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主编 钱伟长

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（第21集）

主编：钱伟长

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王宽诚教育基金会《学术讲座汇编》

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钱伟长　主 编

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王宽诚教育基金会简介

王宽诚先生(1907~1986)为香港著名爱国人士，热心祖国教育事业，生前为故乡宁波的教育事业做出积极贡献。1985 年独立捐巨资创建王宽诚教育基金会，其宗旨在于为国家培养高级技术人才，为祖国四个现代化效力。

王宽诚先生在世时聘请海内外著名学者担任基金会考选委员会和学务委员会委员，共商大计，确定采用“送出去”和“请进来”的方针，为国家培养各科专门人才，提高内地和港澳高等院校的教学水平，资助学术界人士互访以促进中外文化交流。在此方针指导下，1985、1986 两年，基金会在国家教委支持下，选派学生 85 名前往英、美、加拿大、德国、瑞士和澳大利亚各国攻读博士学位，并计划资助内地学者赴港澳讲学，资助港澳学者到内地讲学，资助美国学者来国内讲学。正当基金会事业初具规模、蓬勃发展之时，王宽诚先生一病不起，于 1986 年年底逝世。这是基金会的重大损失，共事同仁，无不深切怀念，不胜惋惜。

自 1987 年起，王宽诚教育基金会继承王宽诚先生为国家培养高级技术人才的遗愿，继续对中国内地、台湾及港澳学者出国攻读博士学位、博士后研究及学术交流提供资动。委请国家教育部、中国科学院和上海大学校长钱伟长教授等逐年安排资助学术交流的项目。相继与（英国）皇家学会、英国学术院、法国科研中心、德国学术交流中心等著名欧州学术机构合作，设立“王宽诚（英国）皇家学会奖学金”、“王宽诚英国学术院奖学金”、“王宽诚法国科研中心奖学金”、“王宽诚德国学术交流中心奖学金”，资助具有博士学位、副教授或同等学历职称的中国内地学者前往英国、法国、德国等地的高等学府及科研机构进行为期 3 至 12 个月之博士后研究。

王宽诚教育基金会过去和现在的工作态度一贯以王宽诚先生倡导的“公正”二字为守则，谅今后基金会亦将秉此行事，奉行不辍，借此王宽诚教育基金会《学术讲座汇编》出版之际，特简明介绍如上。王宽诚教育基金会日常工作繁忙，基金会各位董事均不辞劳累，做出积极贡献。

钱 伟 长

二〇〇二年六月

前　言

王宽诚教育基金会是由已故全国政协常委、香港著名工商企业家王宽诚先生(1907~1986)出于爱国热忱，出资一亿美元于1985年在香港注册登记创立的。

1987年，基金会开设“学术讲座”项目，此项目由当时的全国政协委员、现任全国政协副主席、著名科学家、中国科学院院士、上海大学校长、王宽诚教育基金会贷款留学生考选委员会主任委员兼学务委员会主任委员钱伟长教授主持，由钱伟长教授亲自起草设立“学术讲座”的规定，资助内地学者前往香港、澳门讲学，资助美国学者来中国讲学，资助港澳学者前来内地讲学，用以促进中外学术交流，提高内地及港澳高等院校的教学质量。

本汇编收集的文章，均系各地学者在“学术讲座”活动中的讲稿。文章作者中，有年逾八旬的学术界硕彦，亦有由王宽诚教育基金会考选委员会委员推荐的学者和后起之秀。文章内容有科学技术，有历史文化，有经济专论，有文学，有宗教和中国古籍研究。本汇编涉及的学术领域颇为广泛，而每篇文章都有一定的深度和广度，分期分册以《王宽诚教育基金会学术讲座汇编》的名义出版，并无偿分送国内外部分高等院校、科研机构和图书馆，以广流传。

王宽诚教育基金会除资助“学术讲座”学者进行学术交流之外，在钱伟长教授主持的项目下，还资助由国内有关高等院校推荐的学者前往欧、美、亚、澳参加国际学术会议，出访的学者均向所出席的会议提交论文，这些论文亦颇有水平，本汇编亦将其收入，以供参考。

王宽诚教育基金会学务委员会

凡　例

(一)编排次序

本书所收集的王宽诚教育基金会学术讲座的讲稿及由王宽诚教育基金会资助学者赴欧、美、亚、澳参加国际学术会议的论文均按照文稿日期先后或文稿内容编排刊列，不分类别。

(二)分期分册出版并作简明介绍

因文稿较多，为求便于携带，有利阅读与检索，故分期分册出版，每册约 150 页至 200 页不等。为便于读者查考，每篇学术讲座的讲稿均注明作者姓名、学位、职务、讲学日期、地点、访问院校名称。内地及港、澳学者到欧、美、澳及亚洲的国家和地区参加国际学术会议的论文均注明学者姓名、参加会议的名称、时间、地点和推荐的单位。上述两类文章均注明由王宽诚教育基金会资助字样。

(三)文字种类

本书为学术性文章汇编，均以学术讲座学者之讲稿原稿或参加国际学术会议者向会议提交的论文原稿文字为准，原讲稿或论文是中文的，即以中文刊出，原讲稿或论文是外文的，仍以外文刊出。

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Synchrotron Radiation in Mesomechanical Experiments

Wu Xiaoping*

(University of Science and Technology of China, Anhui 230026, China)

In mechanical domain the "MESO "scale is smaller than macro-scope and larger than microscope. For example, as macroscope point of view fibre reinforced epoxy material seems as uniform rather isotropic or un-isotropic. If the fibre and the interface between fibre and matrix are considered, this is meso-scope.

1. Introduction

1.1 Many instruments are used to measure the surface deformations in meso-scale. Such as TEM, FSEM, UHVEM, FAM and optical microscope. The measurement methods for surface are as follows

(1) Correlation

The correlation method is to recognize each "point" position on patterns, which come from any instrument before and after loading. From these information the whole field deformation can be obtained. The "point" can be artificial point array or speckle, laser speckle and other marks.

Experimental examples are bi-crystal copper under tension, solder joints of chip suffers heating. The sensitivity is high as nm.

(2) Moire Interferometry

High spatial frequency grating is attached on surface. The symmetrical collimate laser lights illuminate on surface then the interference fringe pattern can show the whole field displacment component contour lines with high quality.

The residual strain around a cool-fasten hole and strain concentration on interface between different layers of composites are measured.

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* 伍小平教授，中国科学技术大学力学和机械工程系，中国科学院院士，中国实验力学学会主席，由王宽诚教育基金会资助，于 2000 年 11 月赴香港科技大学、香港理工大学讲学，此为其讲稿中的部分内容。

(3) Micro ESPI

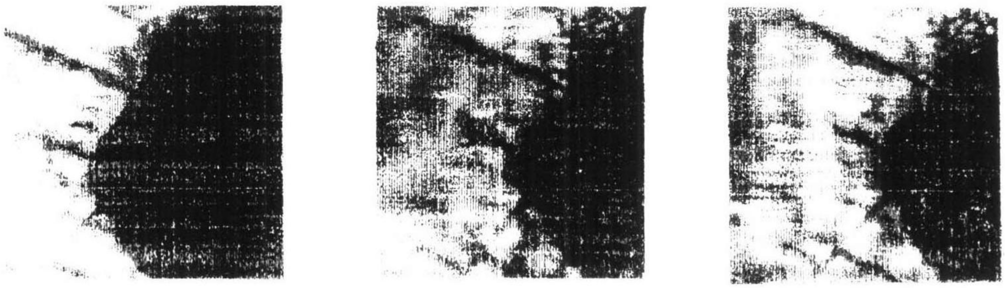
Electronic Speckle Pattern Interferometry (ESPI) is a useful tool for measure the macro-, meso- or micro- scale deformation in situ. Many experiments have been done such as solder joints by heating, crack tip deformation, vibration mode of small element.

1.2 There are some instruments can be used to measure the deformation inside the specimen body, such as STEM, Electron Beams, X-ray microscope, Synchrotron radiation, and Acoustic microscope.

Two examples are shown by Acoustic microscope:

(1) DZ22 stainless steel–around a laser drilled hole (0.125 mm in diameter) inside the specimen.(Fig.1)

➤ SAM(SCANNING ACOUSTIC MICROSCOPE)

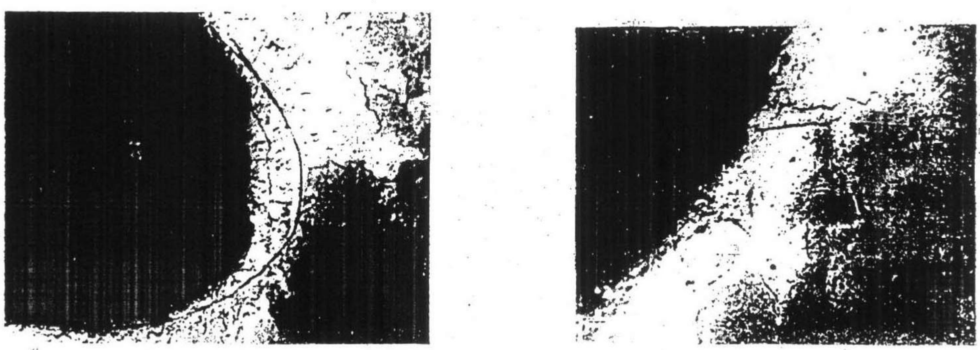


DZ22 SURFACE IMAGE | 50 MICRO INSIDE | 150 MICRO INSIDE

Fig.1 Stainless steel, detecting inner cracks by SAM

(2) 45# steel—same kind hole as above and circular cracks or radio cracks are found under surface 118 and 158 micrometers deep inside the specimen. (Fig. 2)

➤ SAM(SCANNING ACOUSTIC MICROSCOPE)



45# STEEL 158 MICRO INSIDE | 118 MICRO INSIDE

Fig.2 Circular cracks (left) and radio cracks (right) in steel by SAM

1.3 Synchrotron Radiation is a powerful light source for the observation inside the thick specimens either metals or composites.

2. Synchrotron Radiation Source

The brightness of synchrotron radiation is higher than those commercial X-ray sources two orders or more. It is a high collimate, high coherent, high brightness light source and has high temporal frequency structure.

There are not many scientists use synchrotron radiation to study the mechanical properties of materials because it is more expansive. K.Sakamoto studied the microstructure of SiC(fibre)/Si3N4 and T. Hirano observed the crack in it. S.R. Stock researched the structure of SiC/A1 under three-point bending. T.M. Breung and T Hirano studied the damage evolution under tension of SiC/A1 and the latter did more research on fibre (long or short) pull out and debound. U. Bonse observed the phase of A1203/A1. W.B.Lindquist measured the voids of a porous media. Fortunately, China has found two National Laboratories which can support synchrotron radiation cheaply.

(1) HARL–National Synchrotron Radiation Laboratory (The University of Science and Technology of China, Anhui)

There are 5 beam lines are found and over 23 beam lines are building. For mechanical research, among the 5 beam lines, Microscope beam line and Lithography beam line have been used successful. And after Wiggler insert, a material Mechanical Station is found which is a professional station for mechanical research.

(2) BEPC–Beijing Electron Positron Collider (Institute of High Energy Physics, Chinese Academy of Science, Beijing)

This lab can give synchrotron radiation as light source to do researches about two months each year. The brightness is one or two orders higher than NSRL. The Topography Station of synchrotron Radiation Section is suitable.

3. Mesomechanical Experime. ts by Synchrotron Radiation

3.1 Detecting damage in a silicon strip (Fig.3)

In Microscope Beam Line an interferometer cut the spectrum of synchrotron radiation as barrow band source and focus in 2 μm by Fresnel Zone. Using two-dimensional PZT stage the specimen can be moved and 50 μm×50μm area is detected. The transfer energy is received by "multi-wire proportional chamber " and the damaged areas are shown, Fig.3. The found smallest hole is about 5 μm in diameter inside the strip. The interesting resolute is a set of holes in the front of crack tip are shown. This kind damage had been found in macro-scale too.

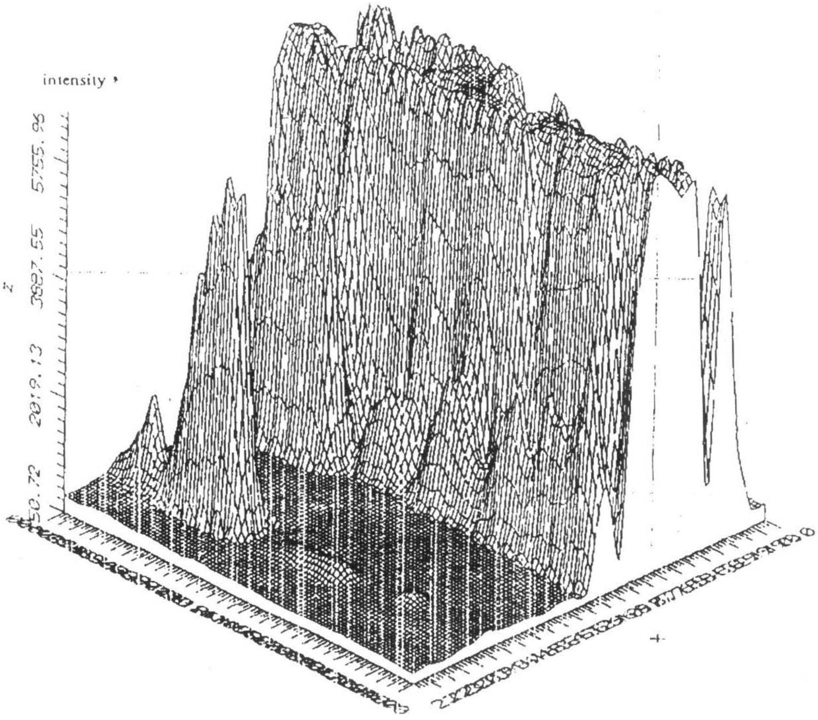


Fig.3 Damage in a silicon strip (Measured area: 50μm × 50μm)

3.2 Boron fibre /epoxy (Boron fibre embedded in epoxy (Fig. 4–Fig.7)

This experiment is done in Lithography Beam Line. At experiment section entrance the synchrotron radiation is expanded as 10 mm wide. An iron mirror reflects and scans it almost 10 mm × 10mm area can be detected. The receiver is PMMA (Photo resist for X-ray) and the resolution is 0.1μm.

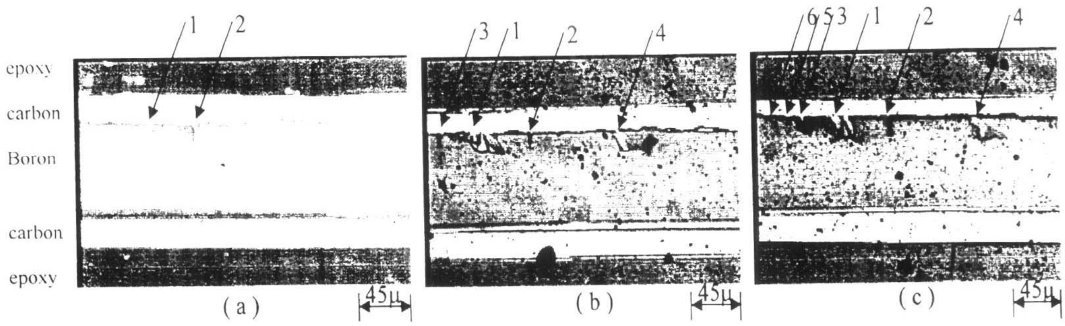


Fig.4 Boron fibre/epoxy. The damages between Boron/carbon and Carbon/epoxy. The damage evolution under tension loading step by step.

Boron fibre is 120 μm in diameter and carbon cover 30 μm thick. When the fibre suffers tension and loading increase step by step the damages between boron and carbon are serious and the damage evolutions can been seen clearly.

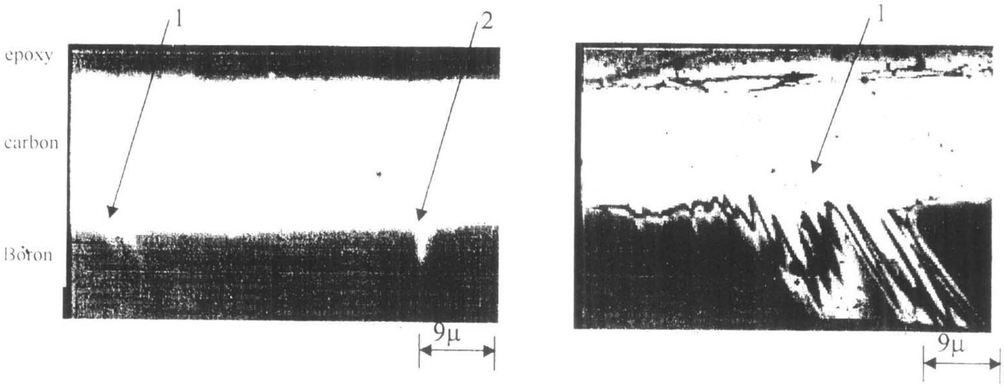


Fig.5 Enlarged area of Fig.4 (a) and (b)

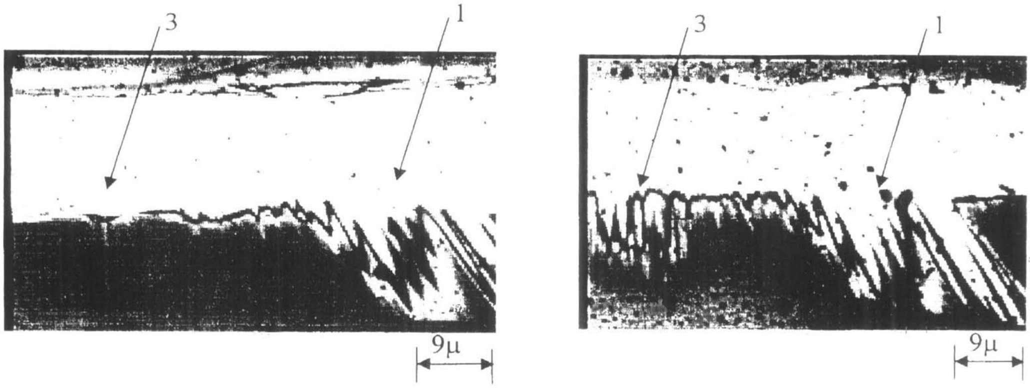


Fig.6 Enlarged area of Fig.4 (b) and (c)

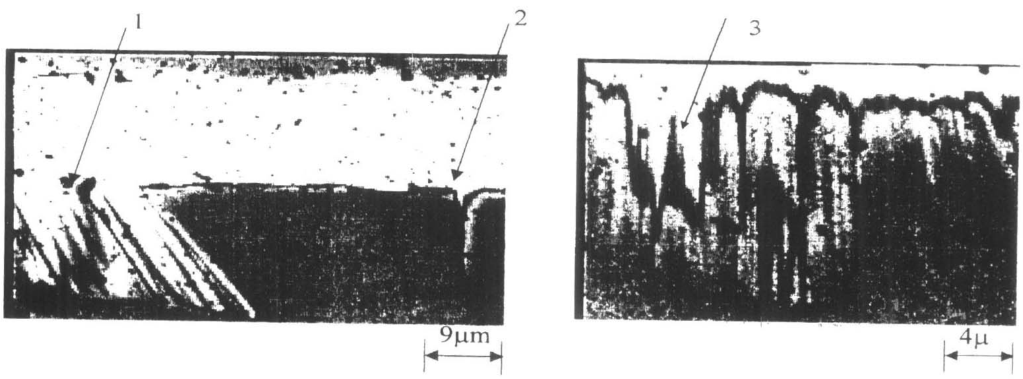


Fig.7 Enlarged area of Fig.4 (c). Point 2 has not yet changed

3.3 SiC/A1 (SiC particle reinforced Aluminum matrix) (Fig.8–Fig.10)

The specimen is 0.3 mm thick and suffers tension. The film is as receiver.

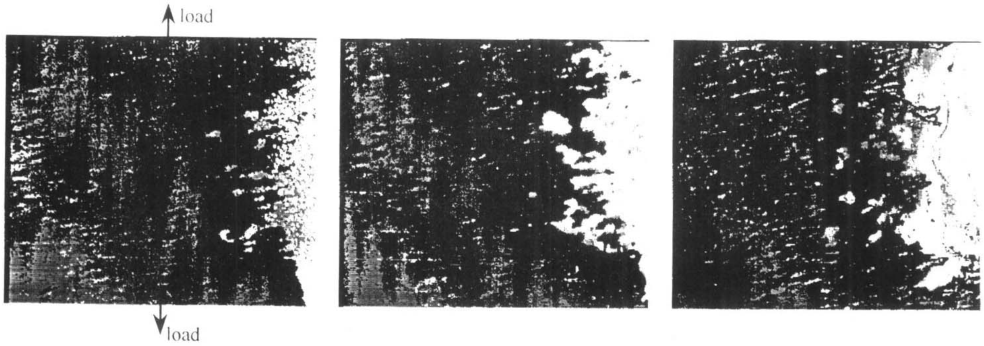


Fig.8 SiC particle reinforced aluminum matrix.

The damages start from boundary and develops through a set of micro holes

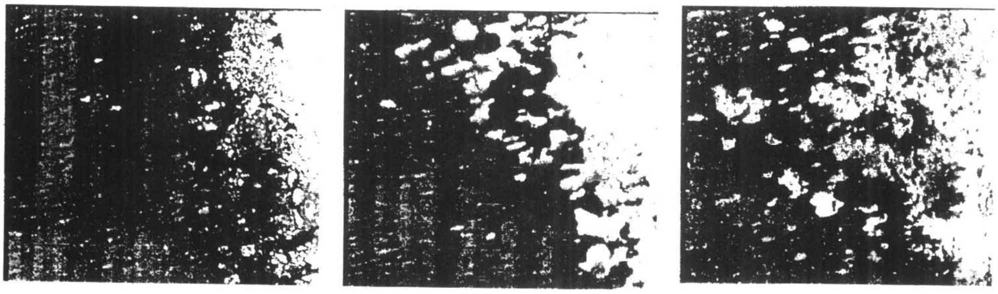


Fig.9 Different area from Fig.8

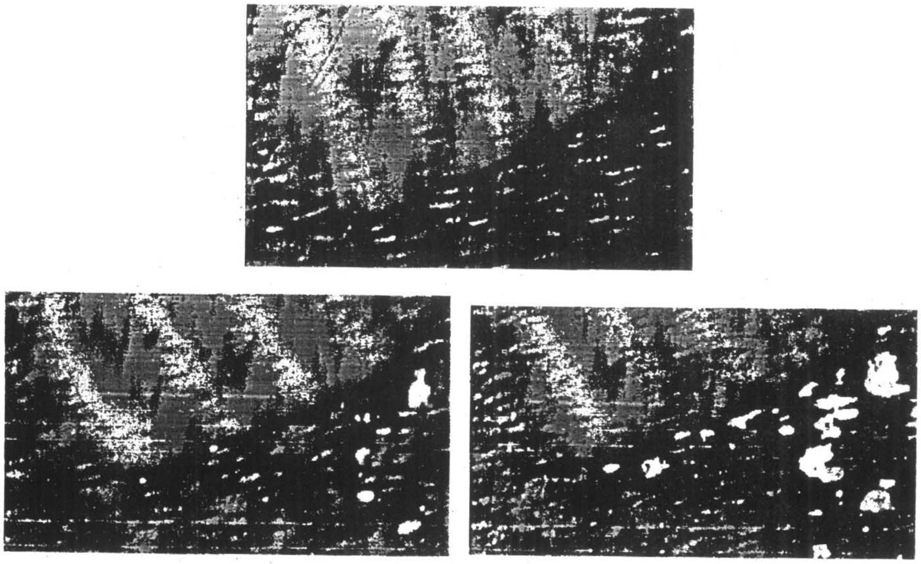


Fig.10 The damage evolution near a contaminent

The damages and their evolutions can be seen. In some areas the aluminium has broken as holes or crack. The damage evolution of those holes can be measured. Many holes near the penny shape crack tip expand when the force increase and other holes appear in the front of them. This situation is similar those in the front of crack tip of damaged silicon strip which is mentioned before but in 2-dimensional.

3.4 Superconductivity tape with single wire or five wires (Fig 11-12)

The superconductivity is Bi-2223 and the section size is 2.3mm × 0.2mm of single wire. The sheath is silver or silver alloy 40μm thick. And the superconductivity wire is 10 um of multi-wire tape.

The environment temperatures are room temperature and 77 K (−196℃).

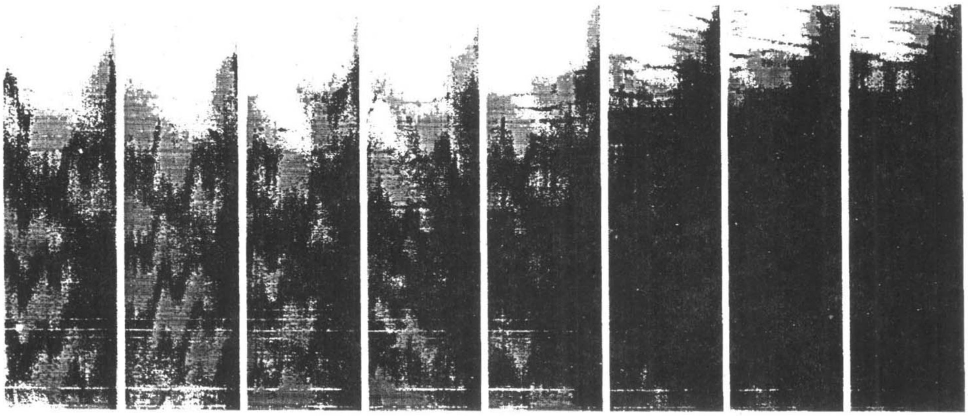


Fig.11 Mono-core superconductivity tape (Bi 2223) under loading step by step at 77K

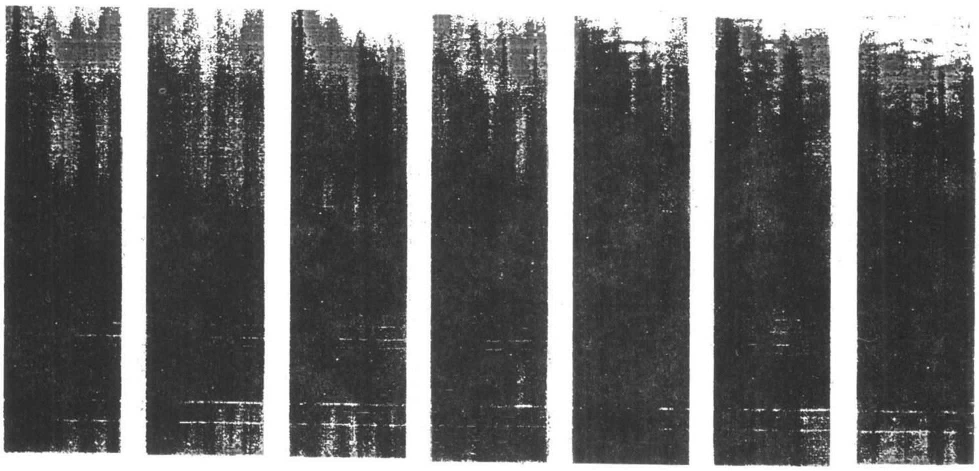


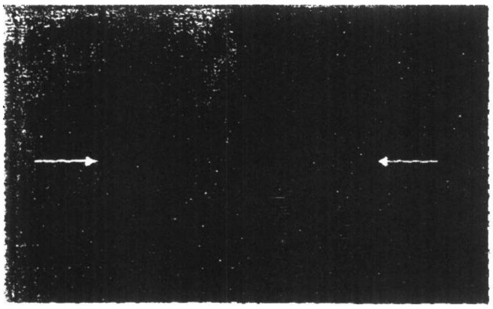
Fig.12 Multi-core superconductivity tape (Bi 2223) under loading step by step at 77K

The amount of crack increases when load increases.

This is the first time to understand the damage evolution in superconductivity. It is useful to judge which sheath material (silver or silver alloy) is better to get higher macro-scope strength which is an important parameter for TOKAMARK.

3.5 C/Al and graphite/Al bundle (Fig.13)

Synchrotron radiation computer tomography is adopted to detect those flaws in three dimensions inside the materials.



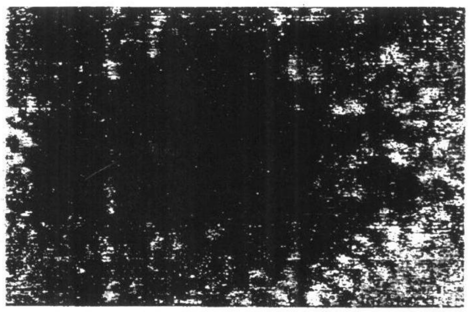


Fig.13 Damaged Carbon/Aluminum bundle (left) and a section (right) by Synchrotron Radiation Computer Tomagraphy

The reconstruced image of aluminum matrix composites reinforced by a carbon fibre bundle is given by SR-CT technique. The bundle is 0.5mm and artificially made notch. The acquire interval is 10 °.

Another experiment is three bundles, one is graphite fibre/Al and two are Carbon fibre/Al, embedded in epoxy. The reconstruction image is better than the first one because the acquire interval is 2 °.

4. Conclusions

Synchrotron Radiation is a powerful tool for study the mechanical properties of engineering materials in macro-, meso-, micro-scale. Especially, the defects or damages and their evolutions inside the materials can be measured qualitatively and quantitatively.

(These researches are done by Dr. HU Xiaofang. And Dr. GIAN Kemao, Dr MIAO Hong, graduate students YANG Jinglei, JIANG Zhenyu, etc. joint the researches too.)

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A Review of Photomechanics and Electronic Speckle Pattern Interferometry (ESPI)

Wu Xiaoping*
(University of Science and Tehchnology of China, Anhui 230026, China)

1. Optical Methods for Mechanical Experiments

1.1 Photoelasticity

For birefringence materials, such as epoxy or polycarbonate etc., there is a "stress-optical law" which shows the relation between principal index and principal stress. A loaded model in photoelastical set-up can give fringes pattern on image plane. The different of two principal stress components ($\sigma_1-\sigma_2$) are obtained from fringe pattern.

Of cause, to get the individual stress components need other methods such as calculation or holographic interferometry. The latter can give the sum of two principal stress components ($\sigma_1+\sigma_2$) . Then the individual stress component can be obtained easily.

Example: by Holo - micro- photoelasticity the stress distribution around a crack tip of carbonate is shown and the stress intensity factor $K1$ can be calculated. (Fig.1)

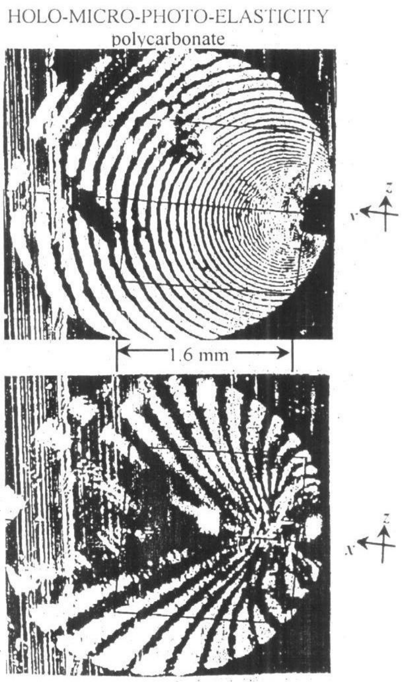

Fig.1

* 伍小平教授，中国科学技术大学力学和机械工程系；中国科学院院士，中国实验力学学会主席，由王宽诚教育基金会资助，于 2000 年 11 月赴香港科技大学、香港理工大学讲学，此为其讲稿中的部分内容。

1.2 Moire

Two grating overlap each other then a set of fringe can be seen which named "Moire". At beginning the white light is used and many kind methods are developed. They are plane moire, reflection moire, project moire and shadow moire. After laser was invented miore interferometry became an important technique because of its high sensitivity and high quality fringes.

Experiment results:

(1) Aluminum bar with two holes under impact loading: moire fringes show the dynamic deformation and the stress diffraction by holes clearly (Fig.2).

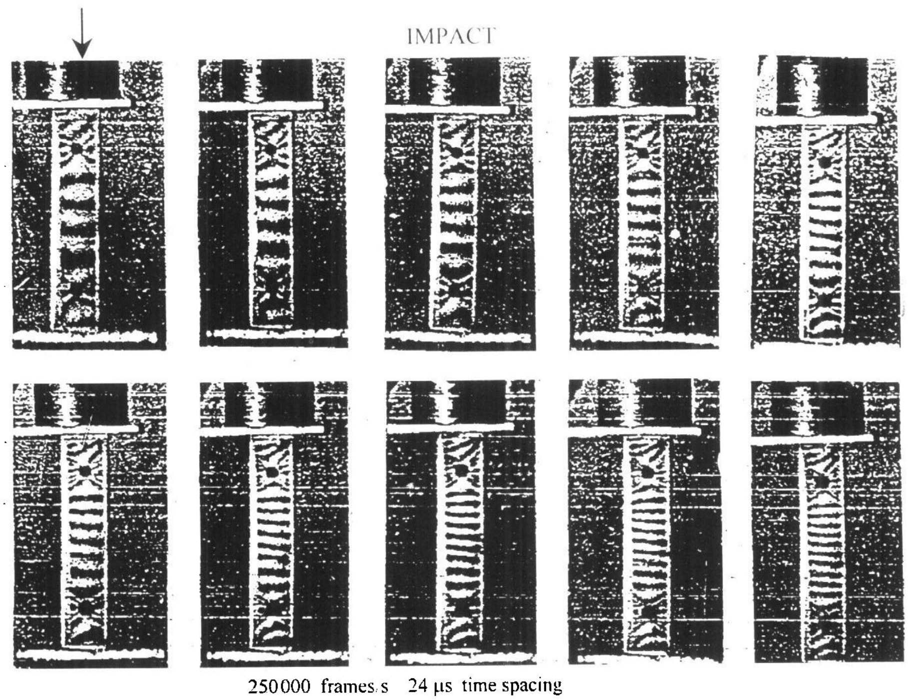

Fig.2 Aluminum bar with two holes under impact loading (in-plane displacement)

(2) Out-of plane deformation of an aluminium plate by explosion (Fig 3).

(3) An object shape in 360°

(4) The strain concentration on the interface between layers in composite material (Fig 4).

(5) The residual stress fields around a cold-expanded fastener holes (Fig 5).

1.3 Holographic Interferometry

Based on holography the object can be recorded before and after loading and reconstructed these two objet waves at same time and same position. The difference of two waves shows fringe pattern which describs the displacement contour with high sensitivity.