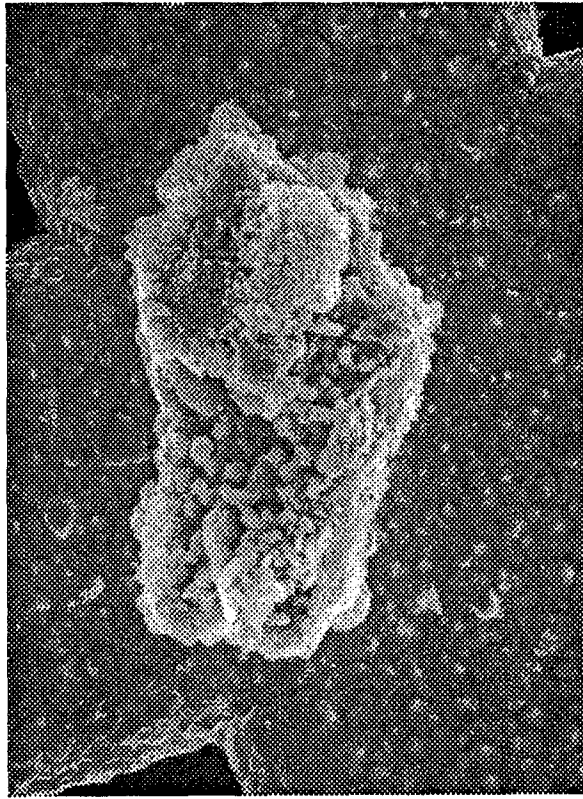
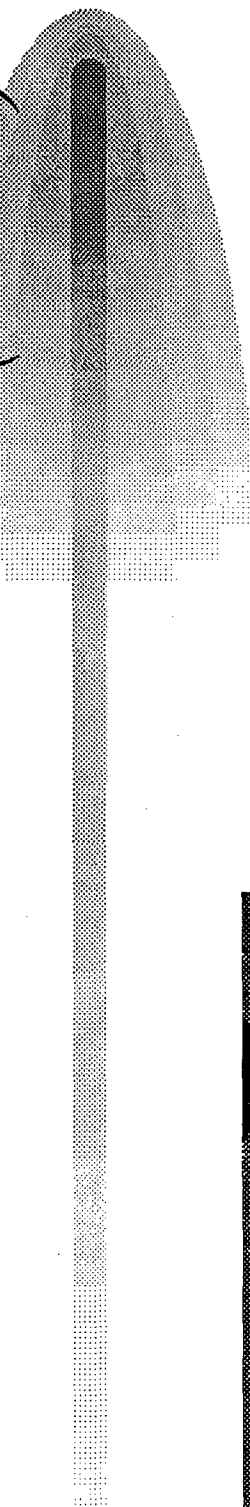
DOP Target Assembly



*SHS Composite Titanium
Diboride (TiB_2) - Alumina (Al_2O_3)*



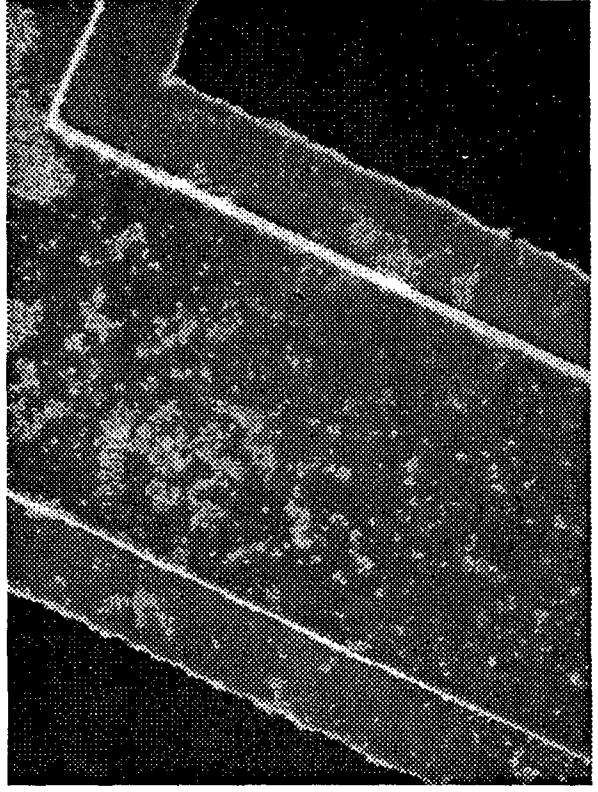
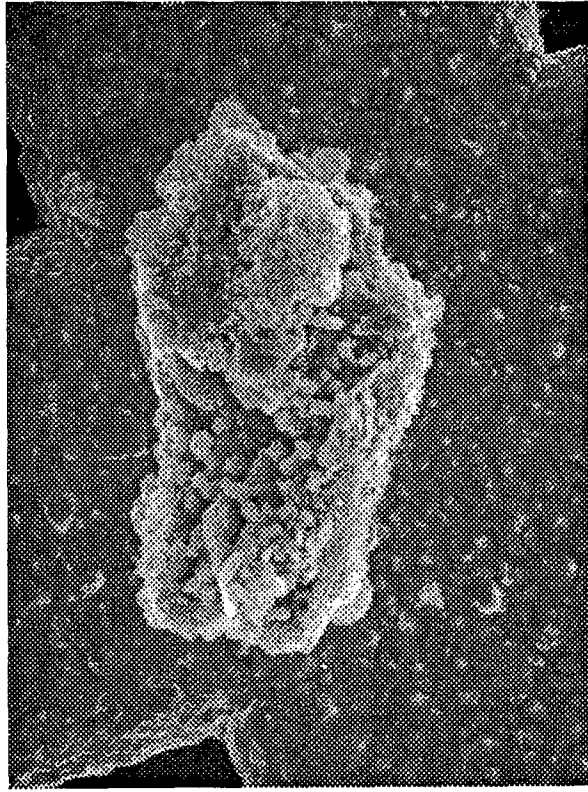
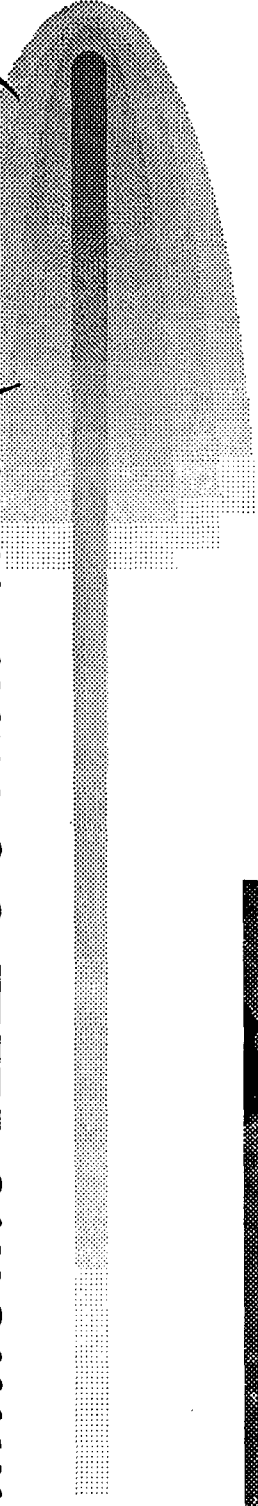
*SHS Titanium Diboride (TiB_2) -
Alcoa-SG 1000 Alumina (Al_2O_3)*



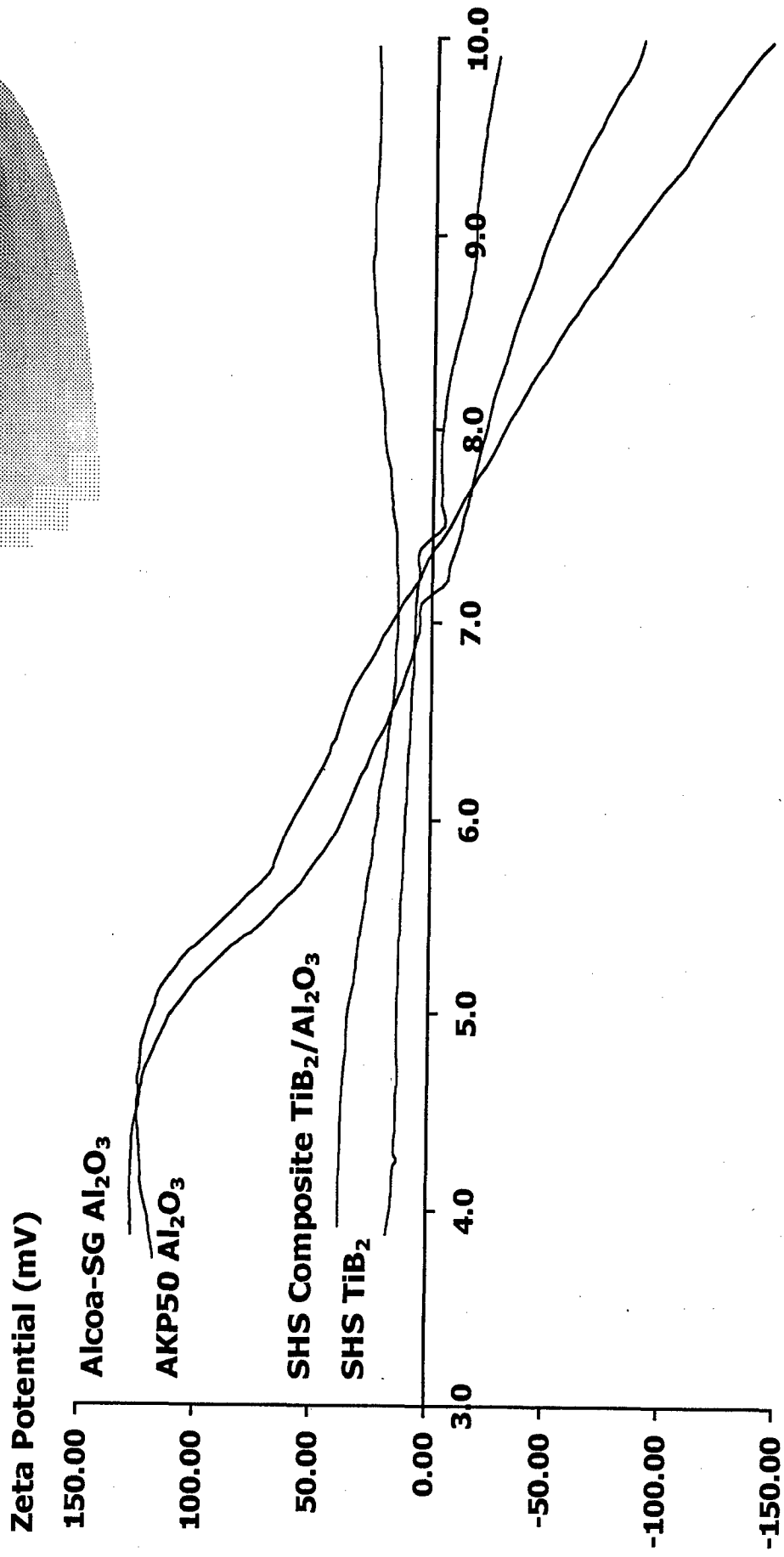
10

C

*SHS Titanium Diboride (TiB₂) -
Sumitomo AKP50 Alumina (Al₂O₃)*



Electrokinetic Sonic Analysis (ESA)



pH

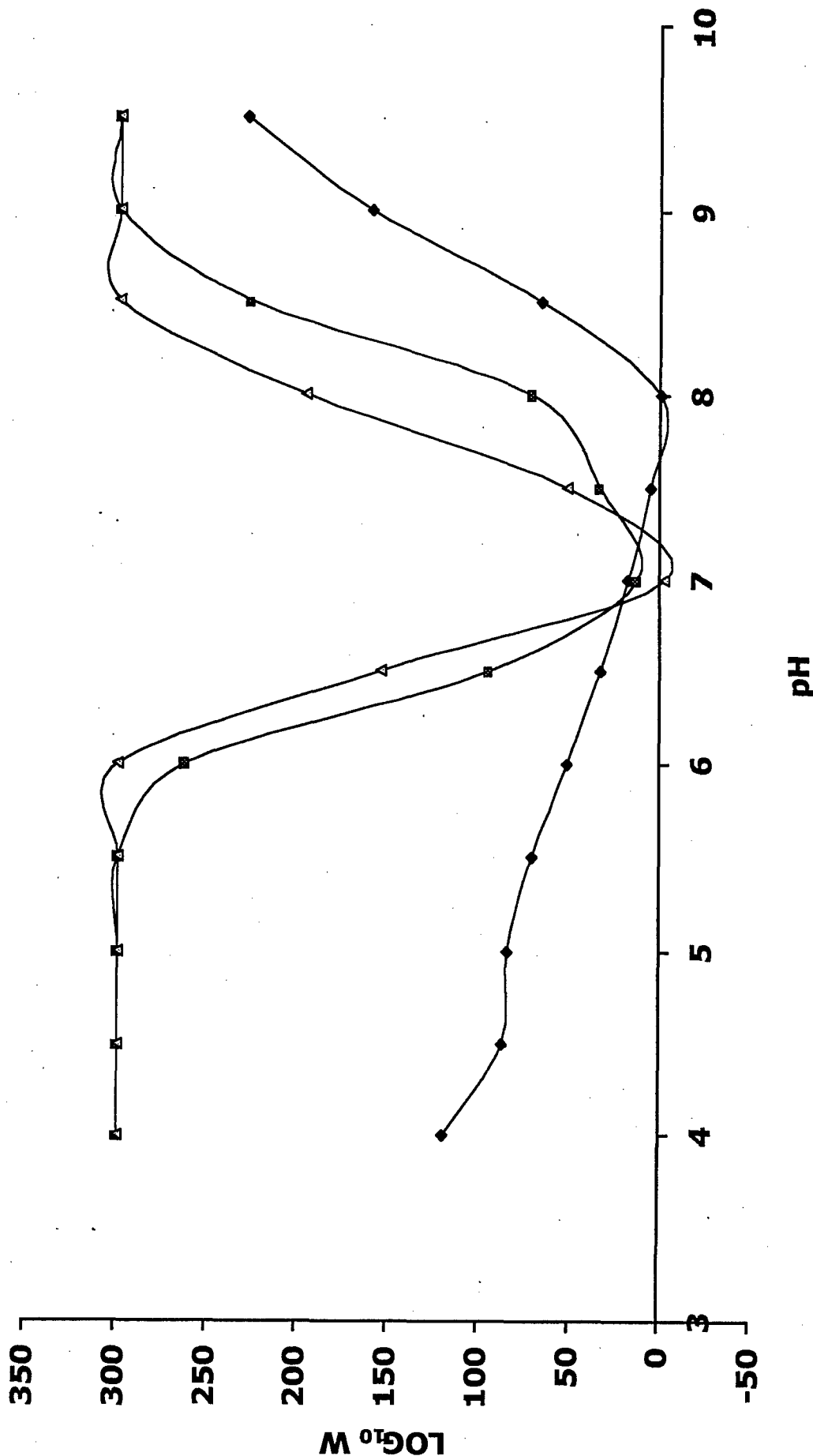
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Suspension Stability[©] Predictions

Stability Ratio <i>W</i>	SHS TiB ₂ /SHS TiB ₂ Interactions	SHS TiB ₂ /AKP50 Al ₂ O ₃ Interactions	AKP50 Al ₂ O ₃ /AKP50 Al ₂ O ₃ Interactions
Range of Predicted Stability	pH 4-6 and pH 8.5-9.5	pH 4-6 and pH 8.5-9.5	pH 4-7 and pH 8-9.5

Stability Ratio <i>W</i>	SHS TiB ₂ /SHS TiB ₂ Interactions	SHS TiB ₂ /Alcoa-SG Al ₂ O ₃ Interactions	Alcoa-SG Al ₂ O ₃ /Alcoa-SG Al ₂ O ₃ Interactions
Range of Predicted Stability	pH 4-6 and pH 8.5-9.5	pH 4-6 and pH 8.5-9.5	pH 4-6.5 and pH 7.5-9.5

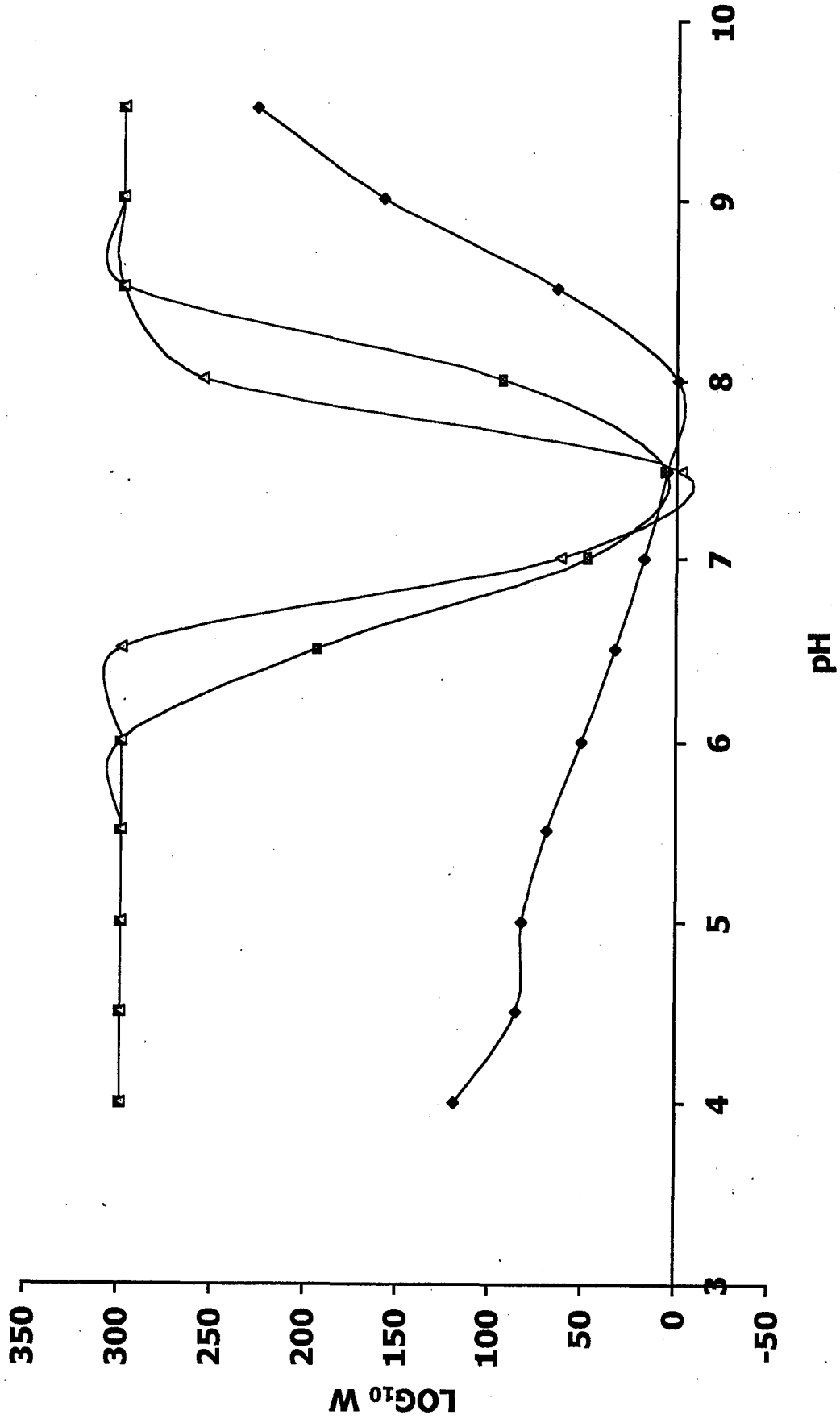
Stability Ratio (W) Data
Titanium Diboride (SHS TiB₂) : Alumina (Alcoa-SG Al₂O₃)
Electrolyte Concentration 10⁻³M KNO₃



◄ SHS TiB₂ : SHS TiB₂ : Alcoa-SG Al₂O₃ ◻ SHS TiB₂:Alcoa-SG Al₂O₃ ◄ Alcoa-SG Al₂O₃:Alcoa-SG Al₂O₃

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Stability Ratio (W) Data
Titanium Dioxide (SHS TiB₂) : Alumina (AKP50 Al₂O₃)
Electrolyte Concentration 10⁻³ M KNO₃



◆— SHS TiB₂:SHS TiB₂ ■— SHS TiB₂:AKP50 Al₂O₃ ▲— AKP50 Al₂O₃:AKP50 Al₂O₃ ▴— SHS TiB₂:AKP50 Al₂O₃:AKP50 Al₂O₃

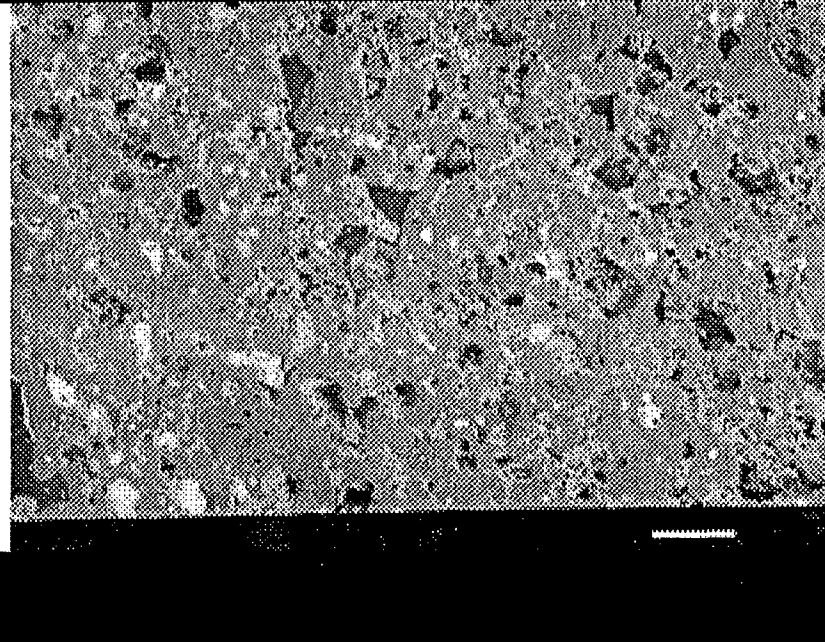
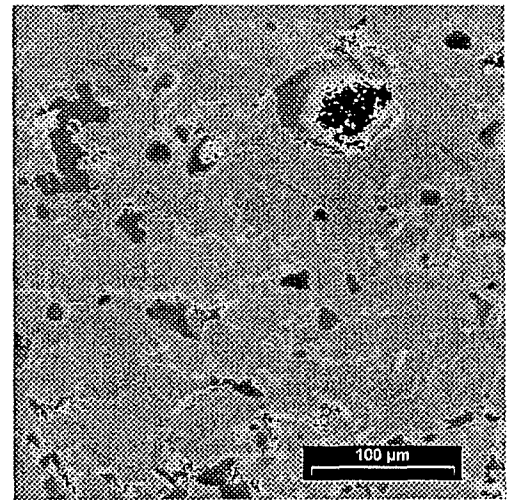
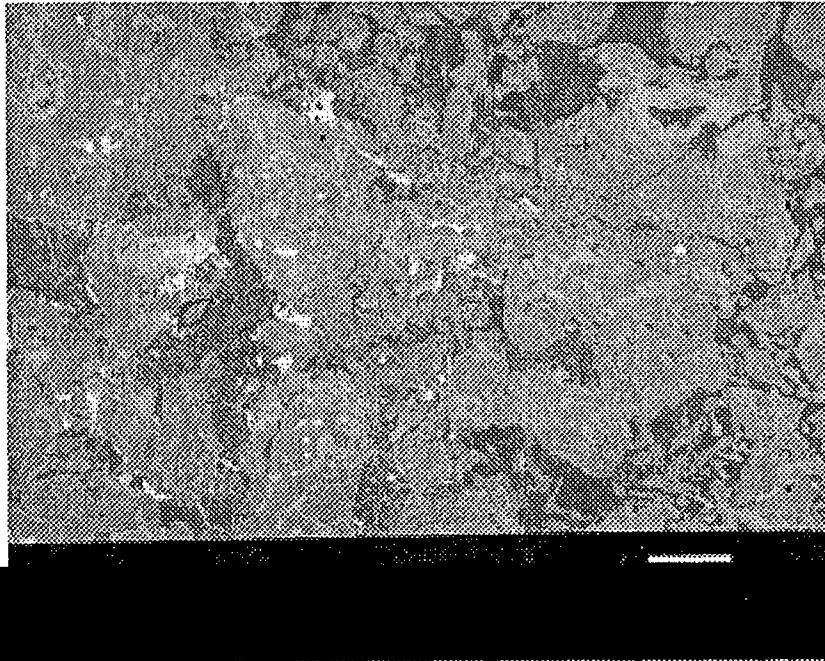
Processing Conditions

Processing Conditions	SHS Composite TiB ₂ /Al ₂ O ₃	SHS TiB ₂ / AKP50 Al ₂ O ₃	SHS TiB ₂ / Alcoa-SG Al ₂ O ₃
Traditional Binder	PEG	PEG	PEG
Dispersed	pH 4	pH 4	pH 4
Coagulated	pH 7	pH 7.5	pH 7
Heterocoagulated	pH 9	pH 8	pH 8

66

*PEG Binder
(no colloid processing - no
influence on coagulation)*

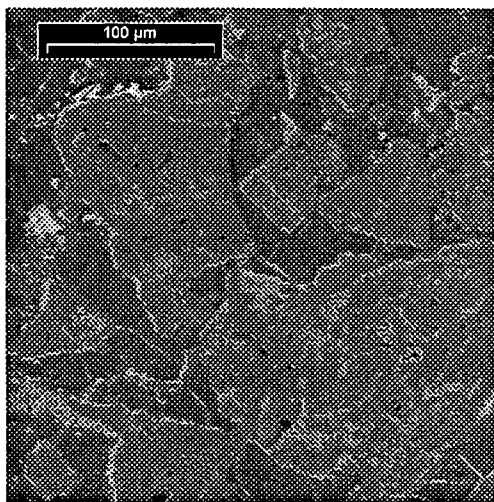
11



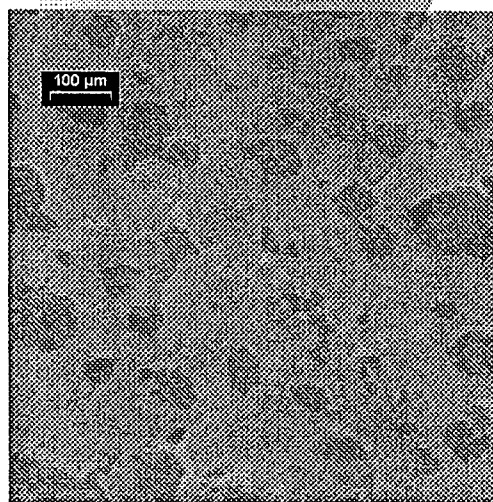
*SHS TiB₂ -
AKP50 Al₂O₃*

Dispersed Phases - Low pH

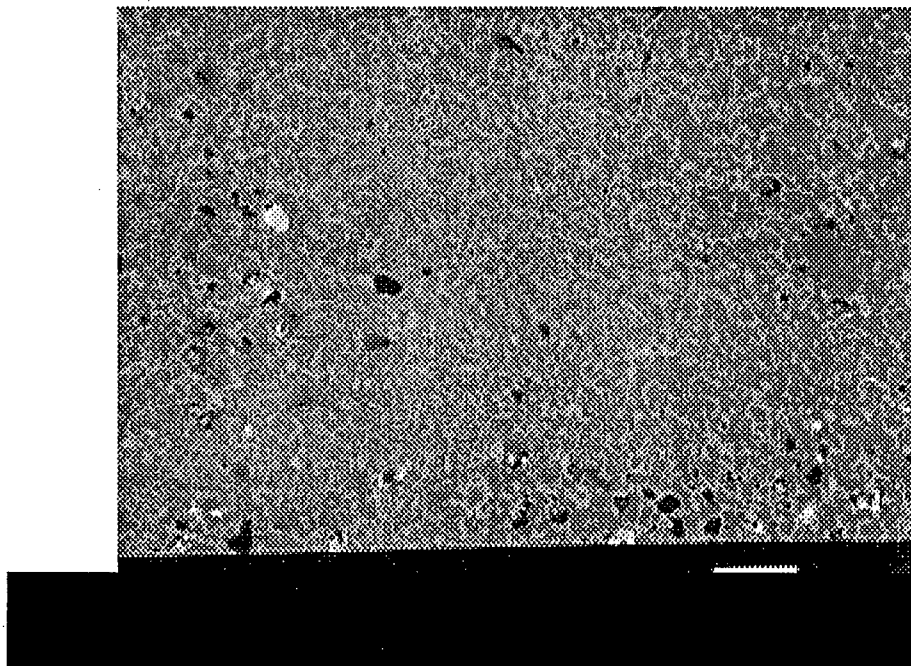
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SHS Composite

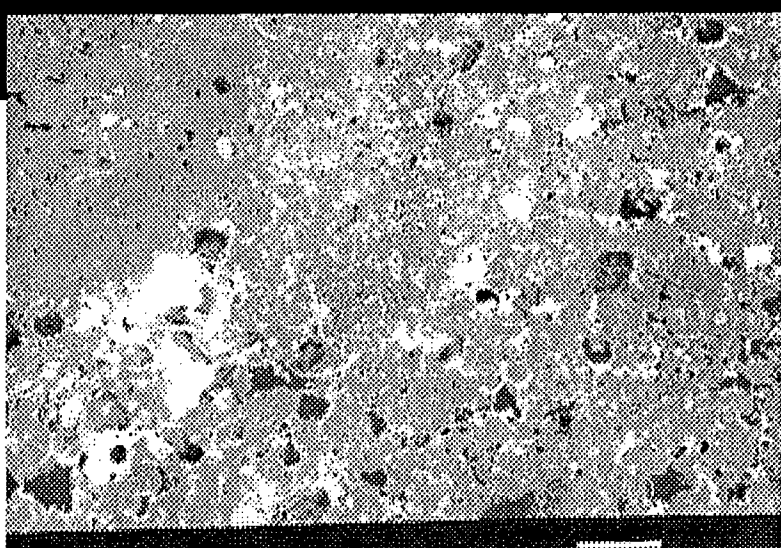
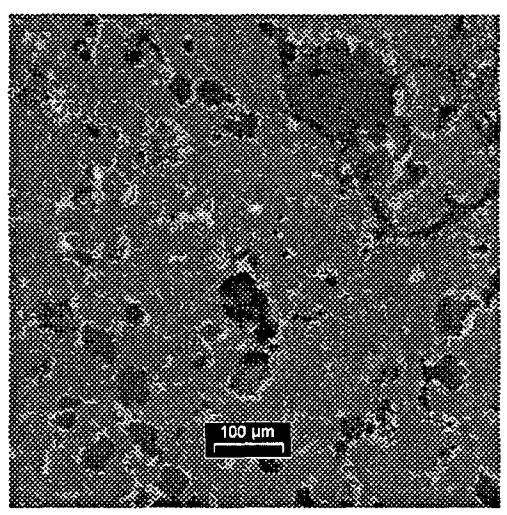
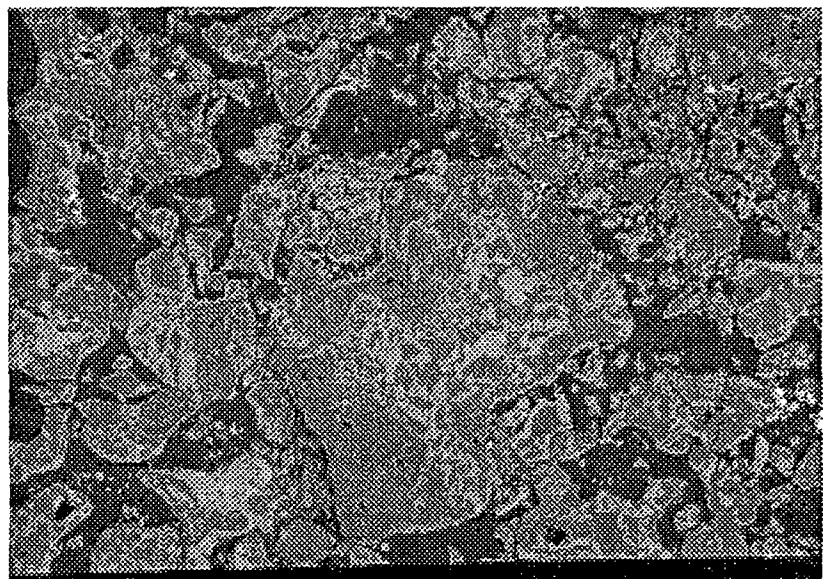


SHS TiB₂ - AKP50 Al₂O₃



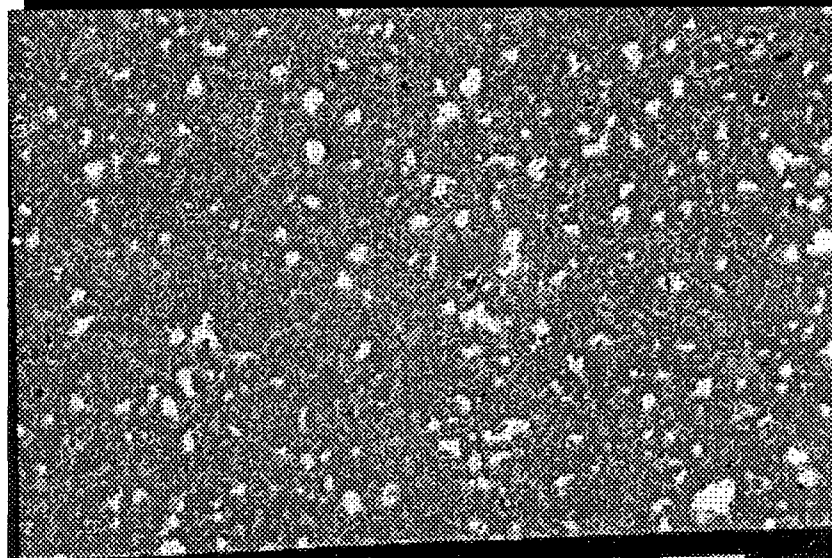
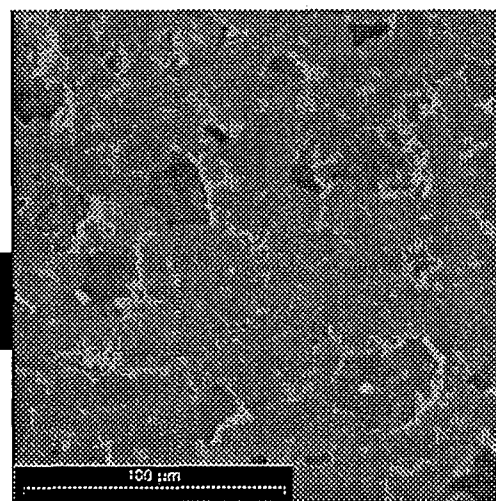
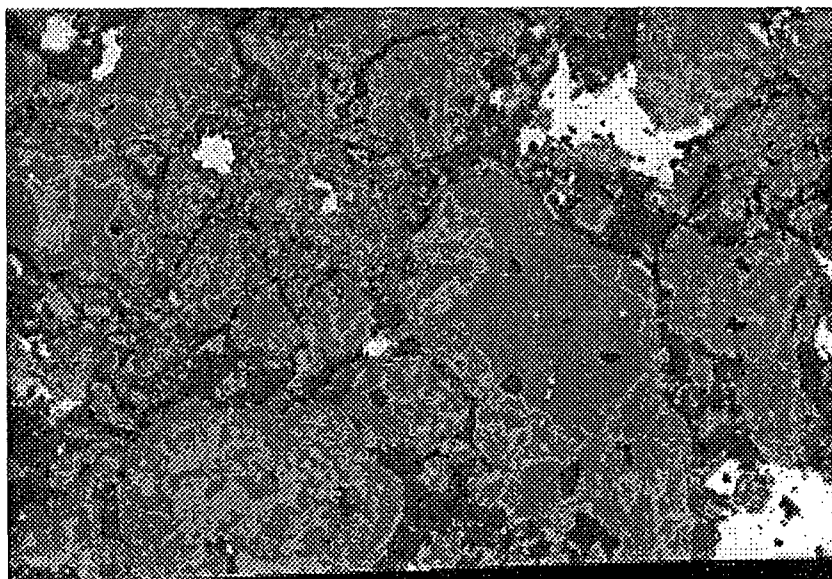
Coagulated Phases - Neutral pH

31



Heterocoagulated Phases - Basic pH

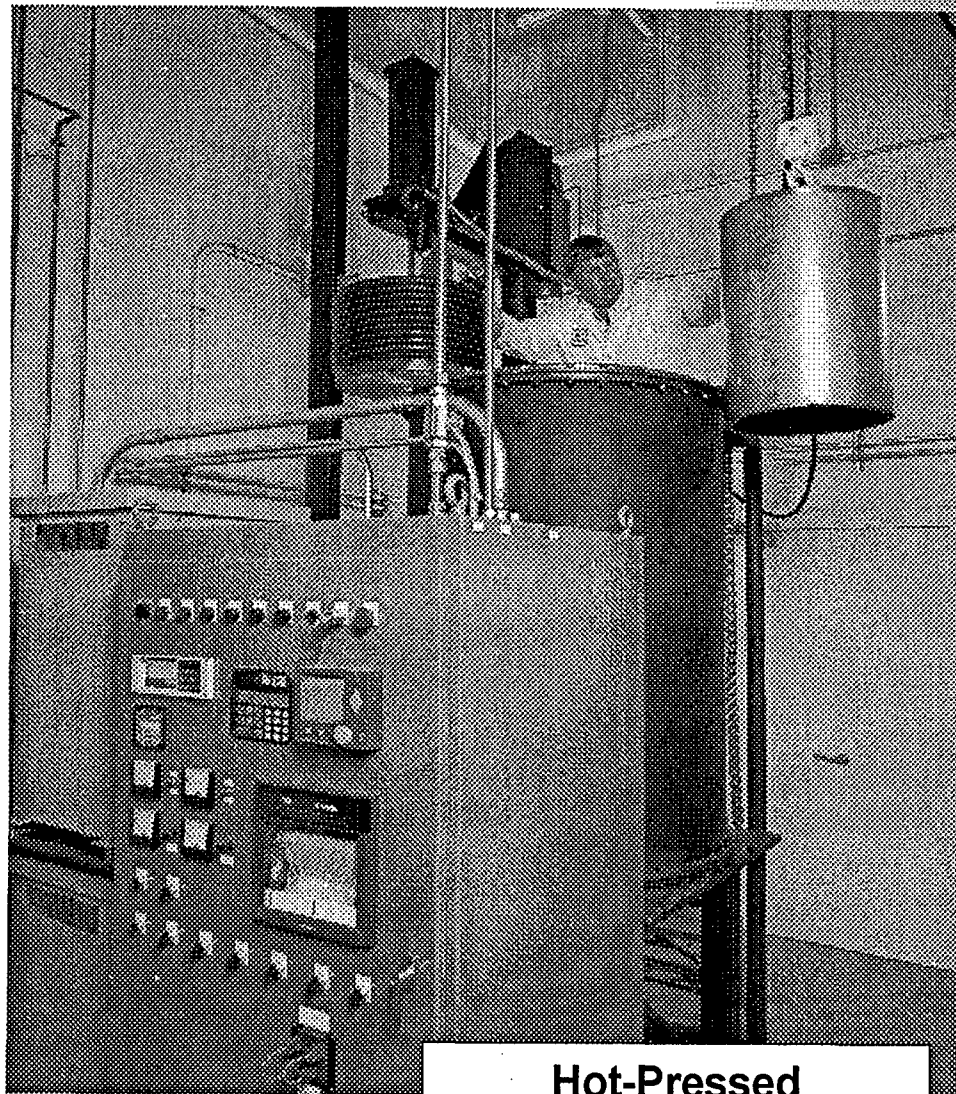
20



*SHS TiB₂ -
AKP50 Al₂O₃*

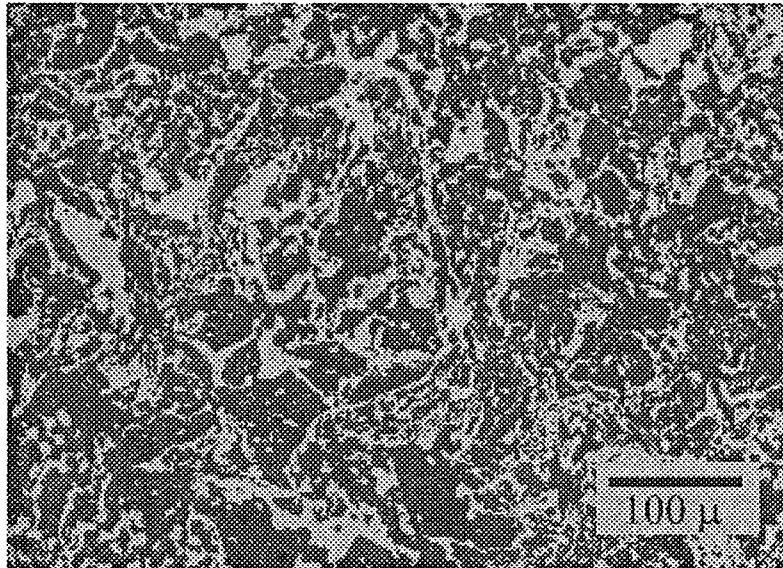
12

Hot Isostatic Press



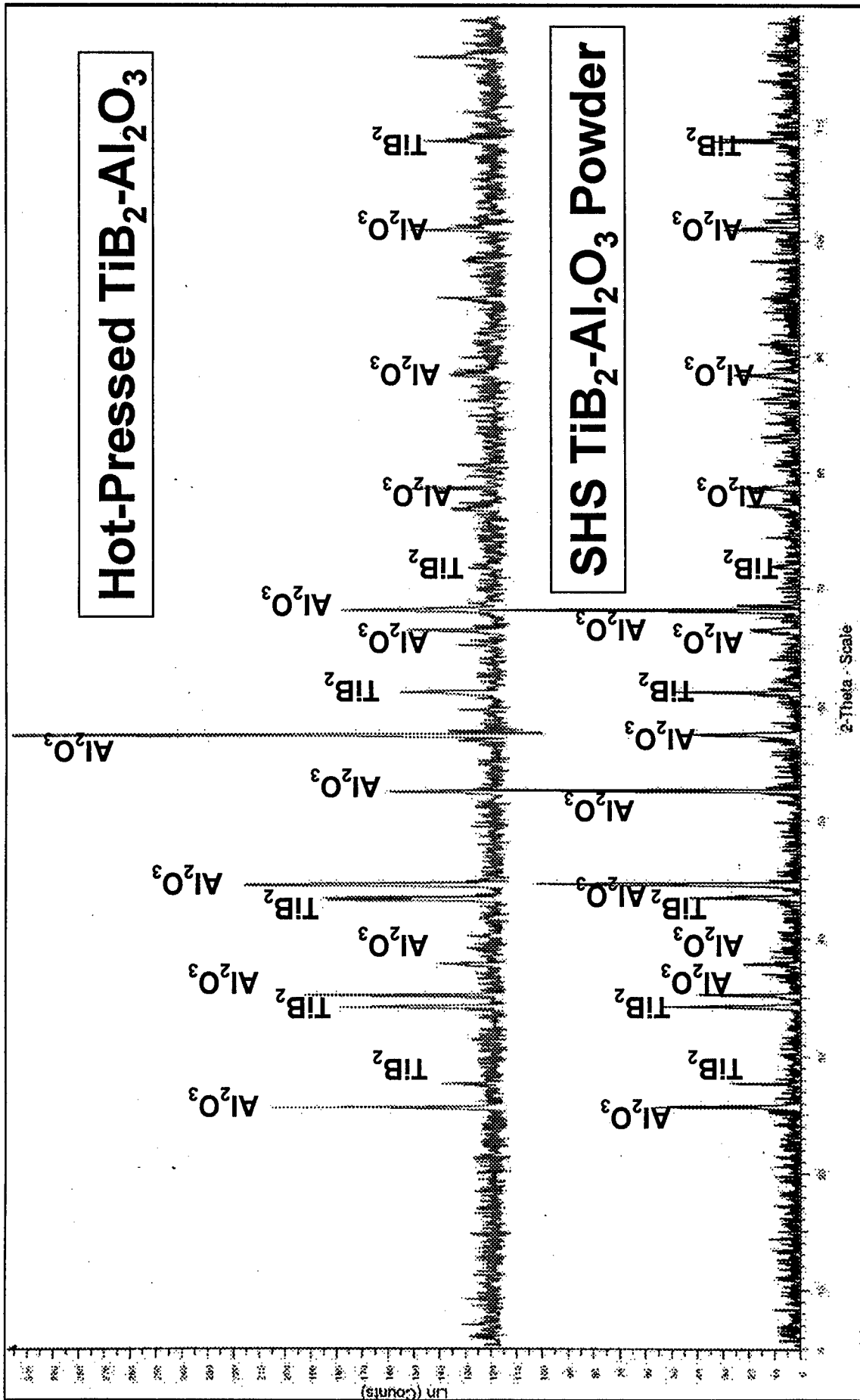
**Hot-Pressed
4" Diam.
 $TiB_2-Al_2O_3$**

Complete Densification



SHS Composite $TiB_2-Al_2O_3$

X-Ray Diffraction Patterns



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Conclusions

- SHS Composite $\text{TiB}_2/\text{Al}_2\text{O}_3$ powders are insensitive to colloidal processing and require HIP'ing for complete densification
- *Suspension Stability*® successfully predicted the behavior of SHS TiB_2 in Alumina
- The Continuous Microstructure is characteristic of SHS Composite $\text{TiB}_2/\text{Al}_2\text{O}_3$ starting powders

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 Purpose of Release: Participation in Ground Vehicle Survivability Symposium

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