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ENGINEERING BRANCH | DIRECTION D'INGÉNIERIE

ENGINEERING REPORT | RAPPORT D'INGÉNIERIE

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ENGINEERING REPORT
RAPPORT TECHNIQUE **LP125/2006**

Compressor Turbine Blade

DHC-6-200, N203E

Occurrence Date: 29-Jul-06

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AMENDED - MODIFIÉ

1.0 INTRODUCTION

1.1 The aircraft, a De Havilland DHC-6-200 Twin Otter, registration N203E, which was carrying seven skydivers and one pilot, reportedly lost power on the right engine immediately after take off. The aircraft started an uncontrolled turn to the right and crashed killing all but two of the occupants.

1.2 Disassembly of the engine, a Pratt & Whitney of Canada (PWC) Model PT6A-27, serial number, 20529, at the PWC facility in Montreal, Quebec, disclosed a number of broken blades on the compressor turbine wheel. The blades were found to carry the part number, T-023401, which identifies the blades as manufactured by Doncasters Inc., Turbo Products Division under a Federal Aviation Administration Parts Manufacturing Approval (FAA/PMA). Since PMA parts had been used and were considered to be contributory to the engine failure the failure analysis was discontinued by PWC. The parts were subsequently submitted to the Engineering Branch Laboratory of the Transportation Safety Board of Canada (TSBC) by the investigating officer of the Quebec Regional Office along with a request to determine possible cause of blade failure.

2.0 EXAMINATION AND ANALYSIS

2.1 The as received parts as shown in Figure 1 comprise a bladed P/N 3013511 H, S/N A7189 compressor turbine wheel. A single blade had been removed from the wheel prior to submission in order to identify the blade part number. The part number, T-023401, was that of a PMA produced blade manufactured by Doncasters Inc. and carried a heat code marking 8ERE. The blade which is a cast IN738 alloy has been installed in place of the original PWC blades which are made from an IN 713C nickel-based superalloy.

2.2 All blades on the wheel as received show damage ranging from the loss of blade structure in the region of the tip, as Figure 2, to complete loss of the airfoils by fracture just above the blade platform, see Figure 3. The fracture surfaces of all missing portions were examined in the in situ blades using the binocular microscope. The fracture surfaces had a uniform dark appearance with a coarse granular texture, as Figure 4, usually associated with the overload fracture of a cast material. The overall appearance is consistent with fracture of an interdendritic nature. No evidence was found of any precrack formation such as a change in the colouration of the surface or in the fracture surface topography. The possibility that precracking had occurred in another location only for the impact of released blade material to cause further blade loss cannot be entirely discounted, although progressive failures are most often found close to the blade platform and one surface of the fracture is usually retained. Because of the uniformity of the fracture surfaces further examination using the scanning electron microscope was considered unnecessary. Three blades, shown as #1, #2 and #3 in Figure 1, were selected. These blades, which show the longest undamaged airfoils within ~ 0.25 inches of the blade trailing edge, were sectioned and mounted for metallographic examination.

2.3 The blade microstructures were examined following the procedure detailed in the original PWC publication “Microstructural Standard for Turbine Blades” Manual Part No. 3041190, issued 28 August 1996, which is used to examine turbine blades for evidence of exposure to high temperature operating conditions. The microstructures were examined for the presence of high temperature creep in the presence of voids in those grain boundaries aligned perpendicular to the principal tensile stress, and in the formation of inter-crystalline cracks. No such features were found in any region of the three blades sampled, example Figure 5 for blade #3. Failure of the blades due to high temperature creep can be discounted as a failure mechanism. The blades were also examined with respect to the change in the morphology of the gamma prime precipitation hardening phase for evidence of an operational over-temperature condition. Figures 6 through 8 show the gamma prime for the blade root, mid span and blade tip locations. Figure 9 for a region between the mid span and the tip shows the transition more clearly with the number of gamma precipitates becoming progressively more rounded and decreasing in number and the number of smaller second phase precipitates increasing. At the tip region it would appear that all of the original gamma prime particles had disappeared to be replaced by the distribution of finer precipitates. TSB Engineering has no information on how this population of precipitates would affect the high temperature strength relative to the original gamma prime structure. Figures 10 to 12, for an unused exemplar blade supplied by Doncasters Inc., show the unchanged nature of the gamma prime precipitates from the blade root out to the blade tip. The distinctive cuboidal morphology of the gamma prime precipitates can be seen in all three photographs.

2.4 Energy dispersive X-ray analysis of the blade material indicated a complex nickel base alloy containing quantities of chromium, cobalt, titanium, aluminum, tungsten, tantalum, niobium and molybdenum consistent semi-quantitatively with the IN 738 material specified by the PMA Part manufacturer. Metallographic examination of the blade microstructures showed no microstructural anomalies or deficiencies which would account for the blade failure.

3.0 CONCLUSIONS

3.1 Examination of the blade fractures found surface features which were consistent with an overload separation. No fractures were found which showed evidence of precracking or of any form of progressive failure.

3.2 Examination of the blade microstructures found no evidence of creep failure either in the form of grain boundary microcracking or formation of microvoids. Some changes in the morphology of the gamma prime precipitation hardening phase and overall microstructures were found out towards the blade tips relative to an exemplar new blade which are believed to represent natural aging of the microstructure of the IN 738 material as the result of operation in service at normal turbine temperatures.

3.3 No manufacturing or materials deficiencies were found to be contributory to the failure of the turbine wheel.

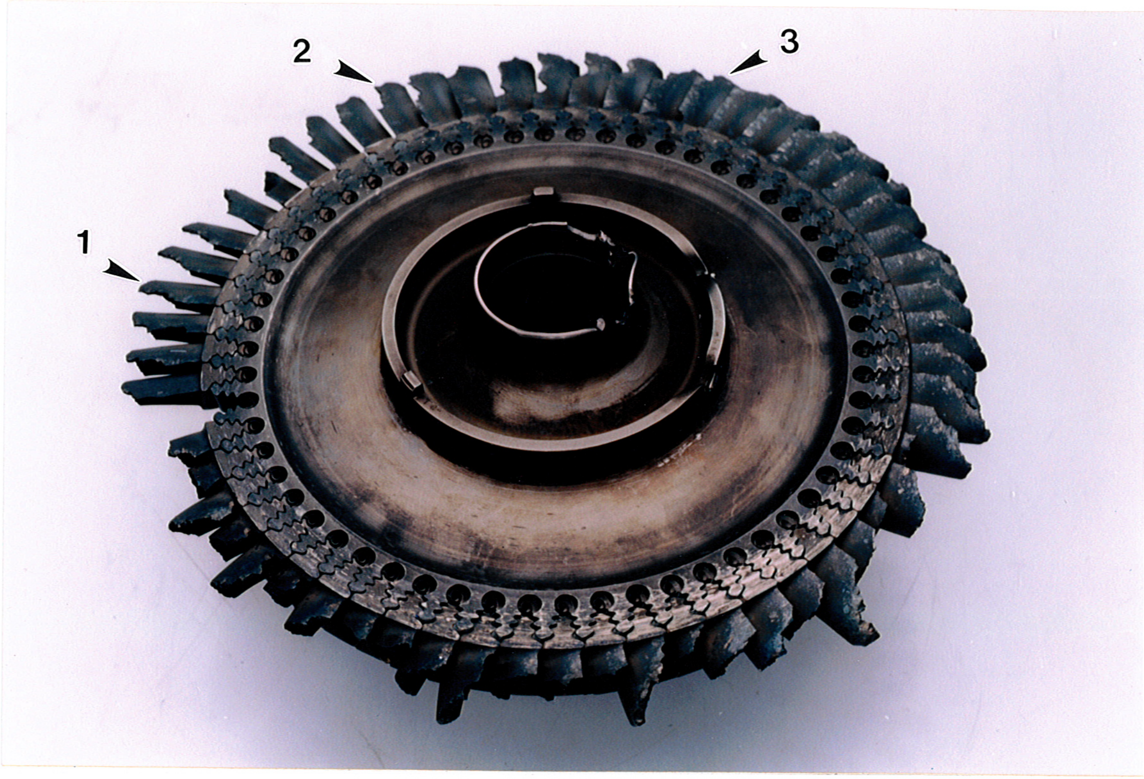


Figure 1 As received P/N 3013511, S/N A7189, compressor turbine wheel. The numbers 1, 2 and 3 indicate the location of the three blades removed for metallographic examination. The other open slot in the wheel is the location of the blade removed by PWC in order to identify the part number.

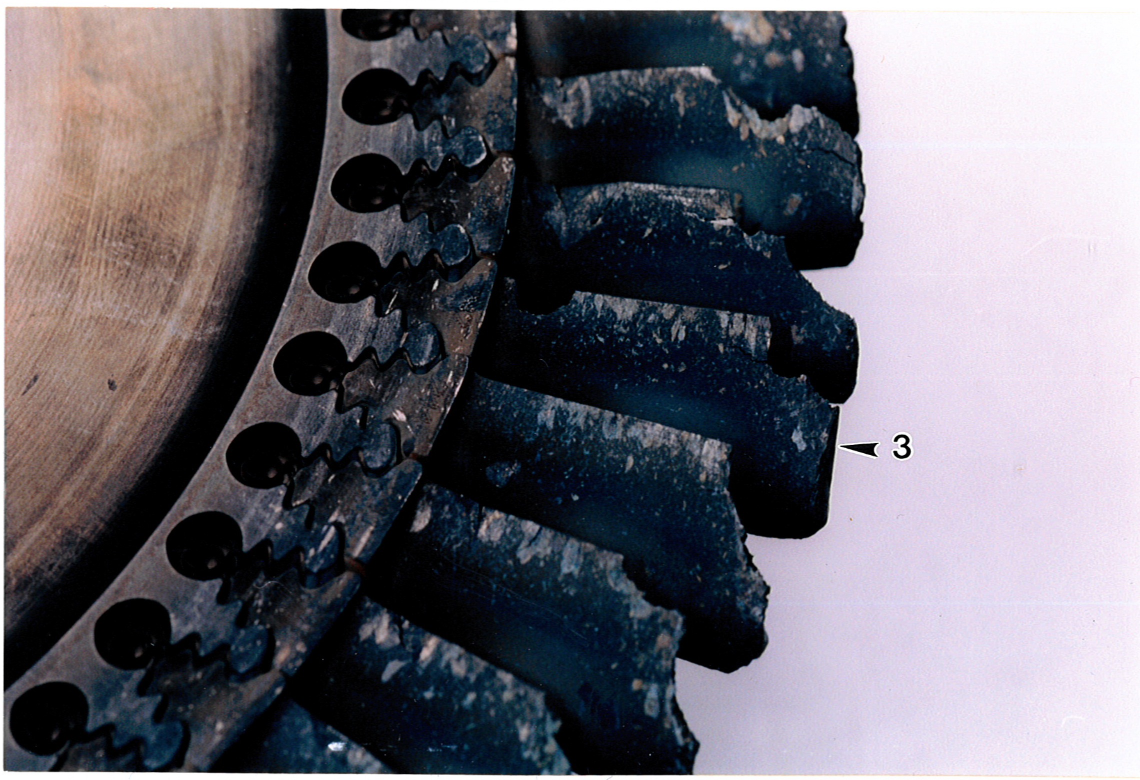


Figure 2 Section of as received turbine wheel showing the most intact blades, including blade #3, indicated. Limited damage with loss of airfoil section both on the tip and blade edges.

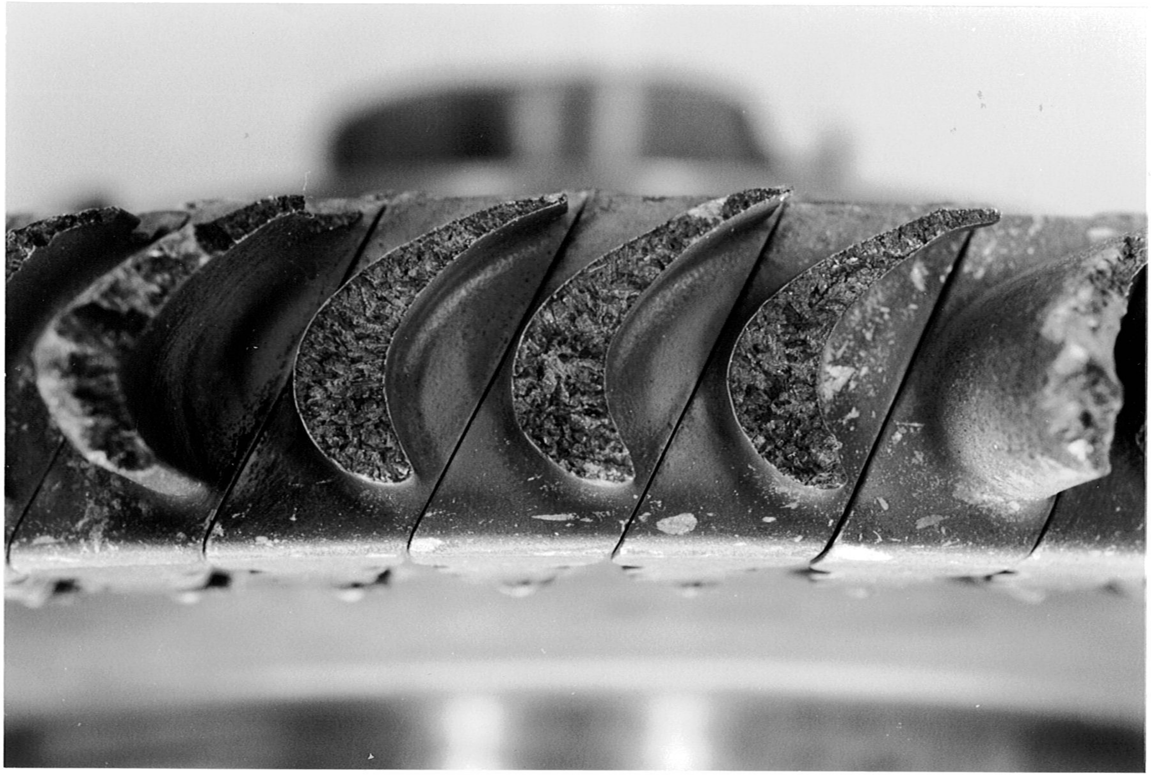


Figure 3 Fracture surfaces of a section of the wheel showing fractures in the blades just above the blade platform. Fracture surfaces are of uniform appearance with no evidence of precracking.

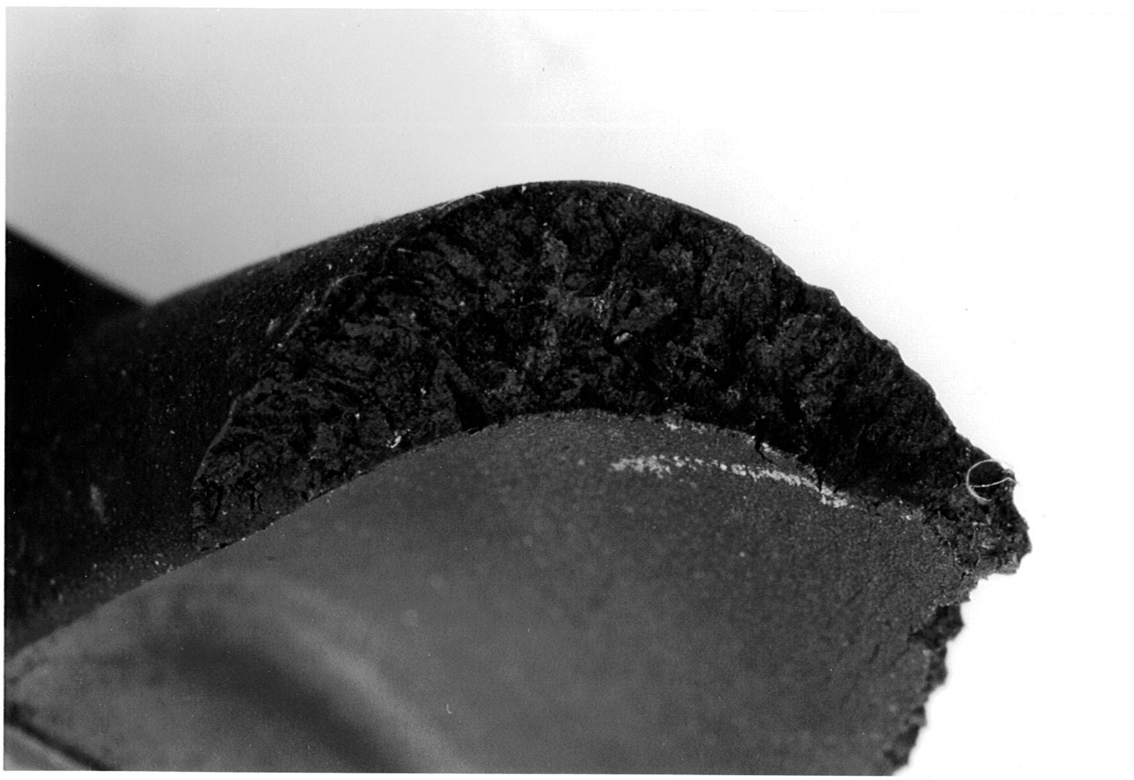


Figure 4 Close up view of a typical blade fracture surface showing an interdendritic fracture from applied overloads.

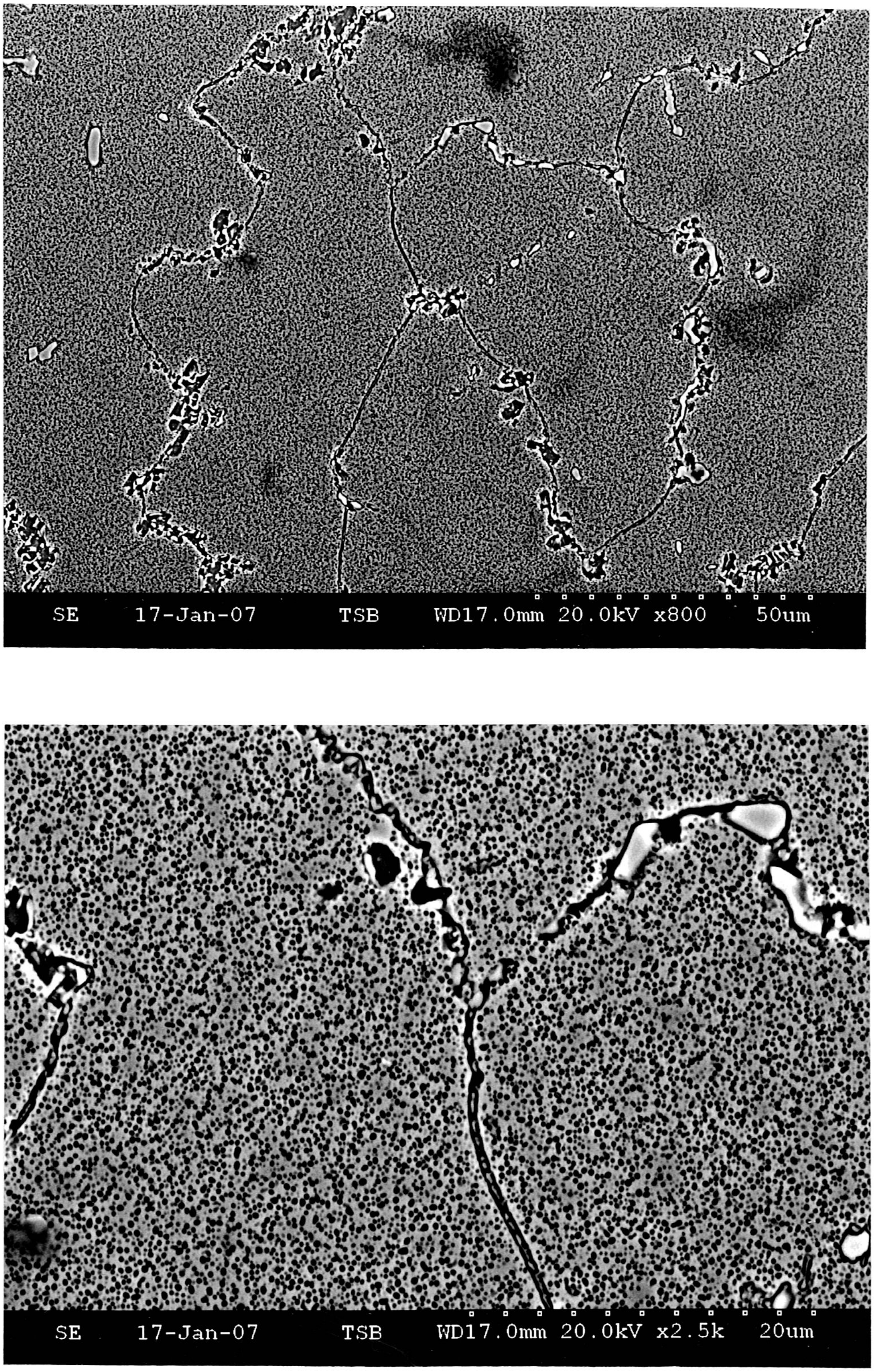
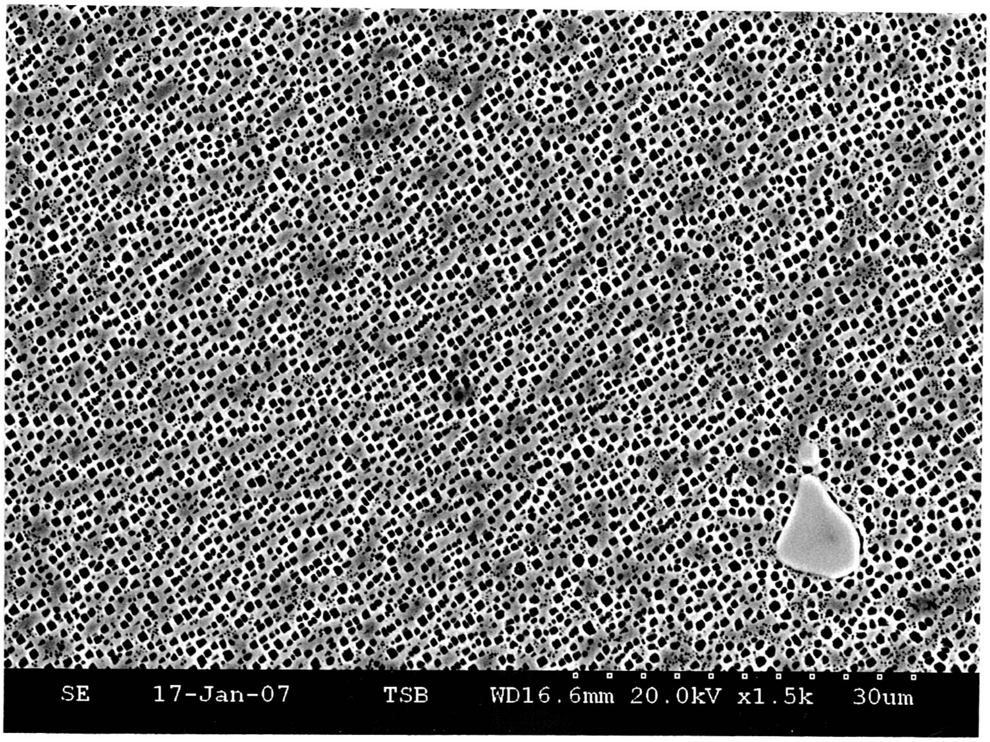


Figure 5 Microstructure of Blade #3 in the region of the tip. No evidence of grain boundary voids or inter-crystalline cracking. Magnification (a) 800X, (b) 2500X.



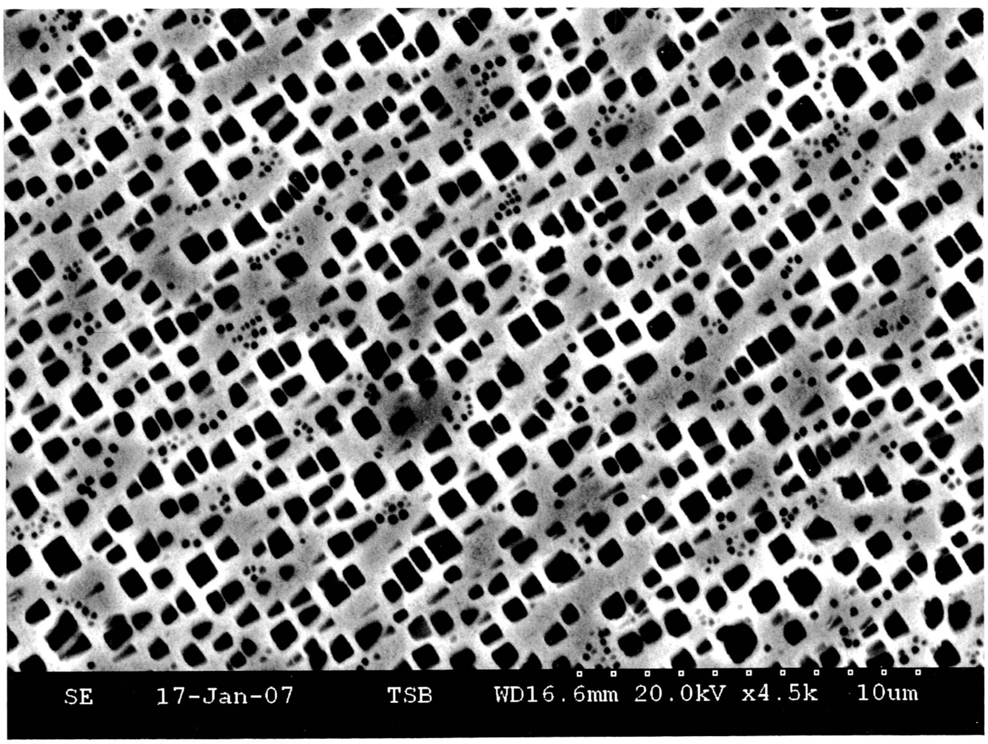


Figure 6 Microstructure of Blade #3 in the blade root region. Magnification (a) 1500X, (b) 4500X.

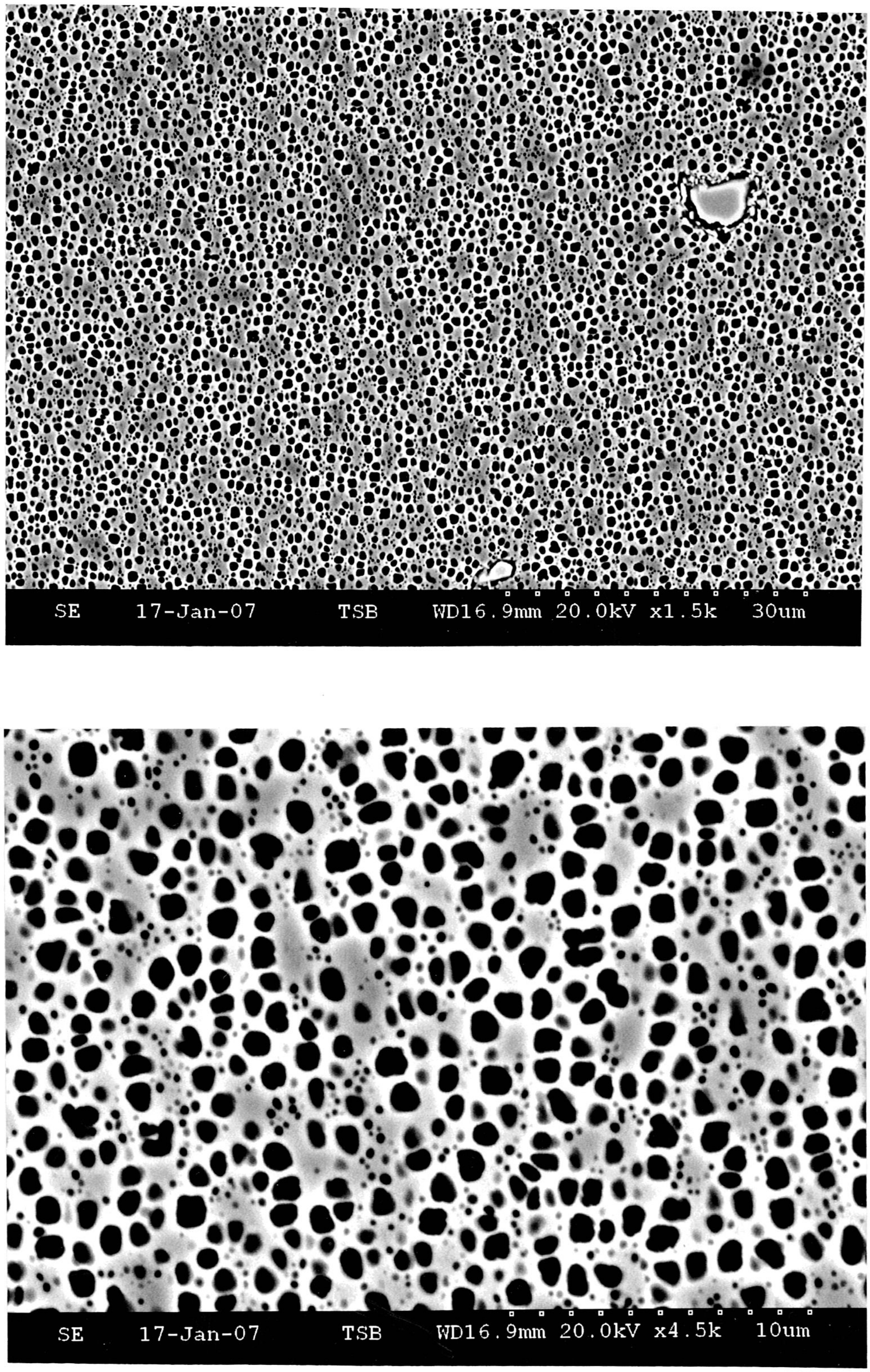
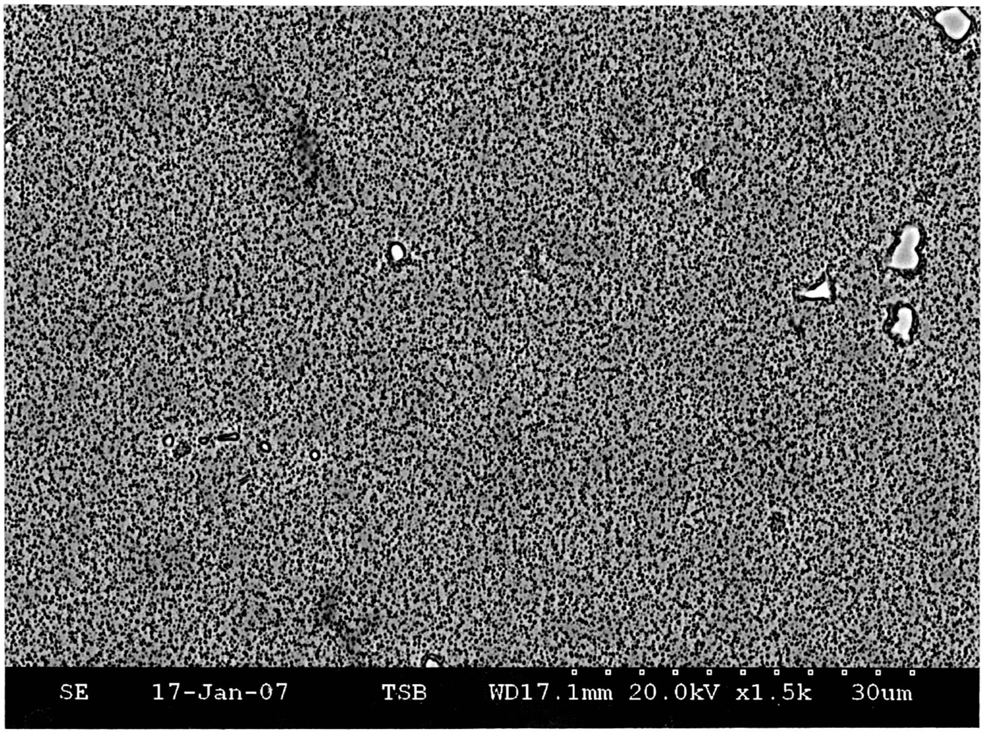


Figure 7 Microstructure of Blade #3 at approximately blade mid-span. Magnification (a) 1500X, (b) 4500X.



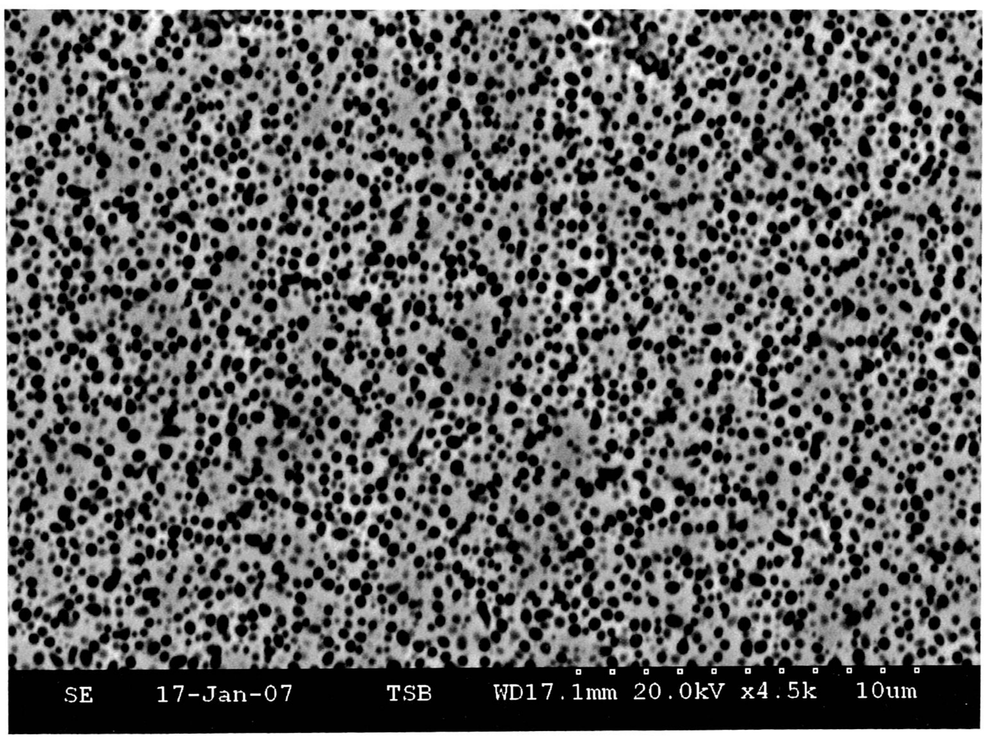


Figure 8 Microstructure of Blade #3 at the blade tip. Magnification (a) 1500X, (b) 4500X.

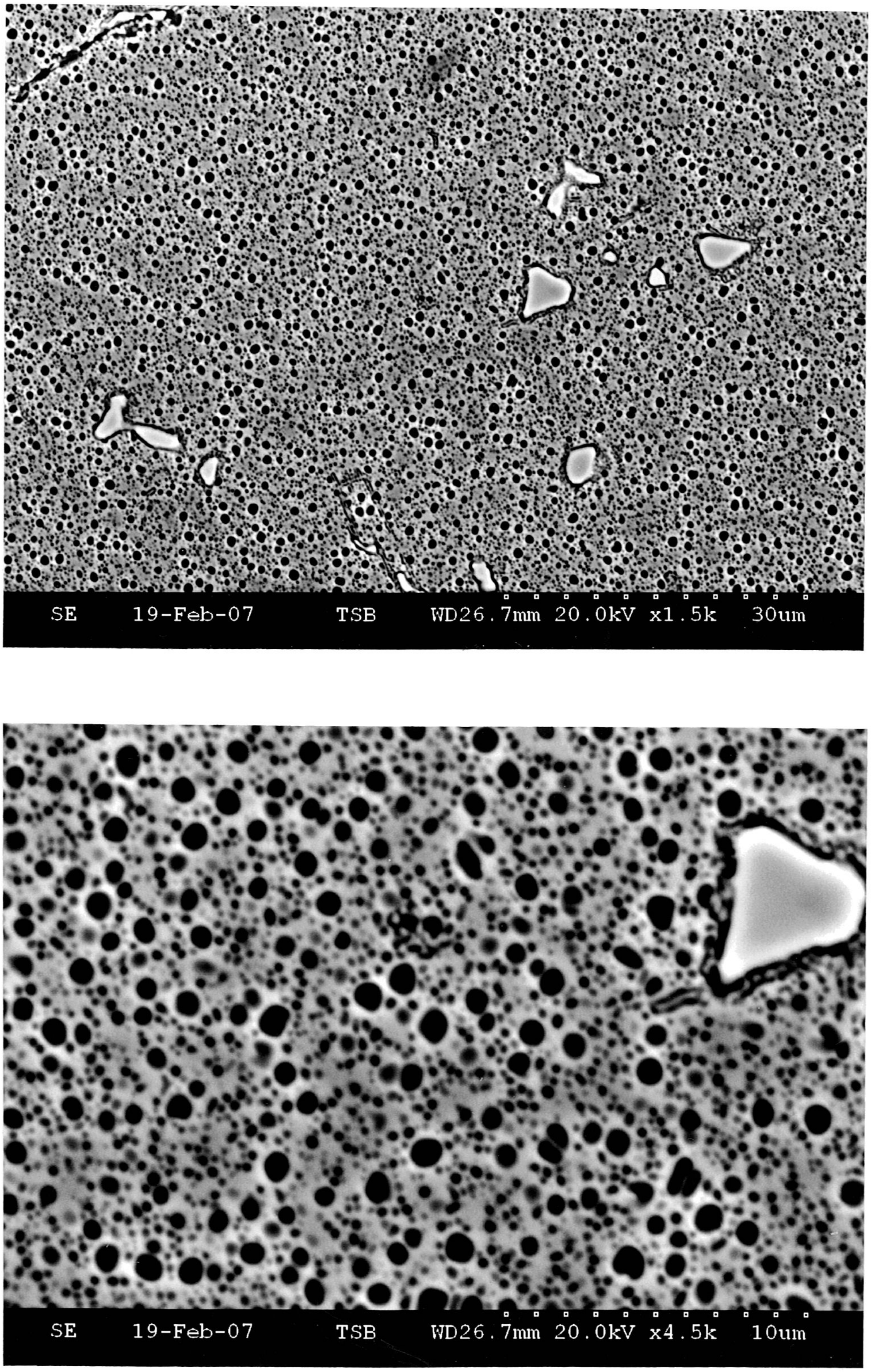
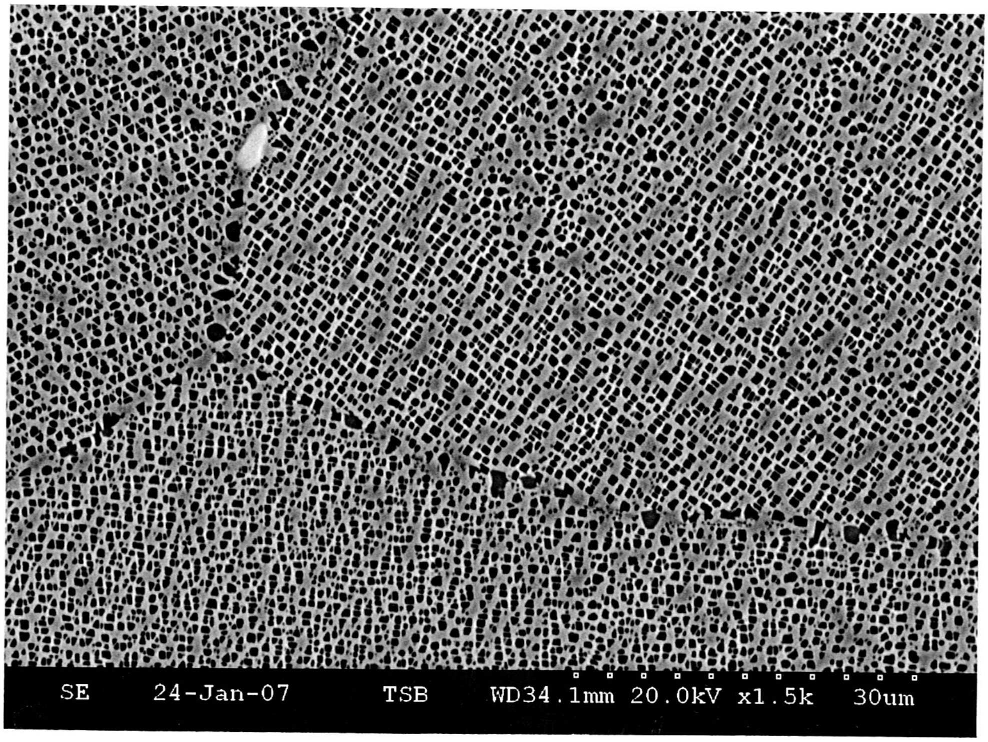


Figure 9 Microstructure of blade #3 in area between mid-span and the tip end showing the re-solutioning of the original gamma prime and appearance of a distribution of smaller second phase particles. Magnification (a) 1500X, (b) 4500X.



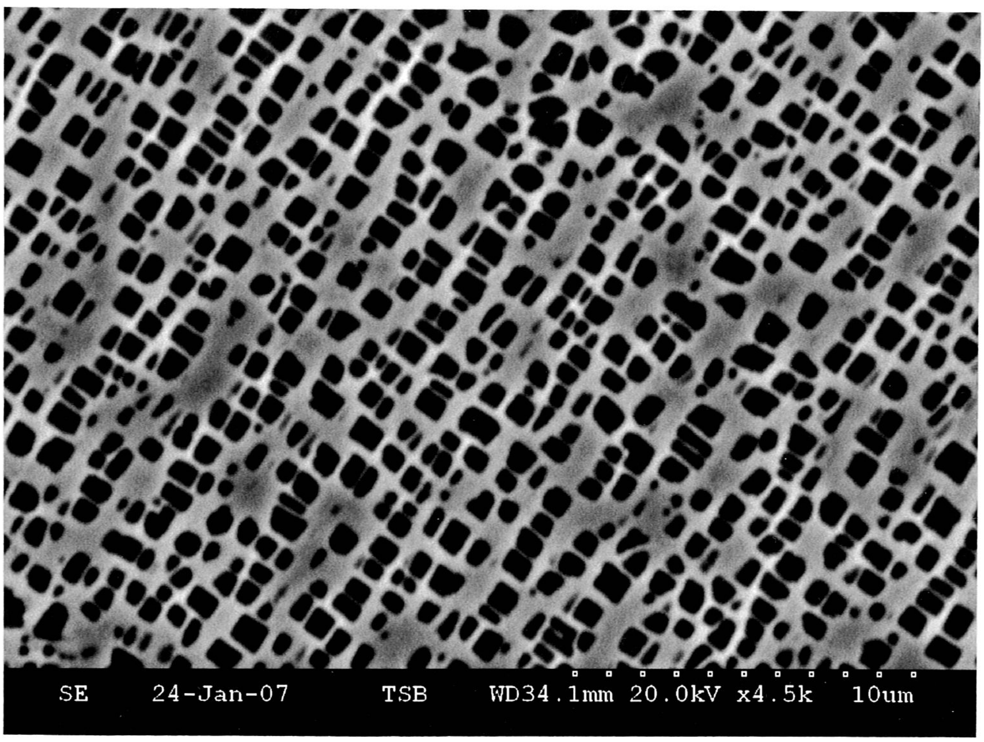


Figure 10 Microstructure of the exemplar blade in the blade root region. Magnification (a) 1500X, (b) 4500X.

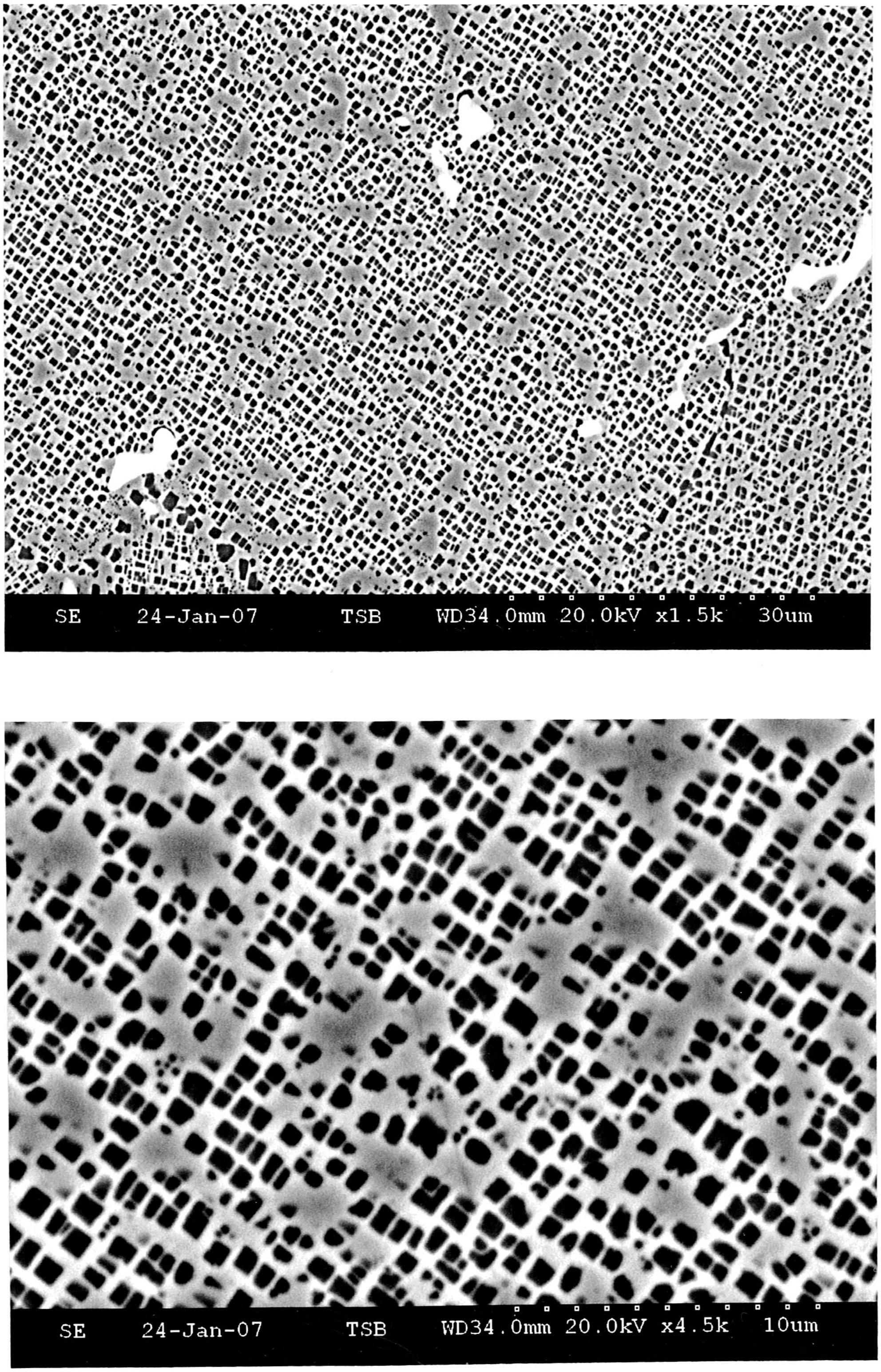


Figure 11 Microstructure of the exemplar blade at blade mid-span. Magnification (a) 1500X, (b) 4500X. Magnification (a) 1500X, (b) 4500X.

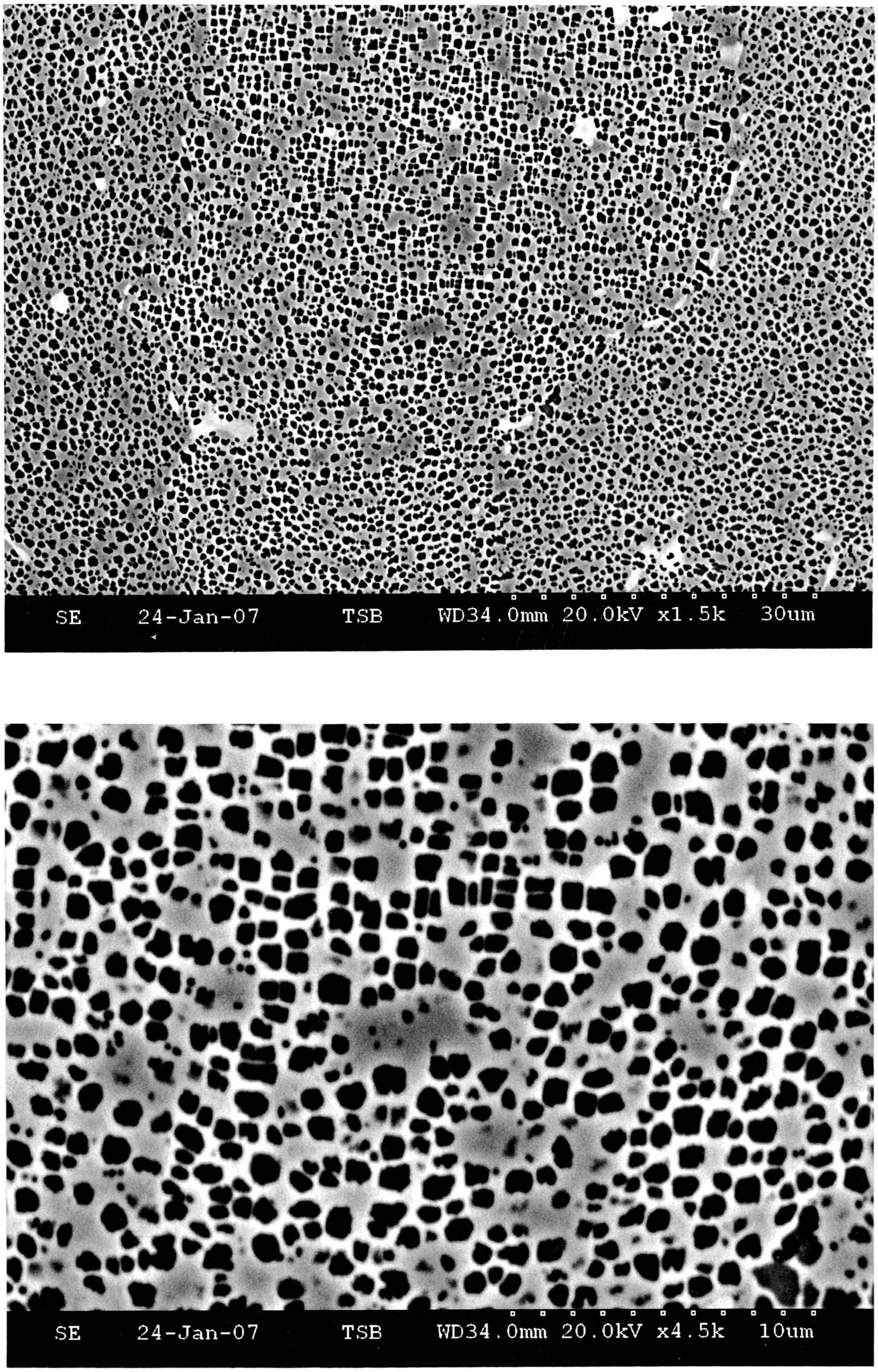
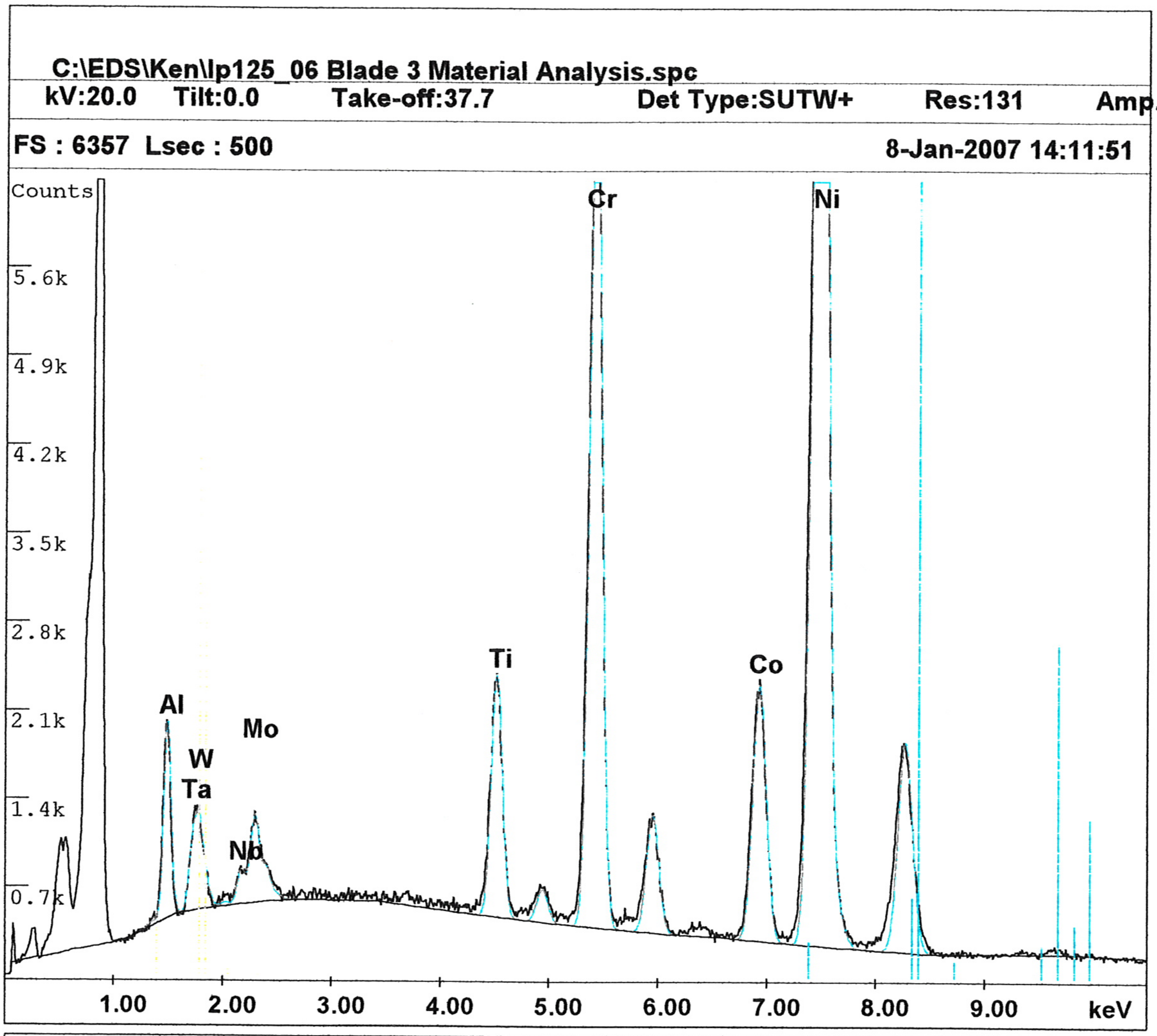


Figure 12 Microstructure of the exemplar blade at the blade tip. Magnification (a) 1500X, (b) 4500X.



EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
AlK	2.30	4.94	0.0077	1.0789	0.3123	1.0005
TaM	2.70	0.87	0.0136	0.8434	0.5961	1.0000
W M	2.13	0.67	0.0113	0.8421	0.6310	1.0000
NbL	0.72	0.45	0.0045	0.9085	0.6898	1.0013
MoL	1.63	0.99	0.0107	0.8994	0.7296	1.0017
TiK	3.24	3.92	0.0322	0.9953	0.9406	1.0617
CrK	15.65	17.46	0.1633	0.9947	0.9662	1.0859
CoK	8.60	8.46	0.0822	0.9791	0.9714	1.0056
NiK	63.03	62.25	0.6286	1.0161	0.9794	1.0022
Total	100.00	100.00				

Figure 13 Energy dispersive X-ray analysis spectrum of the material of Blade #3.