Thermal Sprayed Nanostructured Coatings

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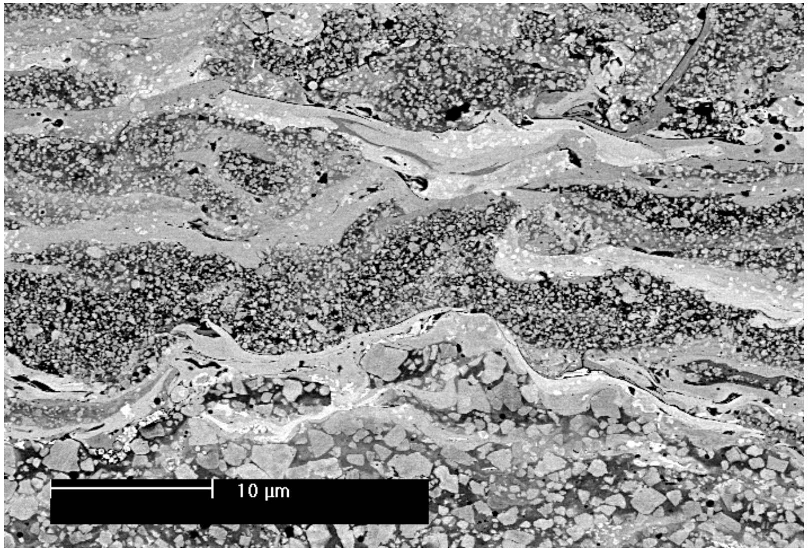
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Thermal Sprayed Coatings

- Thermal spray inevitably forms layered structures
- Properties dominated by “splat boundaries
- Mechanical Bond
- Evaluation can be a very complex business
- Process control limited (for now)



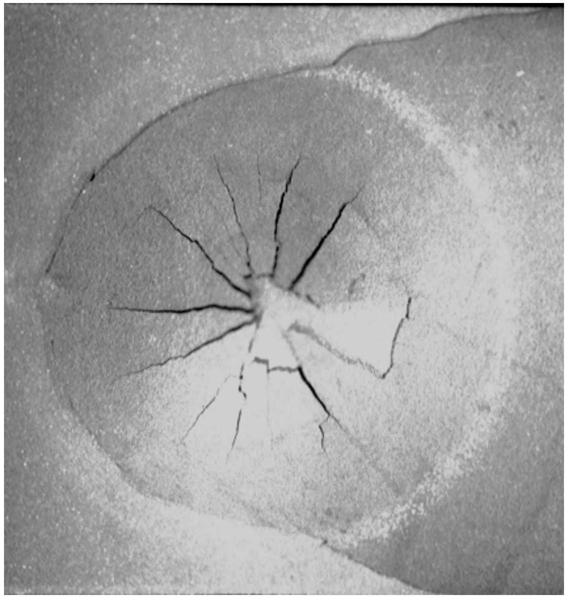
Formation of Nanoscale Microstructure in Coating

- Agglomerates experience significant heating in plasma
- Ways of obtaining nanoscale microstructure:
  - Avoid melting or grain growth (very difficult!)
  - Inclusion of phase or particles with high T_m
  - Formation of new nanoscale microstructure during solidification
    - Two or more immiscible phases present
    - Formation of single metastable phase during quenching (in the case of Al_2O_3-TiO_2, this is highly defected spinnel)
    - Decomposition into nanocomposite

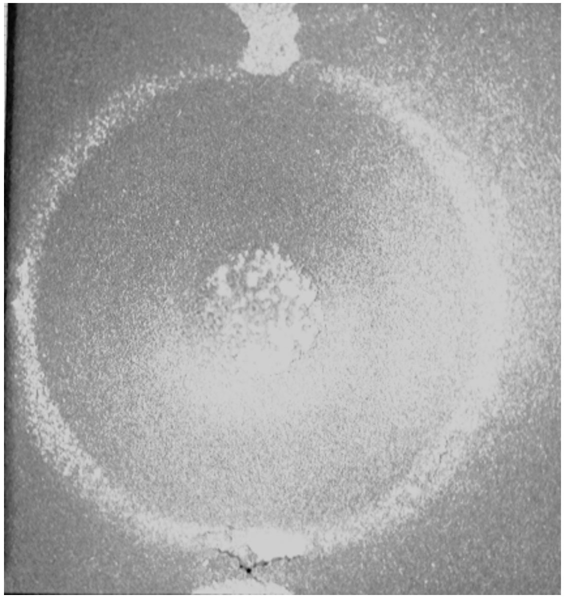
Ceramic Coatings

- Feedstock
  - Conventional: fused and crushed
  - “Nano”: Spray dried agglomerates of nanoparticles
- Properties
  - Distinctly different microstructures
  - “Nano” better only within specific range of spray parameters
  - For optimum parameters, “nano” distinctly “better
    - Higher bond strength and wear resistance
    - Remarkable strain tolerance and “toughness

Strain Tolerance: Cup Test



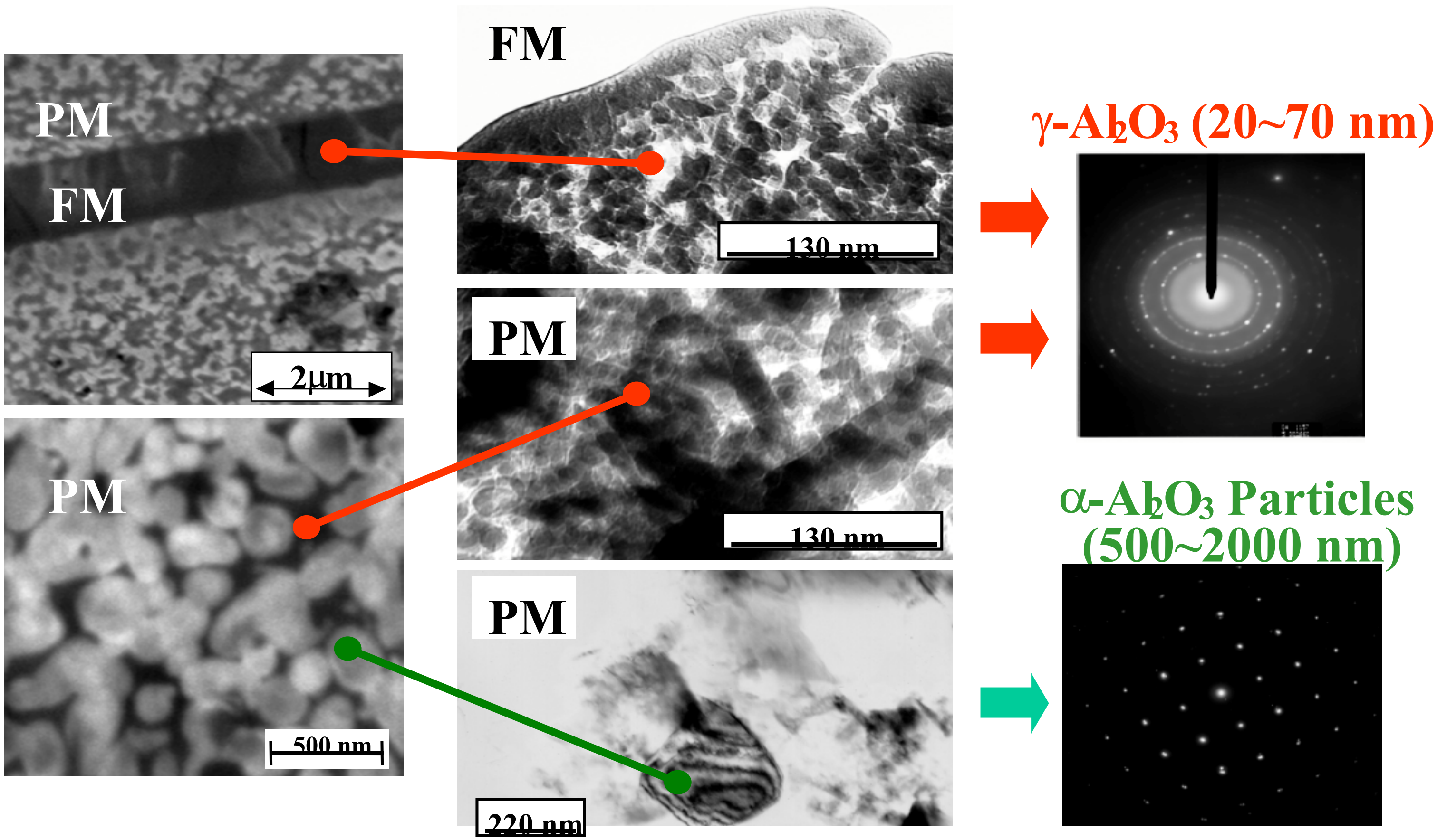
CONVENTIONALLY GRAINED ALUMINA TITANIA



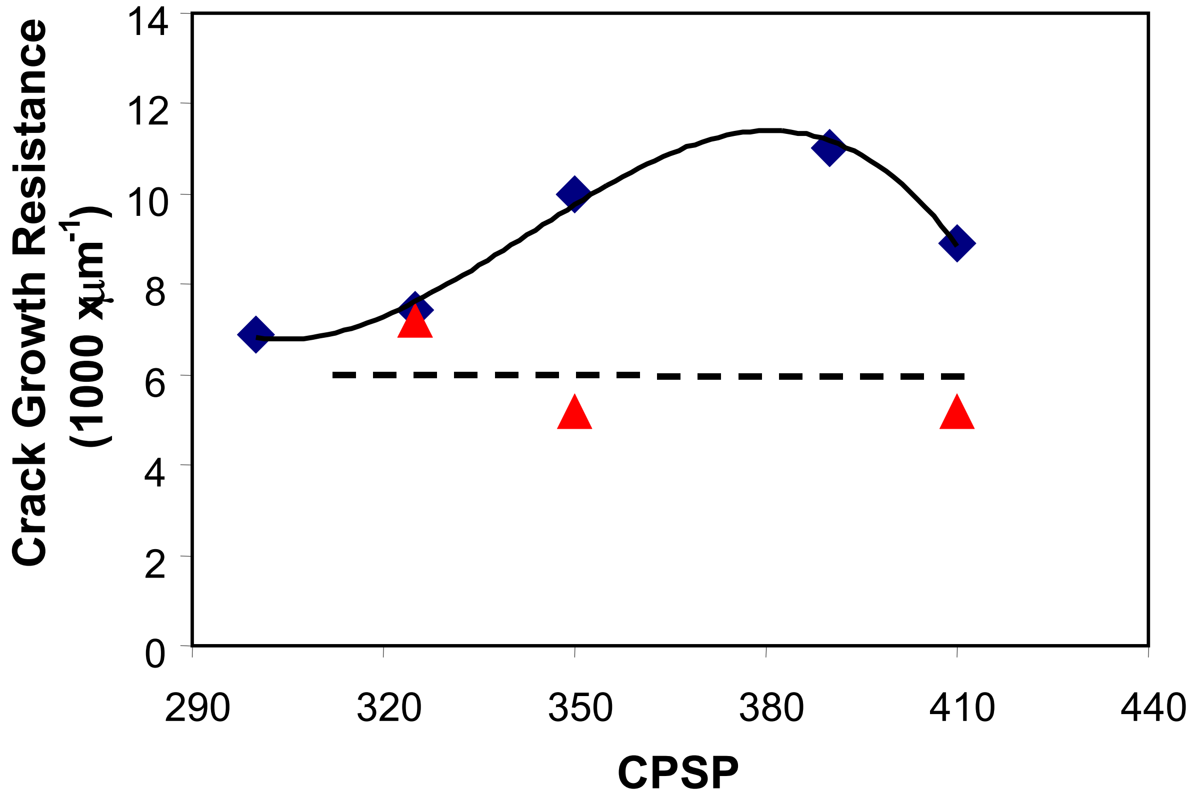
NANOSTRUCTURE GRAINED ALUMINA TITANIA

Courtesy of R. Rigney, A&A Company

Microstructure of Nanostructured Alumina-Titania Coatings

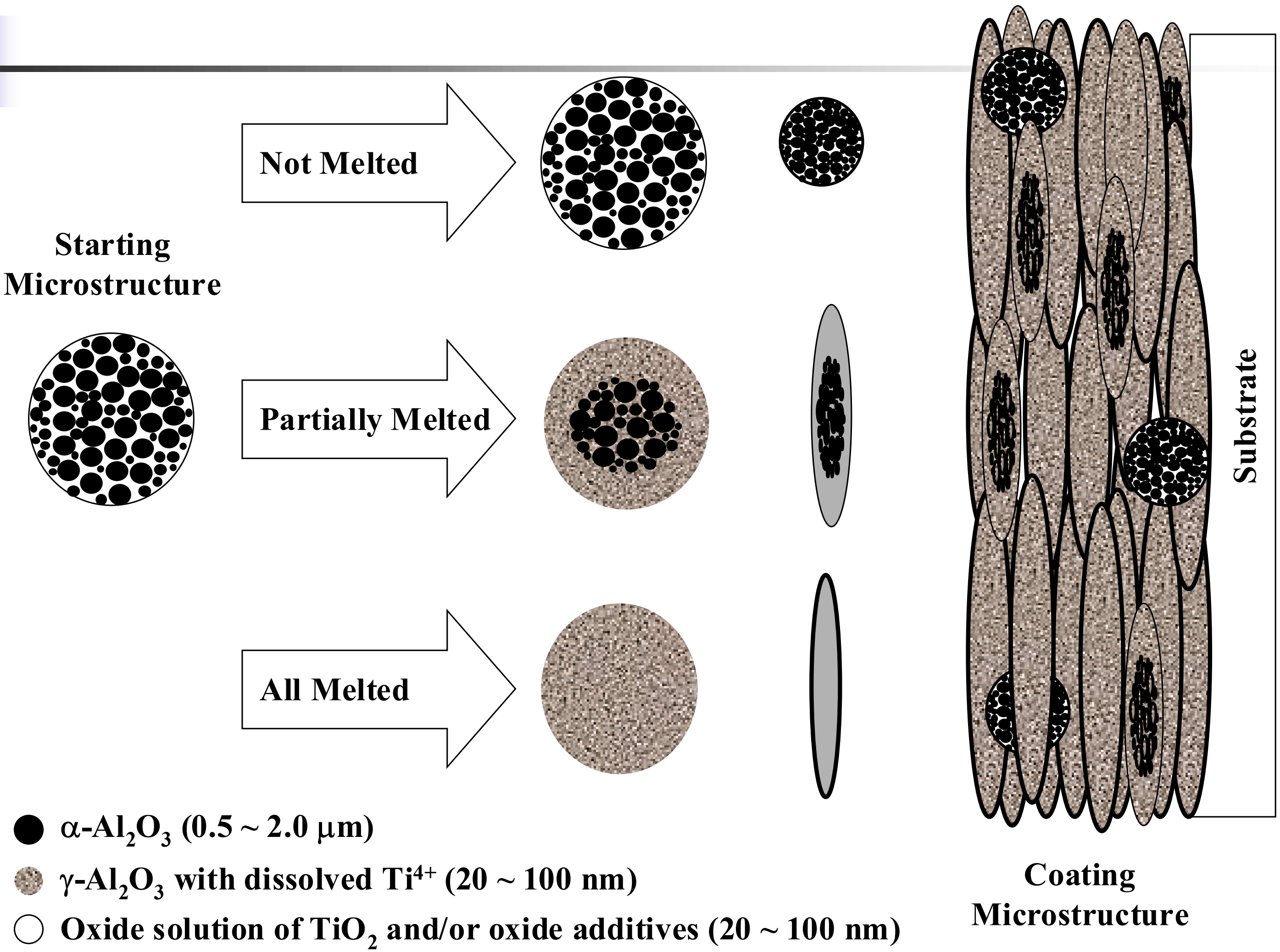


Comparison of Indentation Crack Growth Resistance



Courtesy of M. Gell and E. Jordan, UCONN

Microstructural Development of Nanostructured Alumina-Titania Coatings



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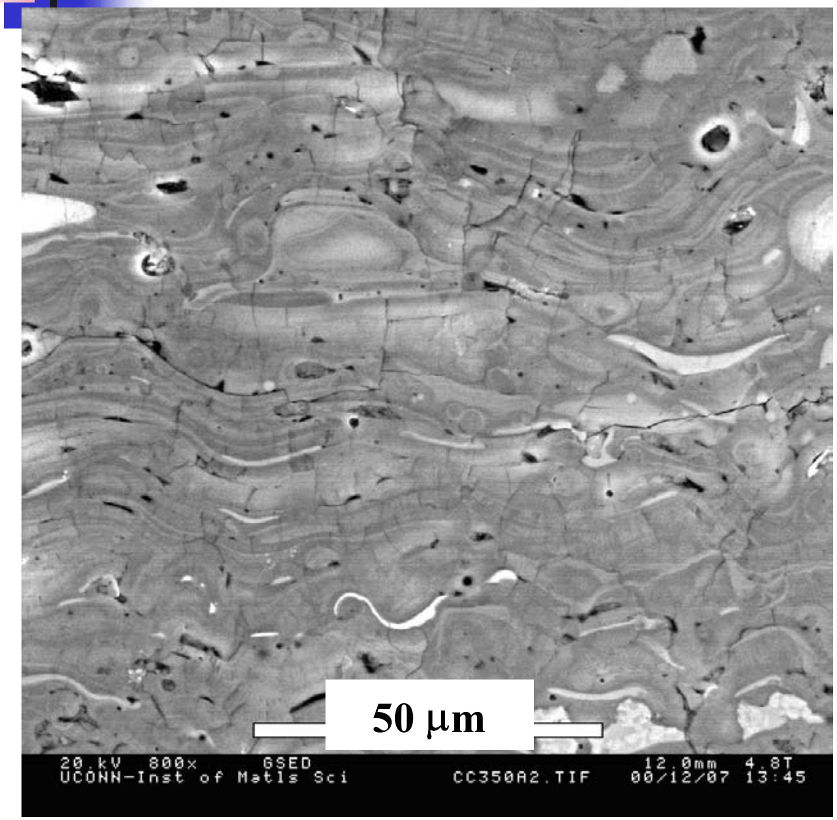
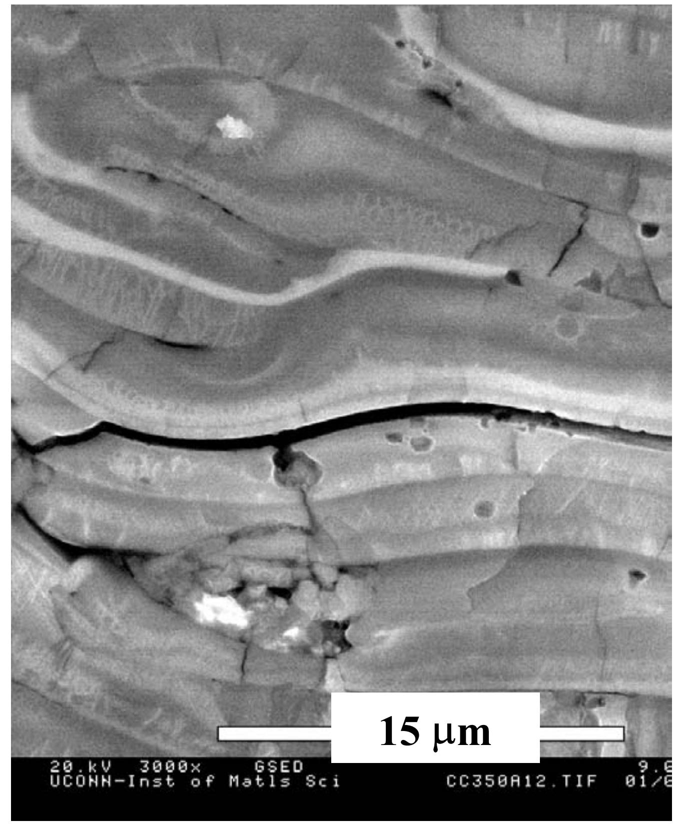
Interactions between Cracks and Microstructure (Metco 130)

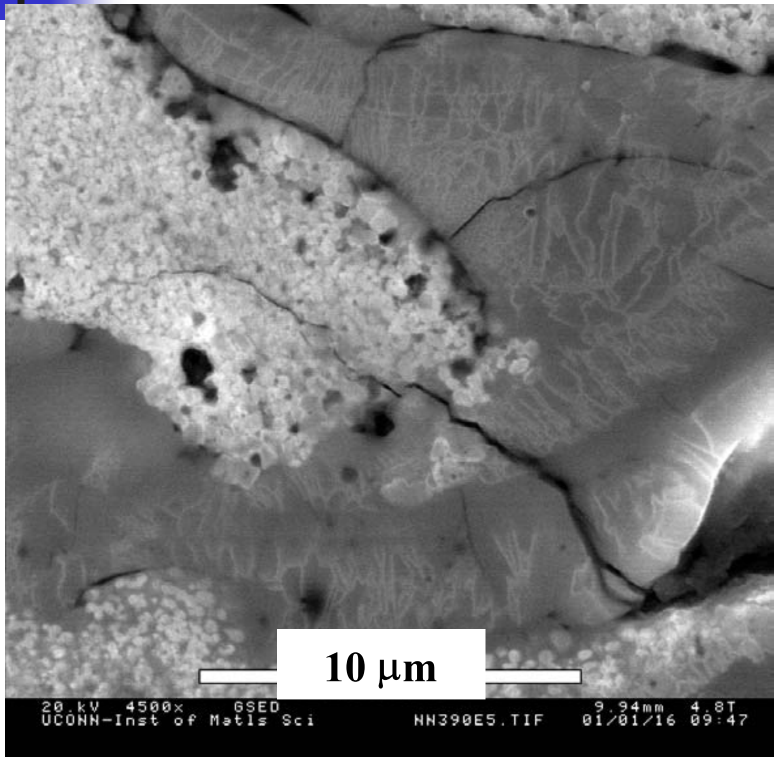




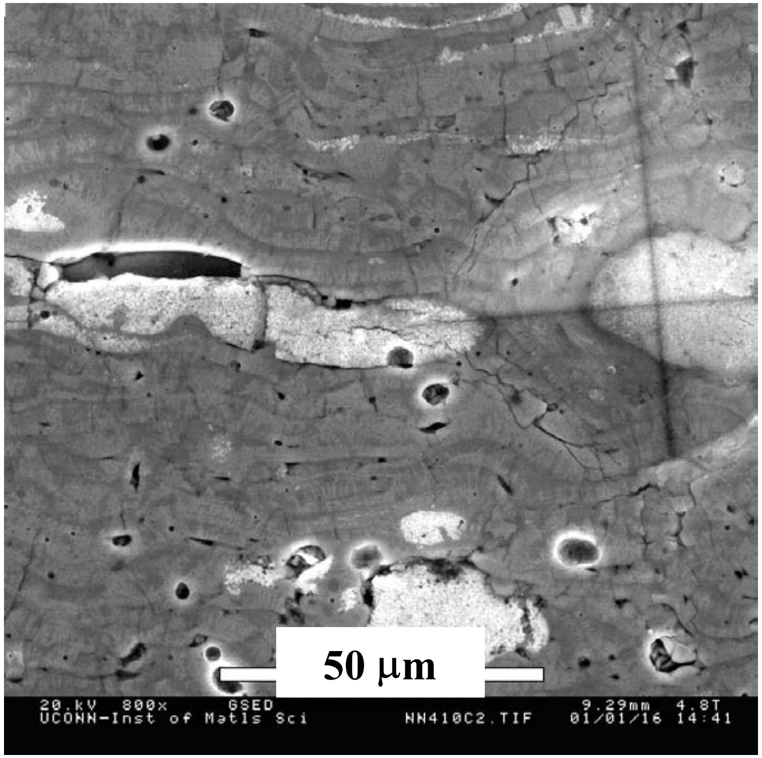
Most of the cracks propagate along splat boundaries!

Courtesy of M. Gell and E. Jordan, UCONN

Interactions between Cracks and Microstructure (NN Series)



NN 390

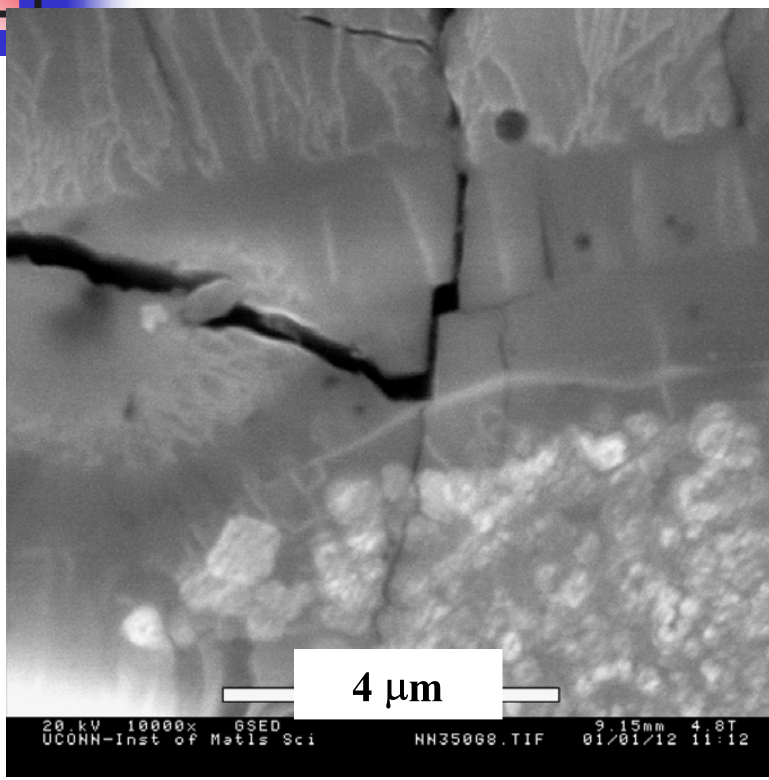


NN 410

Cracks are trapped in partially melted regions!

Courtesy of M. Gell and E. Jordan, UCONN

Interactions between Cracks and Microstructure (NN Series)



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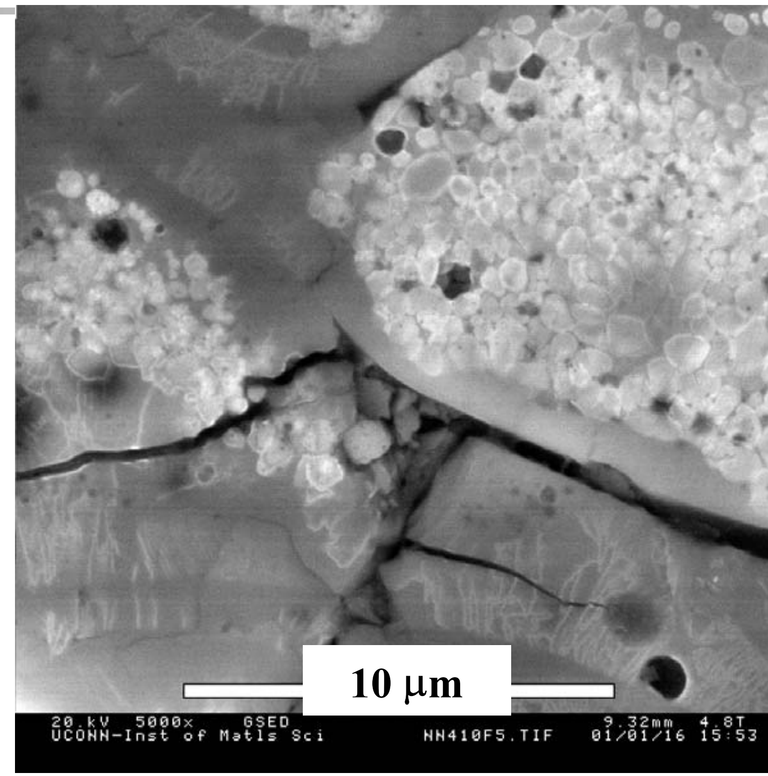


NN 410

Cracks are deflected by partially melted regions!

Courtesy of M. Gell and E. Jordan, UCONN

Applications: Examples

- Main propulsion shafting for Mine Countermeasures (MCM) ships
- Through-hull submarine ball valves
- Gear shafts (80 Ton air conditioning units for surface ships)

Cermets

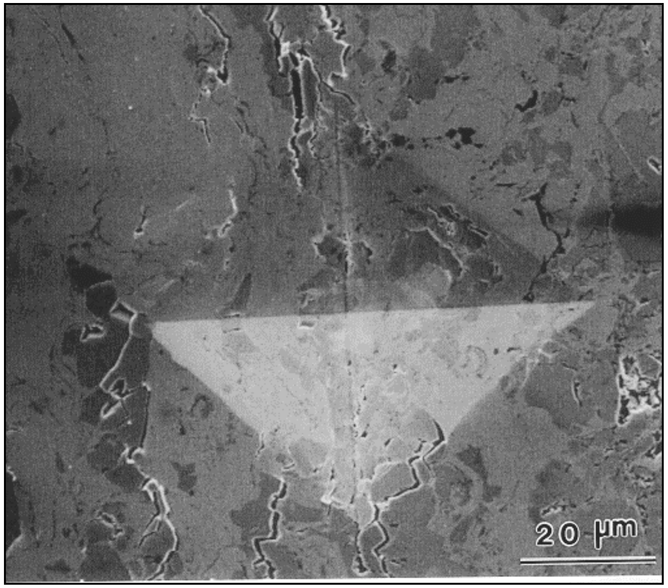
- Maintaining nanostructure "easy" because carbides do not melt
- *n*-WC-Co difficult to spray
  - *High surface area*
    - *Decarburization*
    - *Dissolution*
  - *Very temperature and porosity sensitive*
- *Large carbide particles best for abrasive wear resistance*
  - *"Nano" is for toughness and bond strength*
  - *"Bi-modal" structure may be best*

Status of *n*-Cermet Coatings

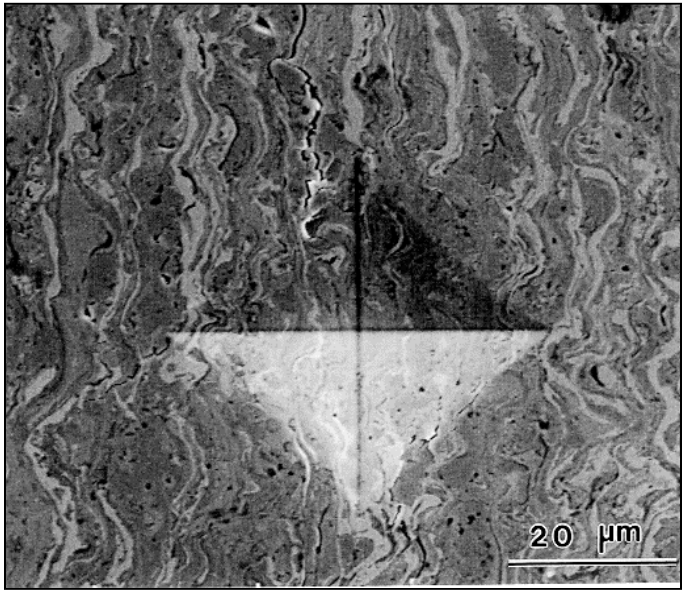
- NiCr-CrC much less sensitive to decarburization
  - Attritor milling of powder for feedstock
  - “Nano” coatings both harder and tougher
- Re-processing of WC-Co powder
  - Densify spray particles
  - New processes for producing *n*-WC-Co
- Mix nano and coarse carbides in 30/70 ratio
- National Research Council of Canada continuing development through consortium

Attritor Milled NiCr-CrC

Conventional



Nanostructured



Cr_3C_2/NiCr Coatings
1000 g load