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THE ROLE OF MICROSTRUCTURE AND PHASE DISTRIBUTION IN THE FAILURE MECHANISMS AND LIFE PREDICTION MODEL FOR PSZ COATINGS

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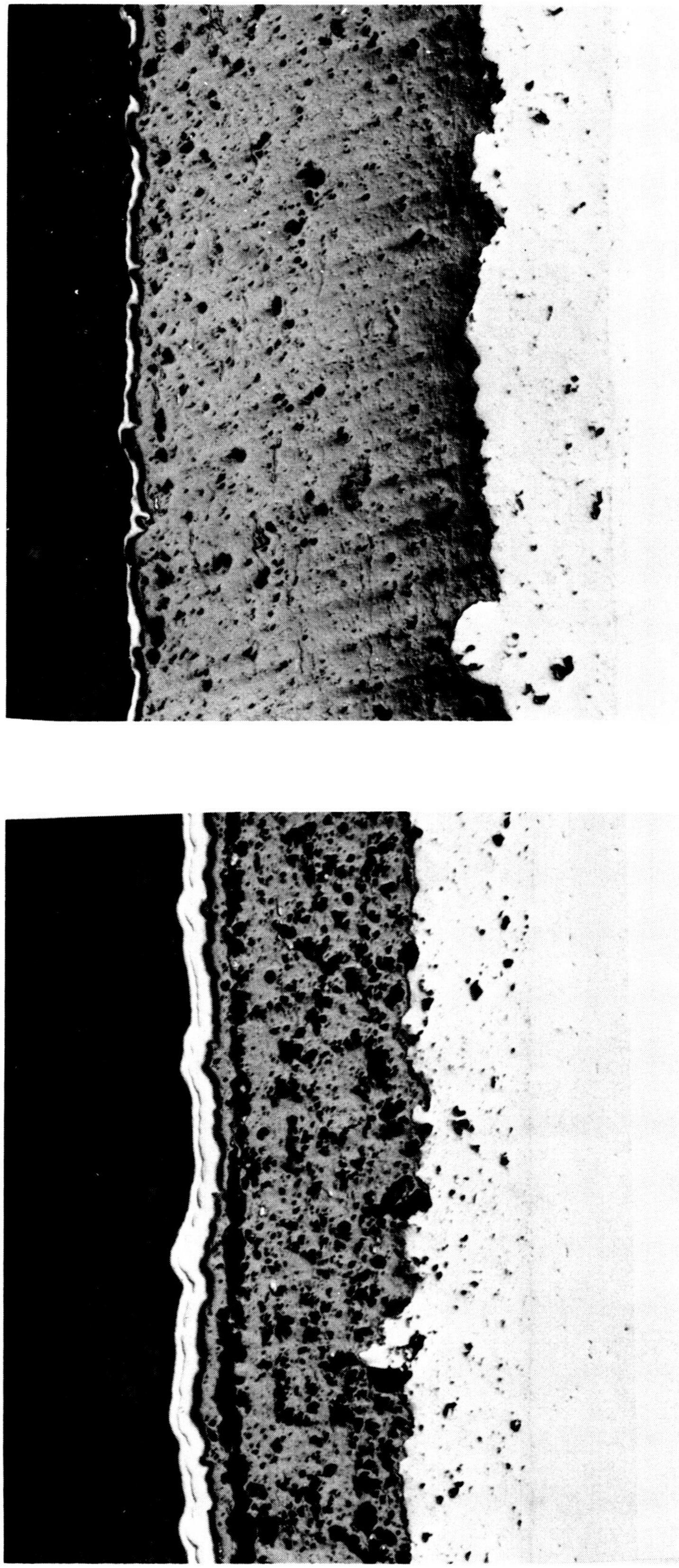
Partially Stabilized Zirconia (PSZ) may become widely used for Thermal Barrier Coatings (TBC). Failure of these coatings can occur due to thermal fatigue in oxidizing atmospheres. The failure is due to the strains that develop due to thermal gradients, differences in thermal expansion coefficient and oxidation of the bond coating. The role of microstructure and the cubic, tetragonal and monoclinic phase distribution in the strain development and subsequent failure will be discussed. A new x-ray diffraction technique for accurate determination of the fraction of each phase in PSZ will be applied to understanding the phase transformations and strain development. These results will be discussed in terms of developing a model for life prediction in PSZ coatings during thermal cycling.

MICROSTRUCTURAL CHARACTERIZATION
OF PSZ COATING

- % POROSITY
- PORE SIZE
- CRACK MORPHOLOGY
- GRAIN SIZE
- PHASE FRACTION
- PHASE DISTRIBUTION
- PHASE COMPOSITIONS

Figure 1.



MICROSTRUCTURES OF PLASMA SPRAYED PSZ
FROM TWO DIFFERENT POWDER SOURCES

Figure 2.

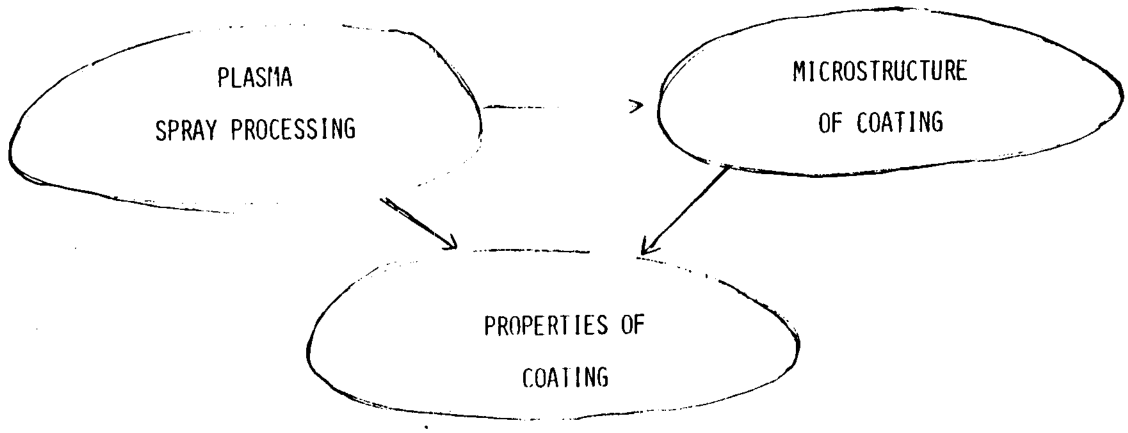


Figure 3.

FAILURE OF PSZ COATING DURING
THERMAL CYCLING

- THERMAL GRADIENTS
- THERMAL EXPANSION MISMATCH
- BOND COAT OXIDATION

Figure 4.

PHASE TRANSFORMATIONS IN PSZ

T ⟶ M + F EUTECTOID

T′ ⟶ T ? NONTRANSFORMABLE

TEMPERATURE EFFECTS

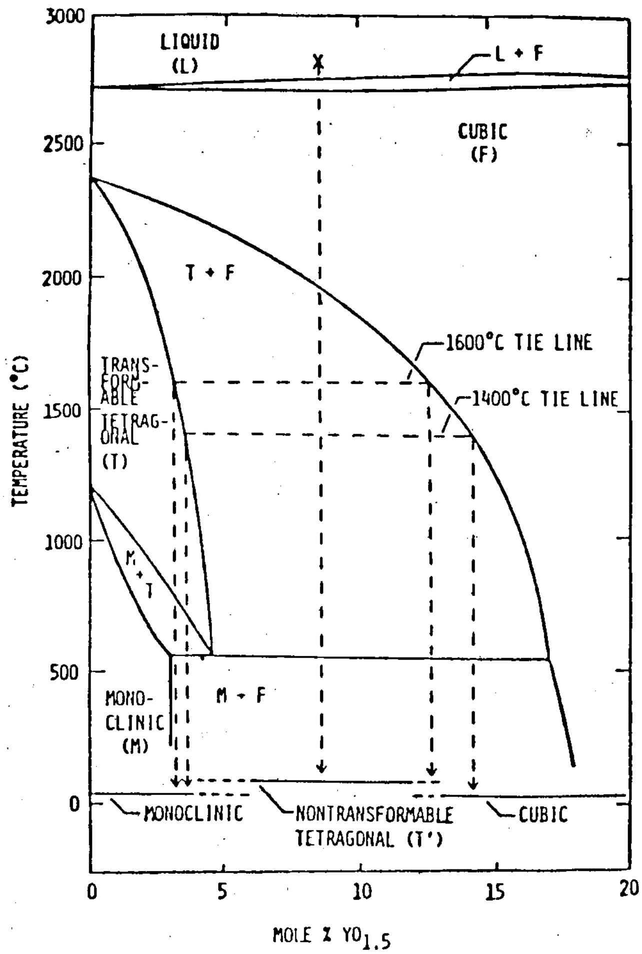
STRAIN/STRESS EFFECTS

Figure 5.

INCREASE TOUGHNESS OF PSZ COATING

- SEGMENTED COATINGS
- MICROCRACKS
- TRANSFORMATION TOUGHENING
- IMPROVE THERMAL EXPANSION MATCH
- OXIDATION RESISTANT BOND COATING

Figure 6.



Low-yttria region of ZrO_2-$YO_{1.5}$ phase diagram

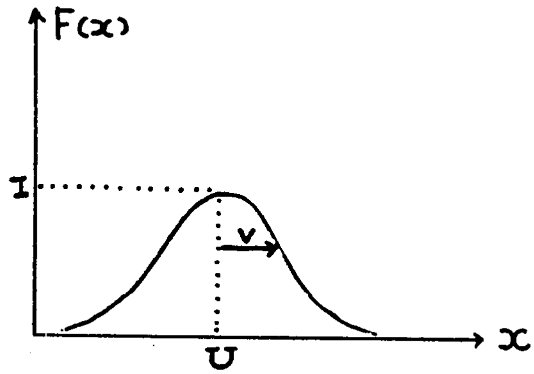
Figure 7.

QUANTITATIVE PHASE ANALYSIS BY

X-RAY DIFFRACTION

- SEPARATION OF T FROM F IS DIFFICULT
- DECONVOLUTE THE (400) REGION
- MANY TECHNIQUES ARE QUALITATIVE
- NEW DECONVOLUTION TECHNIQUES

Figure 8.



$$F(x) = I\ \mathrm{Exp}\left(-\tfrac{1}{2}[(x-U)/v]^2\right)$$

Three parameters

I, U, V

Figure 9.

$$\chi^2 = \sum_{i=1}^{n} \frac{(e_i - o_i)^2}{e_i}$$

where $e_i = I\ \mathrm{Exp}\left[-\tfrac{1}{2}[(x_i-U)/v]^2\right]$

o_i = Raw XRD data

Figure 10.

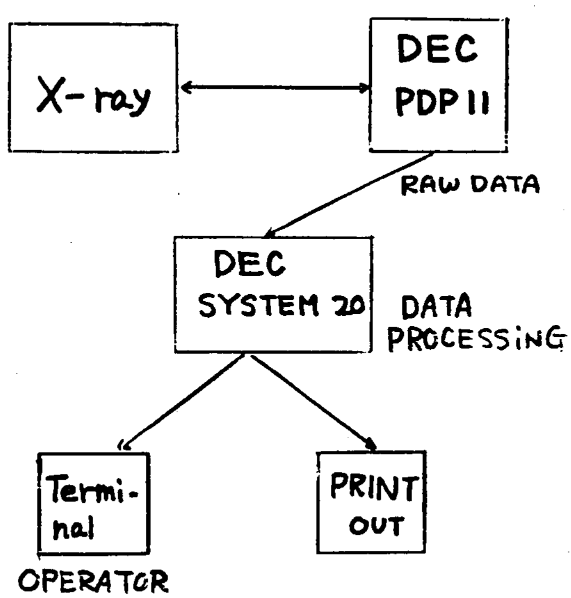


Figure 11.

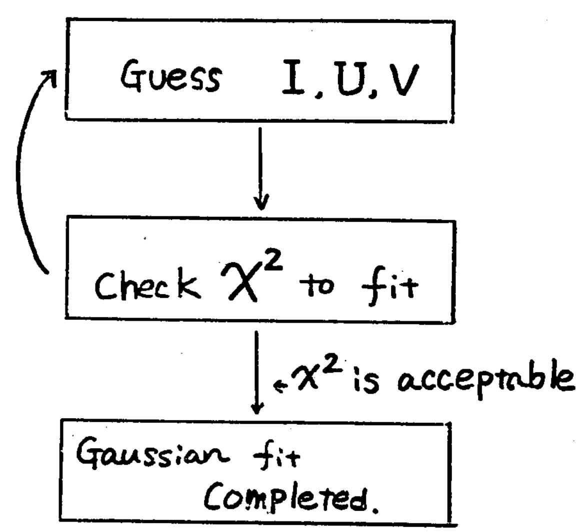


Figure 12.

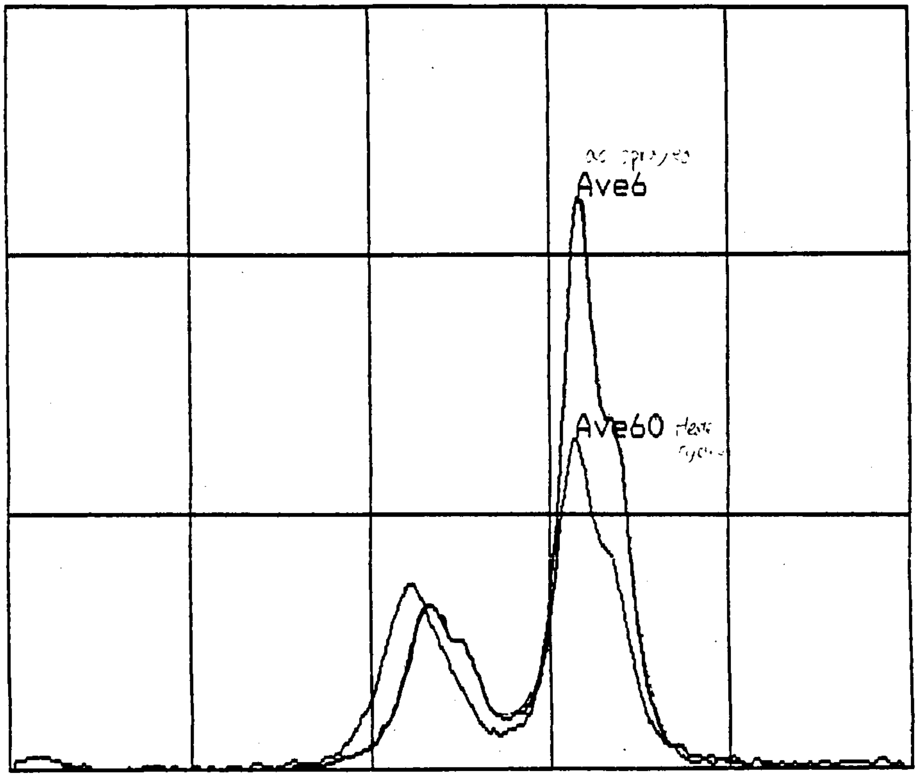


Figure 13.

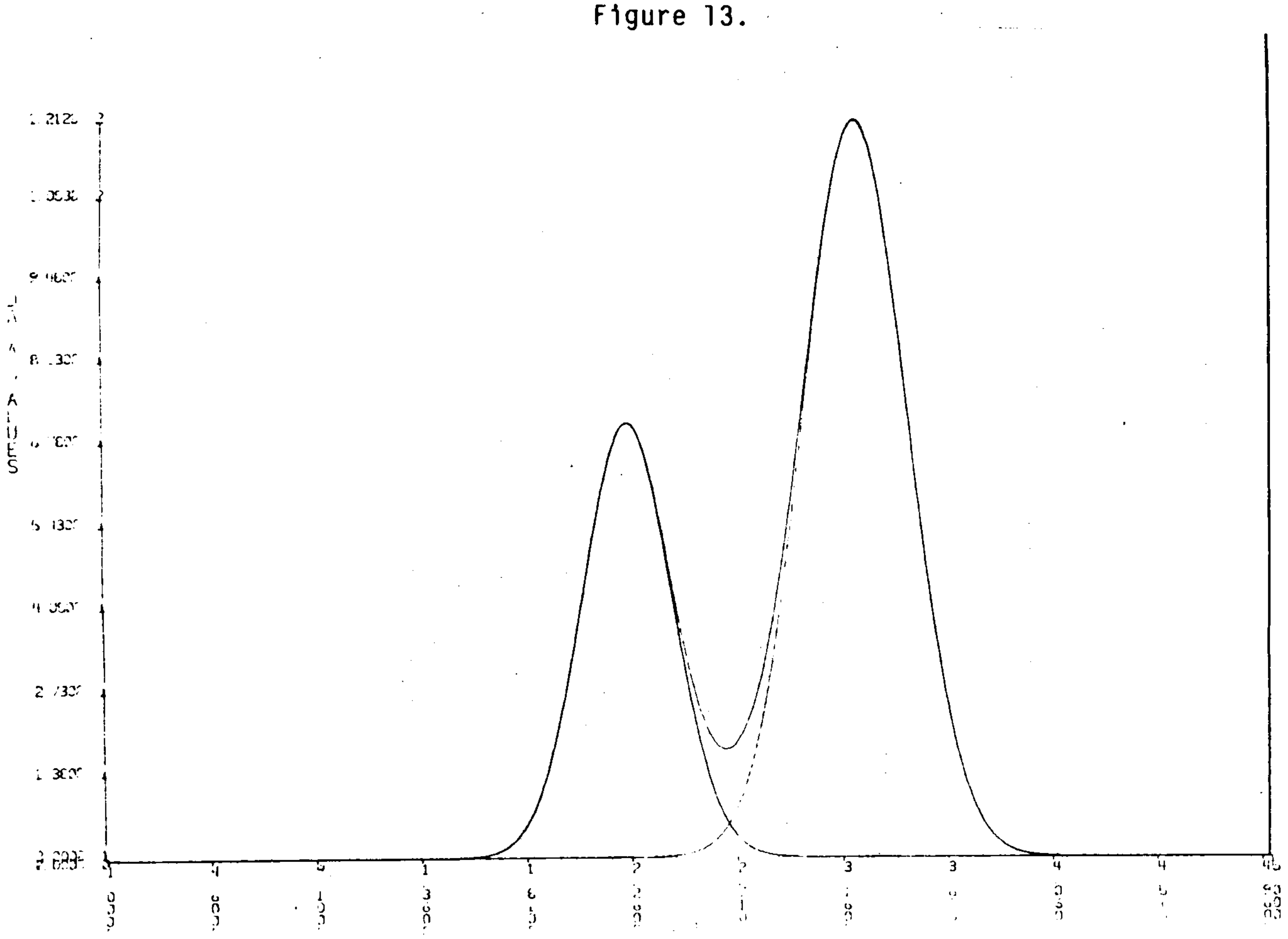


Figure 14.

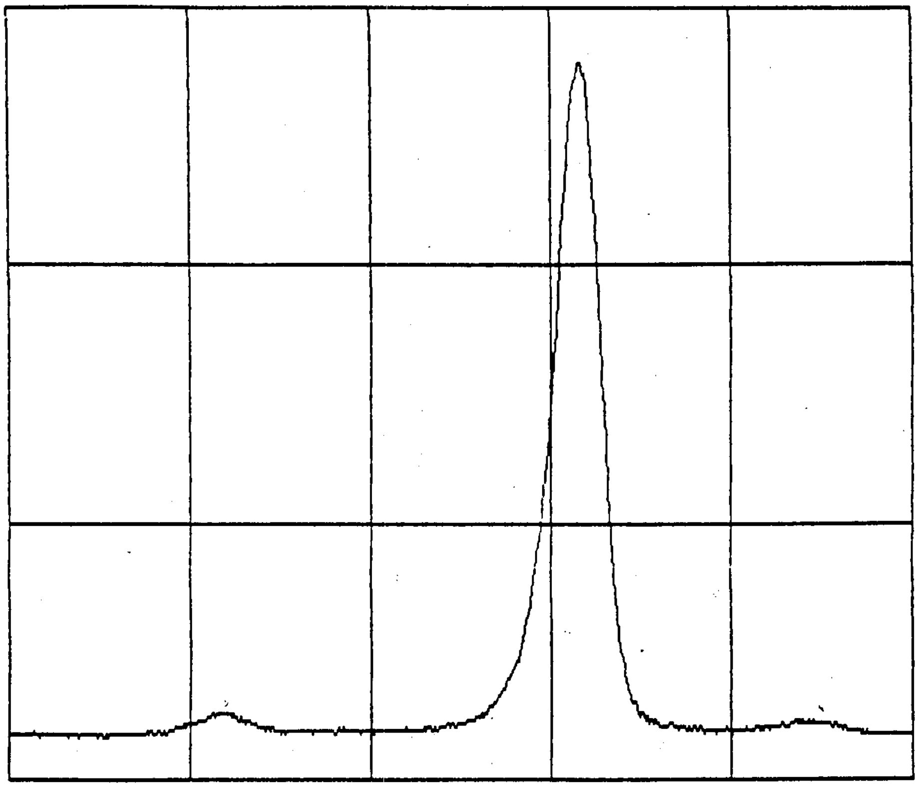


Figure 15.

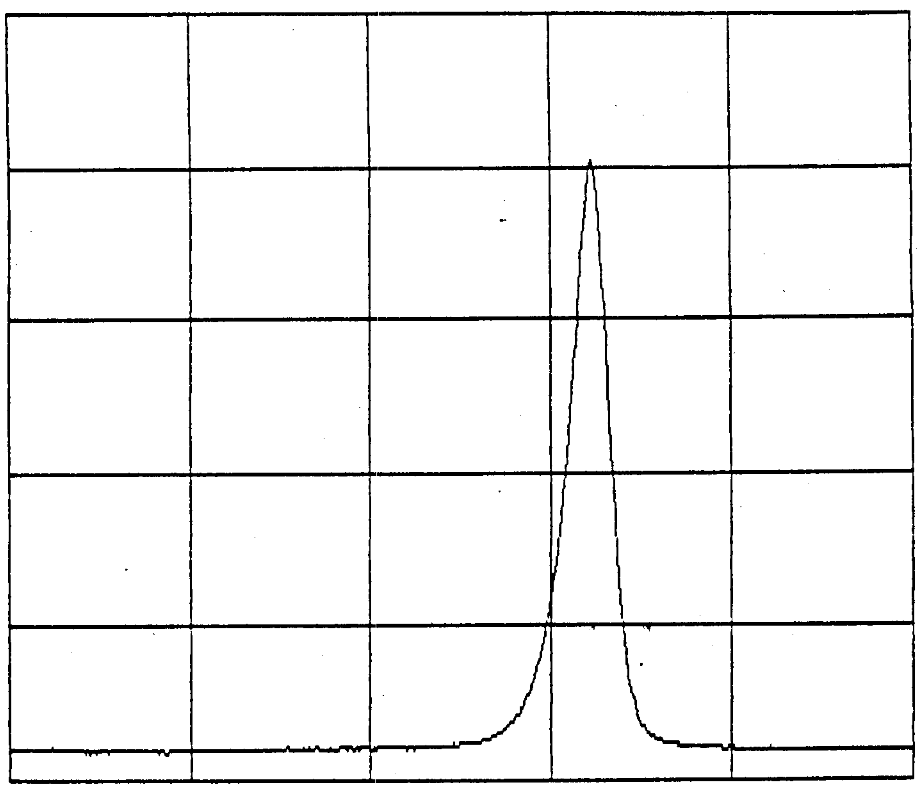


Figure 16.

Table I.

		COATING		POWDER	
		HEAT TREATED (CENTER)	AS SPRAYED (CORNER)	THERMALLY (CYCLED)	AS RECEIVED
PHASE (MOLE) FRACTION %	TET	91.9	98.3	78.9	80.0
	CUBIC	3.0	0.9	20.7	18.4
	MON	5.1	0.8	.5	1.6
PEAK INTENSITY (400) REGION (UNIT ARBITRARY)	400 TET	66.6	100.6	---	---
	004 TET	33.8	29.8	---	---
	400 FCC	3.7	1.4	---	---
PEAK INTENSITY (111) REGION UNIT ARBITRARY	111 (F+T)	882.9	1138.0	---	---
	111 M-N	37.3	7.7	---	---
	111 MON	20.1	4.2	---	---
INTENSITY RATIO $\frac{I (400) T}{I (004) T}$ THEORETICAL VALUE = 3.15		1.97 TEXTURE EFFECT	3.38		