炭相圖譜

ATLAS OF CARBON MICROGRAPHS

吉林科學技術出版社
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內 容 提 要

本書共分十三章。前六章主要介紹無煙煤、冶金焦、石油焦、炭纖維等顯微結構的特點及其分類。後七章主要介紹石墨材料、炭纖維複合材料、熱解炭等顯微結構的特點以及這些特點與材料的性能、生產工藝的關係。

本書對從事炭素材料的研製、生產和使用的工程技術人員、工人及大專院校有關專業的教師、學生都有一定參考價值。

Summary

The Atlas contains thirteen sections. The classification and the microstructural characteristics of anthracites, metallurgical cokes, petroleum cokes and carbon fibers are treated in the first six sections and the topics dealt with in the remaining seven sections are graphite materials, carbon fiber composites and pyrolytic carbons, giving descriptions about their microstructural features and the bearings of these features on their performance and manufacturing technology.

The Atlas may provide something valuable for technicians and workers engaged in the research, production and utilization of carbon materials. It can also be used as a reference book for college teachers and students interested in carbon science and technology.

前　言

炭素材料包括炭纖維及其複合材料，它具有强度高、耐高溫、抗腐蝕、耐燒蝕、抗輻照以及導電、導熱性能好等特點，在冶金、化工、機電、電子、原子能以及航空和宇航等許多方面都有着重要作用，是現代科學技術所不可缺少的重要材料。

隨着科學技術的發展，炭素材料品種不斷擴大，對其要求也不斷提高，則人們愈加認識到，炭素材料作爲材料與材料科學的一個組成部分，已進入了一個新的發展時期，迫切需要從基礎上，尤其要從所用原料和製品的組織結構及其與工藝和性能的關係上進行廣泛而深入地研究，逐步認識和掌握它的規律性，以進一步推動炭素材料及其學科的發展。爲此，國內炭素材料方面的部分專家和學者，在有關單位，尤其是吉林炭素廠的大力支持下，組織編寫了《炭相圖譜》這本書。希望對從事炭素材料的研製、生産和使用的科技人員，大專院校有關專業的教學能有所幫助。

這次出版的《炭相圖譜》，比較系統地介紹了炭素材料顯微結構的特點以及這些特點與材料的性能和製備工藝的關係。作者在論述炭素材料顯微結構的分類、結構與性能的關係時，既考慮了生産和應用中積纍的經驗，又吸取了當代某些新的科研成果，並有所開拓，基本上體現了《炭相圖譜》應有的科學性、典型性和實用性。這對於鑑定材料的結構並由此預測材料的性能，對合理選擇原料和生産工藝以製取所需性能的製品都可提供有益的參考依據。

由於《炭相圖譜》是初次編寫出版，如有不足之處，望國內外讀者指正。

高　艮

一九八五年十二月於北京

Preface

Carbon materials, including carbon fibers and their composites, are generally high in strength and good in conduction for both heat and electricity. They are furthermore characterized by their excellent performance in applications where intensive corrosion, strong irradiation and severe ablation are prevailing. Therefore, as a special class of materials indispensable for modern science and technology, carbon materials have been playing important roles in various fields, such as metallurgy, chemical engineering, machinery, electricity, electronics, nuclear energy, aeronautics and astronautics.

It has been recognized by more and more people that carbon materials with their ever-increasing varieties and ever-improving qualities have ushered in a new era in the course of their development. Naturally, it seems urgent at present that an all-side piercing research on the fundamentals of carbon technology should be taken, especially on the relationship between microscopical structures and technological properties for both the raw materials and the products with the prospect that we would gradually be able to master the governing laws and thereby to inspire a great drive to carbon science. Some scholars and specialists, then, came together and got started to compile this Atlas, under the support from many sides, especially from Jilin Carbon Plant, looking forward to providing something useful to those engaging in research and development or in manufacture and utilization of this special kind of materials. It is expected that the Atlas may also offer something valuable to college teachers and students.

The present edition of the Atlas of Carbon Micrographs deals mainly with the raw materials and the products of carbon industry. The compilers did do their best in presentation of the micrographs systematically and in showing the fact that the manufacturing technology and properties of carbon materials are closely related to their microstructural characteristics. On topics, such as the classification of microstructures and the dependence of properties upon structure, the compilers adopted not only the valuable experience accumulated in manufacturing practice and various applications but also the recent achievements in scientific exploration. There are, in addition, some fresh and original views of the compilers themselves. I do believe that the principles of typicality, usefulness and scientific precision have been embodied in the selection of the micrographs. The Atlas can, I should think, provide a valuable aid for the characterization of the relevant materials, for the prediction of properties of the products and also for the reasonable selection of raw materials and manufacturing technology to make products with required qualities.

There must be some defects in the work of compilation and publication, owing to its being the first time for us to deal with a work of this sort. We shall be very glad to accept comments and suggestions from foreign or domestic specialists.

Gao Liang

Beijing

December 1985

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1 無 煙 煤

根據成煤原始物料的不同，煤可分爲腐植煤、殘植煤、腐泥煤三大類，其中腐植煤在自然界中分佈最廣，蘊藏量也最大。腐植煤主要是由高等植物生成的。根據成煤過程中的煤化程度的不同，腐植煤又可分爲泥炭、褐煤、煙煤和無煙煤等不同類型。

無煙煤是腐植煤類中變質程度最高的一種煤，煤中各組份均不透明。因此，在研究無煙煤的顯微結構時，應將無煙煤試樣製成光片，在反射式顯微鏡下進行觀察。

在普通光學顯微鏡下，無煙煤中除了明顯可以辨認的絲炭（絲質體）、不同形狀的突起、稍亮的斑狀物以及殘留的腔孔或孔隙外，其餘部分是相當均一的。由於無煙煤的各向異性程度差，因此，即使是在偏光顯微鏡下也難以獲得令人滿意的清楚的顯微圖像。

炭素工業上所使用的無煙煤是預先在1300℃或更高溫度下熱處理過的無煙煤（即煅燒無煙煤）。煅燒無煙煤除了比原無煙煤的硬度大、裂紋多、反光能力强之外，其各向異性程度也得到相應地提高，但同石油焦相比，其各向異性程度還是很差的：在正交偏光加石膏檢板的條件下，轉動顯微鏡的載物台時，只能略感到干涉色的變化，而且顏色也不鮮艷。

在普通光學顯微鏡下，煅燒無煙煤比原無煙煤更爲均一，各結構成份趨於一致，難以分辨，只有在偏光顯微鏡下才能加以區分，並可獲得其清晰的顯微圖像。

根據煅燒無煙煤在偏光顯微鏡下的形態，可將其顯微結構分爲鏡質體、絲質體、碎屑體和微粒體。

1.1 鏡質體

鏡質體多呈帶狀存在於煤中，且垂直條帶的方向上常常存在裂紋（圖１－１）。根據結構的不同，鏡質體可分爲無結構鏡質體和有結構鏡質體。

無結構鏡質體：無結構，組織均一（圖１－１、２）。

有結構鏡質體：在顯微鏡下可以看到呈綫狀（圖１－３）、透鏡狀（圖１－４）的殘痕，或木質細胞結構（圖１－５），或細胞壁幾乎融成一片，僅在有些地方留下一些形狀不規則的孔隙（圖１－６）。

1.2 絲質體

絲質體多以夾層狀存在於煤中，它是煤中木質細胞結構保存最好的結構成份。根據結構保存完好程度，絲質體可分爲細胞結構較完整的（圖１－７～９）和不完整的（圖１－10）。由於絲質體的細胞腔多被黏土類物質所塡充（圖１－９），故其雜質含量較高。

1.3 碎屑體

碎屑體是由粒度小於100μm的圓形、橢圓形或形狀不規則的各種成份的斷片、碎塊構成

的。碎屑體可呈分散狀態（圖1－11），或聚積狀態（圖1－12）存在於煤中。

1.4 微粒體

微粒體呈圓形，粒度1μm左右。微粒體主要填充在細胞腔裏（圖1－5），或呈聚積狀態（圖1－13），或與碎屑體混合在一起（圖1－14），存在於煤中。

除此之外，無煙煤中還存在部分礦物，如黏土類物質(圖1－9)、黃鐵礦和石英(圖1－15)等。

1 Anthracite

According to the coal-forming plants, coals can be divided into sapropelic, humolitic and liptobiolitic series. The humolites or humic coals derived from higher plants are vastly distributed over the world, the reserve being the most abundant. Humic coals are further divided into peats, lignites, bituminous coals and anthracites according to the degree of coalification.

In the humic series of coals, the anthracites have undergone the deepest metamorphic changes and therefore, all their constituents are opaque to light and their microstructures must be observed under microscope by reflected light with the specimens prepared in the form of polished blocks or polished grain mounts.

Under ordinary optical microscope, on the polished surface of an anthracite, only the fusinites, reliefs in various shapes and pores or cavities can be seen clearly, the other constituents being fairly homogeneous. Generally, for the anthracites, a clear micrograph can hardly be obtained even by a polarized light microscope, owing to their optical anisotropy being rather low.

The anthracites are calcined at a temperature higher than 1300°C, when they are used as raw materials for carbon products. After calcination, the anisotropy of an anthracite is raised while it becomes harder, more porous and more capable in reflecting light. But in comparison with petroleum cokes, the optical anisotropy of the calcined anthracites is still rather low and the interference colours appear very faint on rotating the objective stage, so in no case can a brilliant colourful micrograph be obtained even under a polarized light microscope with cross Nicols and gypsum plate.

Under ordinary microscope the calcined anthracite becomes more homogeneous than the original, the different constituents can hardly be recognized. Only by polarized light microscopy can a clear micrograph be obtained.

According to the morphology of the microstructures, the microconstituents of anthracite may be divided into vitrinite, fusinite, degradinite and micrinite.

1.1 Vitrinite

Vitrinites occur in bands often with fissures perpendicular to the band as shown in Fig. 1-1. There are two types, collinites and tellinites, which are different in structure.

Collinites are structureless and homogeneous as shown in Fig. 1-1 and 1-2.

Tellinites have certain structures which when viewed under microscope appear as filamentous or lenticuiar relics as shown in Fig. 1-3 and Fig. 1-4 respectively, or as cellular structures of a wood as shown in Fig. 1-5. There is sometimes a structure, in which the cell walls are fused together leaving irregular pores or gaps somewhere as shown in Fig. 1-6.

1.2 Fusinite

Fusinites often occur in interstitial layers, the cell structure of the coal-forming plants being reserved to a remarkable degree. The cell cavities are often filled with clayey matter as shown in Fig. 1-9, therefore, in fusinites the content of mineral impurities is higher than in the other petrographical constituents. The cell structures in some fusinites are reserved very well as shown in Fig. 1-7 through 1-9, and in some others, the cell structures are reserved to a less extent as shown in Fig. 1-10.

1.3 Degradinite

Degradinites consist of globular, oval or irregular fragments, of which the size is less than 100 micrometers. The fragments may occur in a dispersed state as shown in Fig. 1-11, or in an agglomerated state as shown in Fig. 1-12.

1.4 Micrinite

Micrinites consist of spherical bodies, of which the size is about one micrometer. They mainly fill up the cell cavities (Fig. 1-5) or agglomerate together (Fig. 1-13) or mix themselves with degradinites (Fig. 1-14).

In anthracite, in addition to the petrographical constituents mentioned above, there are some species of minerals, e.g. clay (Fig. 1-9), pyrite and silica (Fig. 1-15).

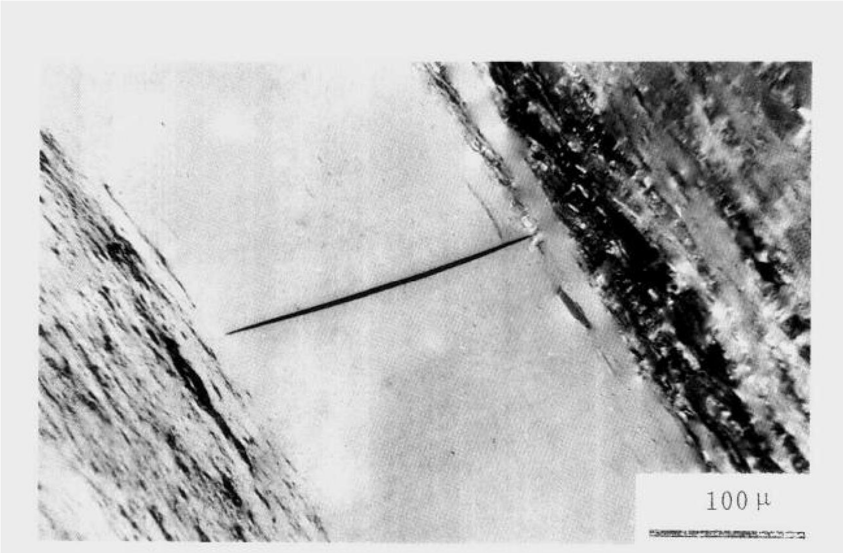

圖 1 － 1 無煙煤　無結構鏡質體（帶狀，有裂紋）交叉偏光95°

Fig. 1－1. Anthracite Collinite in bands with fissures Nicols crossed at 95°

圖 1 － 2 無煙煤　無結構鏡質體　交叉偏光95°

Fig. 1－2. Anthracite Collinite Nicols crossed at 95°

圖1－3 無煙煤　有結構鏡質體（有綫狀殘痕）交叉偏光95°
Fig. 1－3. Anthracite Tellinite with filamentous relics Nicols crossed at 95°

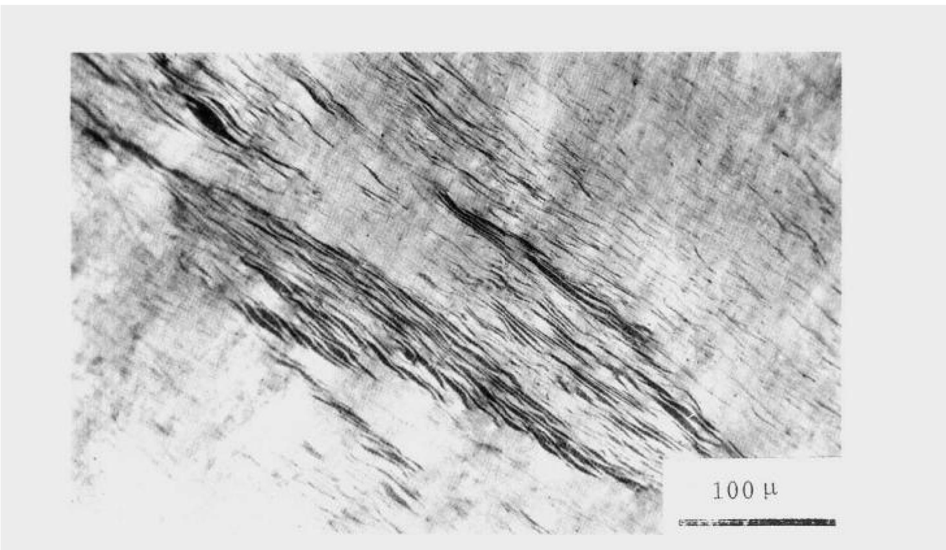

圖1－4 無煙煤　有結構鏡質體（有透鏡狀殘痕）交叉偏光95°
Fig. 1－4 Anthracite Tellinite with lenticular relics Nicols crossed at 95°

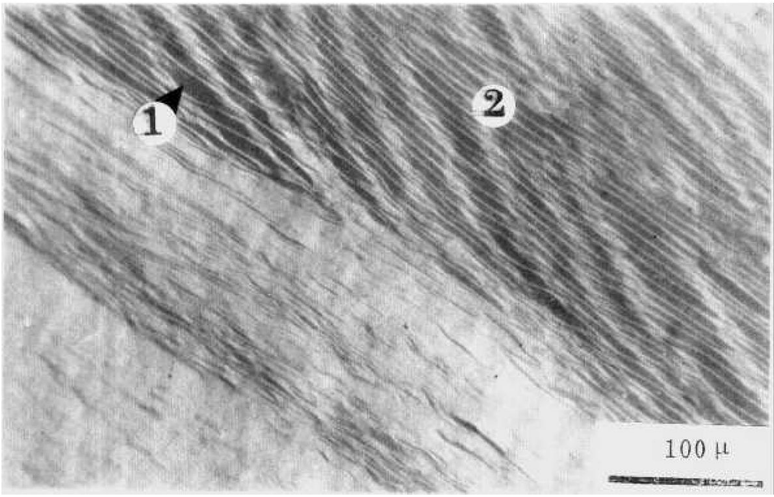

圖 1 － 5 無煙煤　有結構鏡質體

① 微粒體　② 木質細胞結構　交叉偏光95°

Fig. 1－5. Anthracite Tellinite

1. micrinite 2. wood cell structure Nicols crossed at 95°

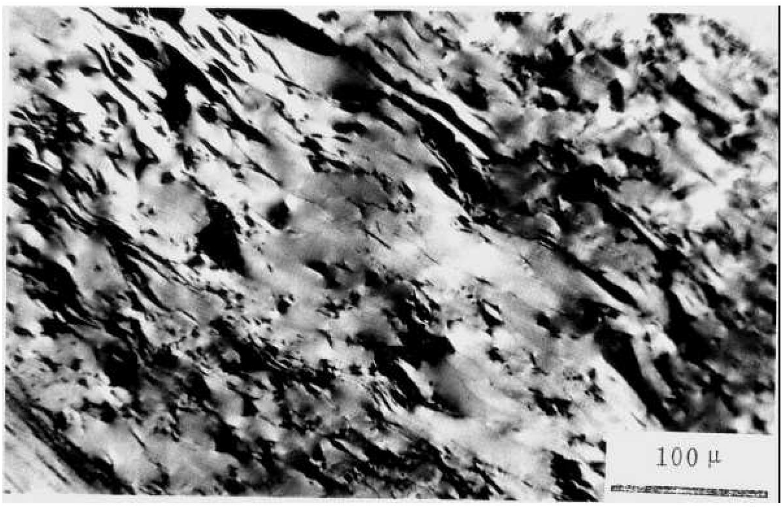

圖 1 － 6 無煙煤　有結構鏡質體

（有形狀不規則的孔隙）交叉偏光95°

Fig. 1－6. Anthracite Tellinite with irregular pores Nicols crossed at 95°

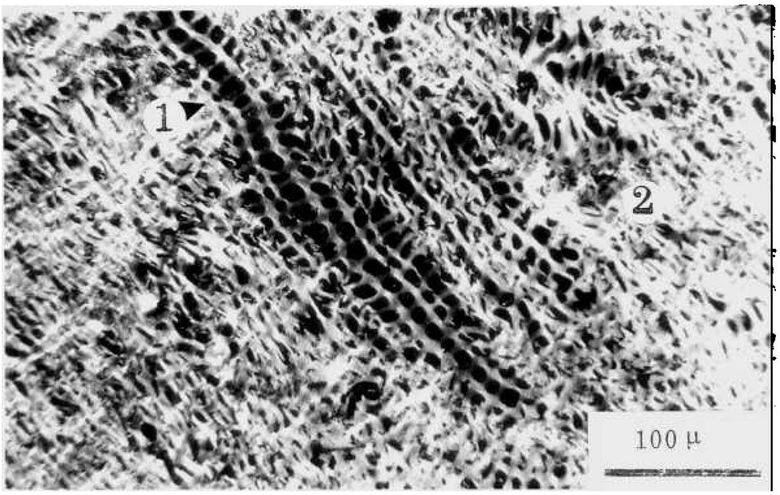

圖 1 － 7 無煙煤　絲質體

① 細胞結構較完整　② 細胞結構不完整　交叉偏光95°

Fig. 1－7. Anthracite Fusinite 1. cell structure reserved 2. cell structure distorted Nicols crossed at 95°

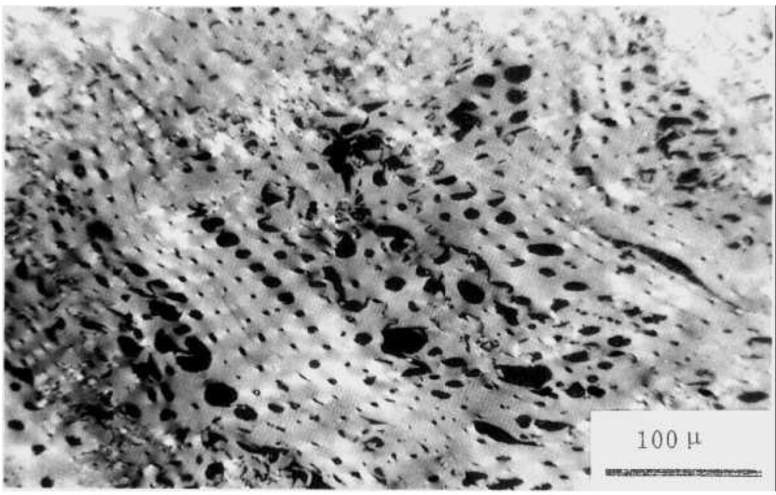

圖 1 － 8 無煙煤　絲質體　交叉偏光95°

Fig. 1－8. Anthracite Fusinite Nicols crossed at 95°

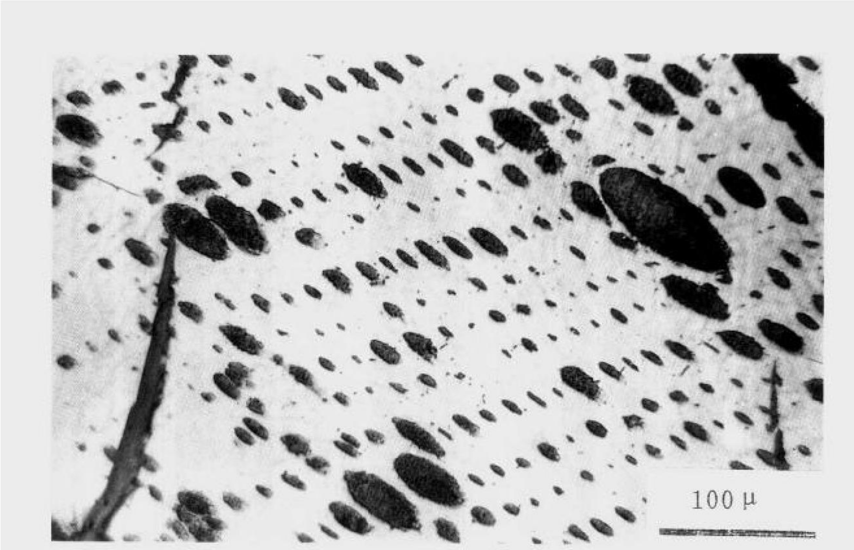

圖 1 － 9 無煙煤　絲質體
（橢圓形腔孔內為黏土）交叉偏光95°
Fig. 1－9. Anthracite Fusinite clayey matter in oval cavities Nicols crossed at 95°

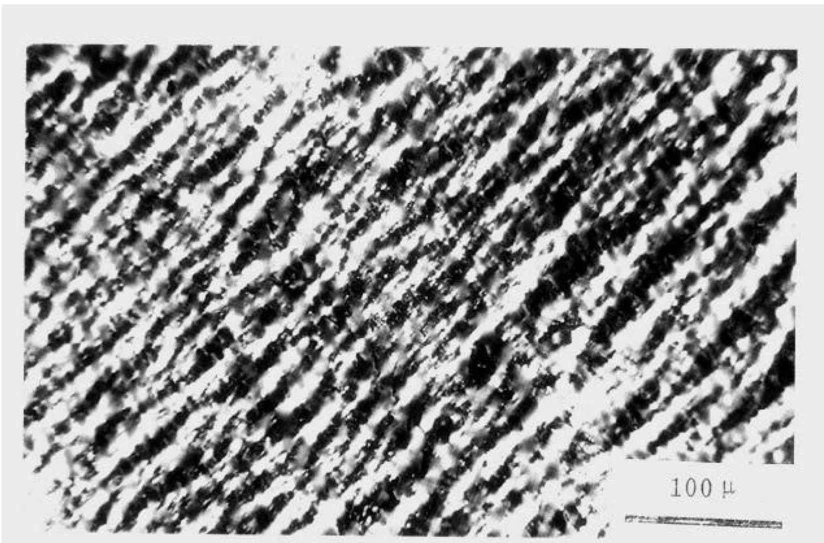

圖 1 －10無煙煤　絲質體（細胞結構不完整）交叉偏光95°
Fig. 1－10. Anthracite Fusinite cell structure distorted Nicols crossed at 95°

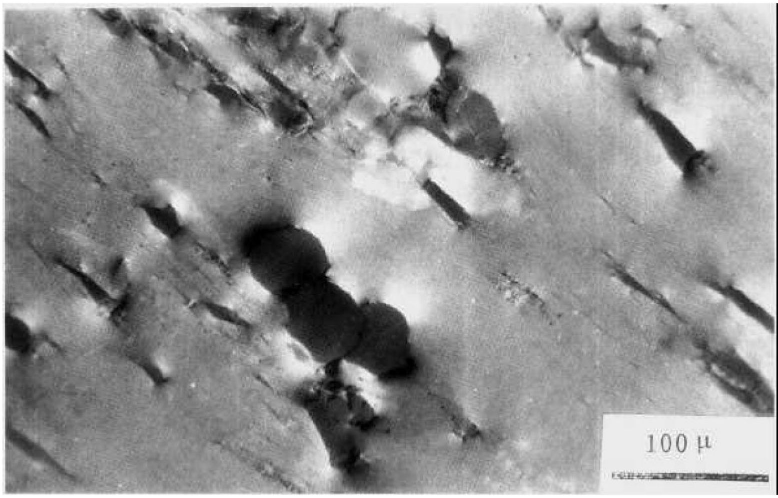

圖 1 －11無煙煤　碎屑體（呈圓形和橢圓形）交叉偏光95°

Fig. 1 -11. Anthracite Degradinite in circular and oval forms Nicols crossed at 95°

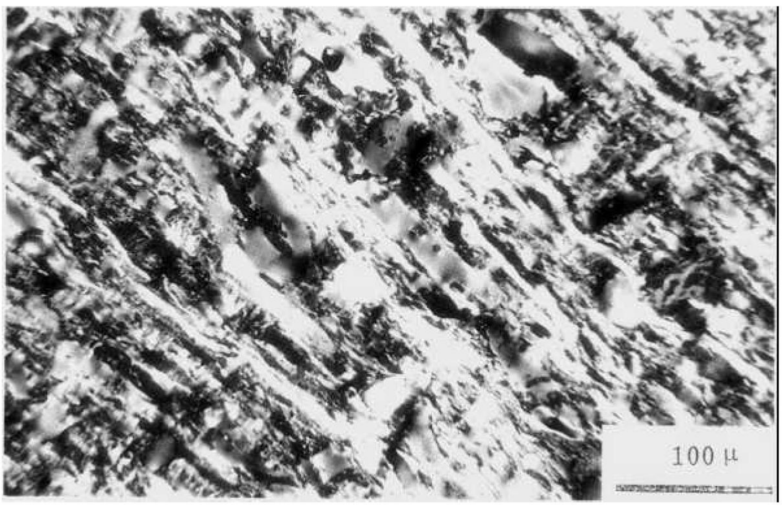

圖 1 －12無煙煤　碎屑體（呈細帶狀）交叉偏光95°

Fig. 1 -12. Anthracite Degradinite in thin bands Nicols crossed at 95°

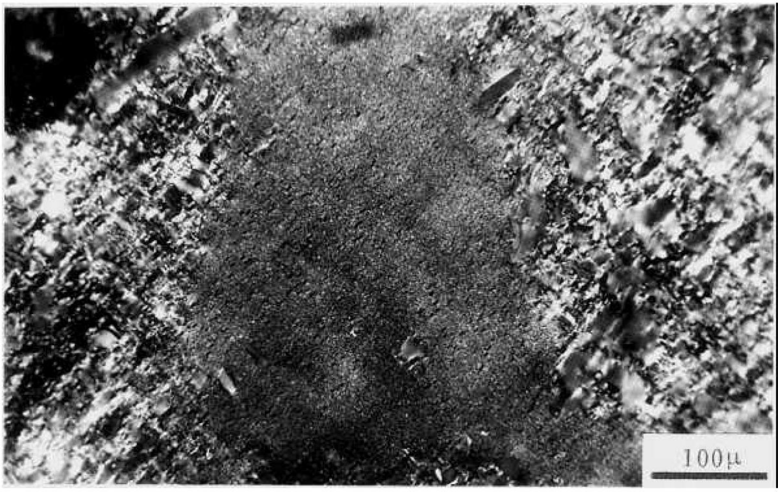

圖 1 －13 無煙煤　微粒體（中間部分）交叉偏光95°
Fig. 1－13. Anthracite Micrinite (in the central part) Nicols crossed at 95°

圖 1 －14 無煙煤　微粒體
（與碎屑體混合在一起）交叉偏光95°
Fig. 1－14. Anthracite Micrinite mixed with degradinite Nicols crossed at 95°