Research on Radiation Damage Characteristics of Optical Fiber Materials Based on Data Mining and Machine Learning

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Abstract. In order to better analyze the damage characteristics of fiber materials under radiation environment, combined with data mining algorithm to calculate the degree of damage of material structure damage. Combine with machine learning method to analyze the calculation results, obtain the damage range of fiber material structure, standardize material damage characteristics and Grade, accurately determine the damage of material structure, and finally improve the radiation damage characteristics of fiber materials. Experiments show that the research on radiation damage characteristics of fiber materials based on data mining and machine learning is accurate and reasonable.

Keywords: Data mining · Machine learning · Fiber material · Radiation damage characteristics

1 Introduction

Research on the characteristics of radiation damage of materials and radiation protection have a wide range of applications. The effective analysis and control of radiation effects of radiation has been the focus of researchers [1]. In recent years, some scholars have studied the radiation damage characteristics of materials and achieved certain results. Literature [2] proposed the damage characteristics of two kinds of radiation sources on the irradiation of optical fiber materials. The irradiation damage characteristics of the three samples of single-mode fiber, erbium-doped fiber and erbium-doped fiber were studied by cobalt source and electron accelerator. The damage mechanism of two kinds of irradiation sources to optical fibers was compared and analyzed. It was found that the rare earth fibers used in the experiments had certain equivalent laws under the damage of two kinds of irradiation sources. The literature [3] proposed the effect of erbium-doped fiber radiation on the output characteristics of fiber-optic source. The gamma irradiation experiment was carried out on the erbium-doped fiber. According to the absorption coefficient and the emission coefficient test data of the erbium-doped fiber before and after irradiation, the absorption cross section and emission cross section of the erbium-doped fiber were calculated. Based on the power law model, the radiation model of the erbium-doped fiber absorption cross section and emission cross section is established. The radiation model of the absorption cross section and the emission cross section is substituted into the erbium-doped fiber

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source model, and the influence of the radiant effect of the erbium-doped fiber on the output spectrum and characteristic parameters of the erbium-doped fiber source is simulated. In order to better study the radiation damage characteristics of fiber materials. Therefore, combined with the mining algorithm to calculate the line energy transfer coefficient in the radiation ray, and based on the calculation results, the machine learning method is used to control the energy attenuation phenomenon in the fiber material. By analyzing the photoelectric absorption effect of the fiber material on the radiation ray, a large amount of photoelectrons are generated in the fiber material and accompanied by Auger electrons, thereby effectively preventing the damage of the material structure of the radiant fiber material, and completing the radiation damage characteristics of the fiber material.

2 Research Method of Radiation Damage Characteristics of Optical Fiber Materials

2.1 Radiation Damage Algorithm Based on Data Mining

The fiber structure information is refined to establish a material hierarchical structure decentralized database, the changes of the synthetic structure data under radiation are monitored and compared, the judgment matrix is formed, the damage characteristics are determined according to the structural safety judgment scale, and the judgment matrix is established as follows:

$$\begin{array}{lllllll} G & G_1 & g_2 & \cdots & g_n & \cdots & g_{\mathrm{m}} \\ G_1 & g_{11} & g_{12} & \cdots & g_{1n} & \cdots & g_{1\mathrm{m}} \\ G_2 & g_{21} & g_{22} & \cdots & g_{2n} & \cdots & g_{2\mathrm{m}} \\ \cdots & & & & & & \\ G_n & g_{n1} & g_{n2} & \cdots & g_{nn} & \cdots & g_{n\mathrm{m}} \\ \cdots & & & & & & \\ G_m & g_{m1} & g_{m2} & \cdots & g_{mn} & \cdots & g_{\mathrm{mm}} \end{array} \tag{1}$$

Combining the above matrix to calculate the strain resistance of the material structure under radiation, the calculation method is as follows.

$$\bar{G}_i = 2g_{ij}^b \frac{\Pi^c k_{ij}^a}{\sum_{\mathrm{i=1}}^{\mathrm{a}} (\Pi^b k_{ij})^{\frac{1}{n}}} \tag{2}$$

Where i, j are the maximum and minimum parameters in the effective radiation tolerance range, and k is the radiation-dependent line energy transfer efficiency, a is the scale of the degree of radiation within the material, b represents the relative variability parameter of structural damage elements, by calculating the safety range of radiation damage of material structure, judging the degree of radiation damage, calculating the standard value of the radiation resistance capacity of the fiber material, combining the mining algorithm to evaluate the quality of the fiber material, and evaluating and constructing the change of suspected erosion elements in the radiation environment. The fiber erosion degree judgment matrix is as follows:

$$V = \begin{Bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \cdots & & & \\ v_{n1} & v_{n2} & \cdots & v_{nn} \end{Bmatrix} \tag{3}$$

The matrix is assigned, the assignment range is from 1 to 9, these values represent different meanings. The evaluation of the material quality index can be summarized as the eigenvector of the matrix and the calculation of the result. The component Q in the characteristic equation represents the weight of each quality index of the material. The specific steps for calculating the matrix characteristic equation are as follows. Calculate each row of security elements of matrix Q as follows:

$$Q = \prod_{i=1}^{j} \overline{G}_{\mathrm{i}} V_{ij} (j = 1, 2, \ldots, n) \tag{4}$$

If m is the reference value of the calculation matrix, the calculation method of the radiation carrying load inside the fiber material structure is:

$$\overline{U} = m^2 \sqrt{Q_{ij}} (i = 1, 2, \ldots, n) \tag{5}$$

The linear energy normalization process for the numerical values calculated in the above steps can be used to calculate the line energy transfer coefficient as follows:

$$W_i = \frac{1}{n} \sum_{j=1}^{\mathrm{i}} \overline{U} Q \frac{\delta_{\max}}{m-1} \tag{6}$$

The $\delta_{\max}$ in the equation represents the characteristic equation root of material quality detection, n, m respectively represent the maximum and minimum values within the range of variation of the radiant ray eigenvectors. Calculate the quality assessment matrix B by combining the above formulas:

$$B = \frac{1}{2} \sqrt{\overline{(\overline{G}_i + \overline{U}_j)}^{m-n} \delta_{\max}} \tag{7}$$

In order to judge whether the material satisfies the average random consistency of radiation damage, the matrix is evaluated: When the matrix check value is less than or equal to 0.1, it is determined that the matrix B has consistency, otherwise the matrix needs to be readjusted. Establish a collection of material damage assessments $\mathrm{B} = [\mathrm{b}_1, \mathrm{b}_2, \ldots, \mathrm{b}_\mathrm{n}]$, assess the degree and grade of damage to materials, The grades include {better, average, qualified, unqualified}. This level of detection set directly represents the radiation resistance of the material. The set of grades is assigned, and the set of factors affecting the radiation resistance of the factors affecting the evaluation factors is established. Finally, the data evaluation algorithm is used to multiply the set of quality assessments and the set of evaluation factors, and the final evaluation value is obtained. Effectively judge the degree of influence of material radiation combined with the final evaluation value [4].

2.2 Machine Learning-Based Material Radiation Influence Judgment Method

The radiation damage caused by the fiber material during the radiation process is mainly related to the action mechanism of the incident ray and the substance. Therefore, it is necessary to analyze the action mechanism of the ray and the substance in the process of studying the radiation damage effect [5]. In terms of radiation types, it can be mainly divided into ionizing radiation and non-ionizing radiation. The biological effects of radiation generated during radiation are related to the energy transfer between the radiating substances. Ionizing radiation refers to the direct or indirect ionization of substances, including particulate radiation and high-energy X-rays, gamma rays, etc. [6]. Non-ionizing radiation generally cannot cause ionization of matter molecules, but only causes vibration, rotation, etc. of molecules. These mainly include ultraviolet radiation and radiation with lower energy than ultraviolet light. The influence of non-ionizing radiation ionization on the ion structure of the fiber material is judged as shown in the figure below (Fig. 1).

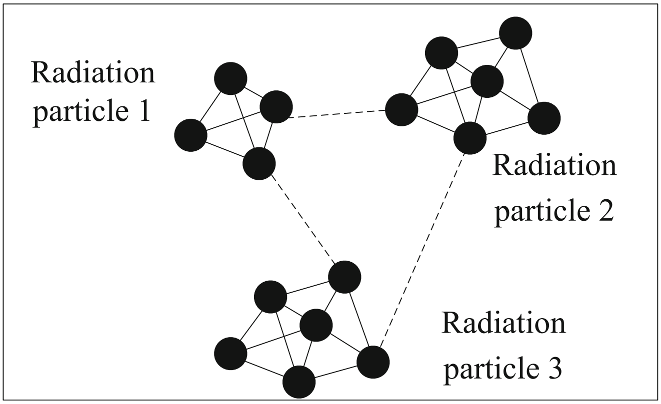

Fig. 1. Judgment of the influence of non-ionizing radiation ionization on the ion structure of fiber materials

As shown in the figure, the process of particle irradiation on fiber materials is an important part of studying the mechanism of radiation damage, Through the high-speed movement of protons, neutrons, mesons, electrons, etc. in the material, the changes of electrons, neutrons and some heavy nuclei are the key research objects in the research of radiation damage characteristics, just like electromagnetic radiation. In the process of fiber radiation, electrons, neutrons, and certain heavy nuclei transmit energy to other substances by losing their own kinetic energy. That is, the interaction with the substance realizes the energy transfer, which leads to the damage of the material structure in the process of particle motion and collision. The principle of determining the radiation influence degree is as follows (Fig. 2).

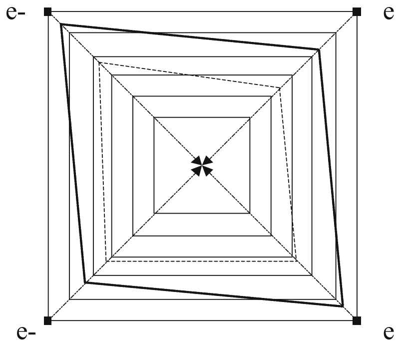

Fig. 2. Schematic diagram of the principle of radiation influence judgment

The study found that when the ray energy is higher than twice the minimum energy of forming electrons of 0.511 MeV, the electron pairing effect often occurs. For high-energy ray, the main mechanism of Compton scattering is to judge the mechanism of radiation and material damage, in the case of radiation acting on a substance, it is often the case that several effects of the material structure are damaged and appear in the form of a mechanism of damage occurrence [7]. In the case of photoelectric absorption as the main low-energy ray, as described above, after the absorption of the ray, the fiber material affects the interaction of the material structure particles through the transfer of the energy of the particles, thereby generating secondary electrons, causing material damage. Based on the above research results, the research on the radiation damage characteristics of fiber materials.

2.3 Study on Radiation Damage Characteristics of Optical Fiber Materials

According to the energy transfer mode of the action of radiation and matter, the process of action is divided into direct and indirect processes. Direct action means that ionizing radiation deposits energy directly on important biomolecules (or other components of the fiber material) and causes physical and chemical changes in these molecules, statistics on the probability of radiation and radiant energy deposition occurring on the same molecule [8]. Indirect action refers to the fact that ionizing radiation deposits energy on other molecules in the environment surrounding important biomolecules, causing physical and chemical changes of important biomolecules, using effects and radiant energy deposition to occur on different molecules. Under normal circumstances, direct and indirect effects always occur simultaneously, and their relative proportion depends on the water content in the living matter, it also depends on the form in which the molecules are "assembled" with each other and with other molecules in the structure of the fiber material. In order to ensure the accuracy of the study, the micro-focus beam performance parameters are statistically obtained, and the following table is obtained (Table 1).

Table 1. Study on performance parameters of microfocus beam.

Focused zone label	CZP_{23}	CZP_{32}	CZP_{45}
Center wavelength	2.1	2.6	3.0
Wavelength range	1.69–1.81	2.15–2.47	2.45–3.12
Radiation spacing	720–740	902–944	803–891
Outlet pinhole spacing	2.4	2.4	2.8
Material structure diameter	1512	1042	1064
Number of bands	432	431	616
Diffraction focal length	513	512	518

A special X-ray beam line dedicated to the study of radiation damage mechanism is established on the KEK2N synchrotron radiation device. The energy coverage is set in combination with the information in the table. From the soft ray to the monochromatic ray in the hard ray band, part of the radiation is carried out. Injury research [9]. At the same time, the radiation damage characteristics of fiber materials were studied by using Munakata and other devices, and the following research results were obtained (Fig. 3).

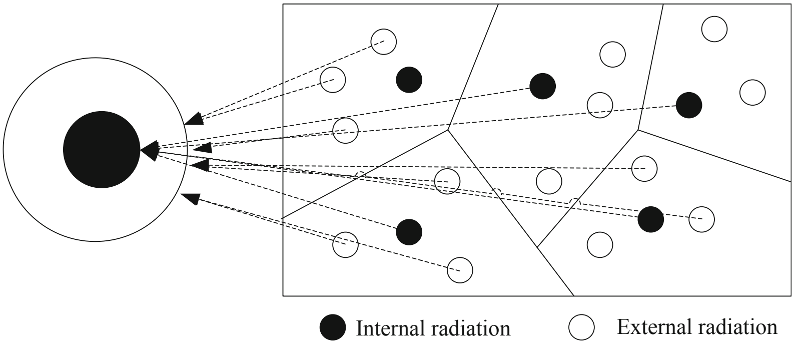

Fig. 3. Damage to the material by ray radiation

Studies have shown that synchrotron radiation can cause radiation damage to fiber materials to varying degrees, and the higher the absorption energy of the internal structure and elements of the material, the stronger the material damage effect, there is an enhancement effect on the radiation damage of fiber materials under different radiation environments [10]. In addition, the use of synchrotron radiation to different degrees of variation and damage to the radiation core, and the impact on the surface and structural deactivation damage of the fiber material is relatively large, resulting in different degrees of fiber material death, variation and radiation damage.

3 Analysis of Experimental Results

In order to verify the accuracy of the research results, a simulation experiment was carried out. Combined with the radiation damage algorithm of data mining, the radiation secretary of the fiber material was set, and the material damage value was calculated effectively. The specific information is as follows (Table 2):

Table 2. Experimental test data.

Experiment number	Radiation description	Damage degree
2	Radiation environment 400 rad	1412w
4	Radiation environment 420 rad	1124w
6	Radiation environment 450 rad	1349w
8	Radiation environment 520 rad	15674w
10	Radiation environment 540 rad	1430w

Combine the above table information for further data calculation, in order to accurately study the damage characteristics of fiber materials, and compare the results of the previous studies on the damage characteristics of fiber materials. By integrating multiple test results for analysis, the damage characteristics of the fiber material are displayed, and the damage of the fiber material under radiation environment is shown in the figure below (Fig. 4):

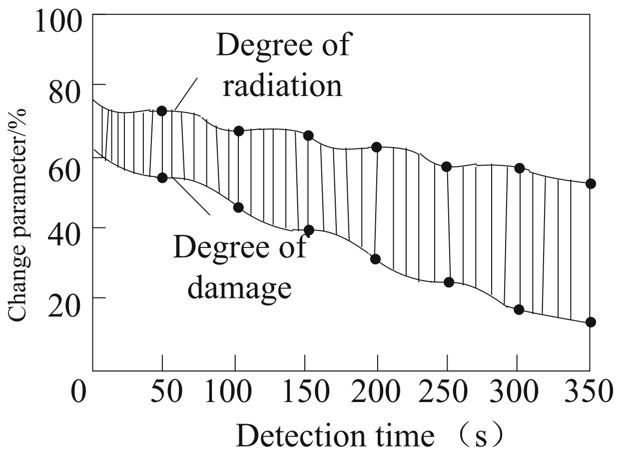

Fig. 4. Detection of damage of optical fiber material under radiation environment

According to the above test results, it can be found that the degree of radiation damage of the fiber material changes with the change of the degree of radiation in the case of changes in the degree of radiation, and the accuracy of the research results of the damage characteristics of the fiber material is repeatedly confirmed. In addition, it was found during use that the radiation damage of ordinary single-mode fibers is much smaller than that of doped fibers at the same radiation dose. Since the experimental results are not highly correlated with the previous research results and have no effect on the experimental results, they are not stated here.

4 Conclusions

According to the research of radiant radiation damage effect, using different radiation high brightness, energy continuously adjustable and other information for analysis and research, combined with data mining algorithm to calculate the radiation damage degree, according to the calculation results, the influence degree of the material radiation of the machine learning is judged, so as to realize the radiation damage effect on the fiber material.

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