***Chapter One***

***Introduction and Literature Review***

**1.1 A brief history of solid-state nuclear track detectors-SSNTDs**

During the last 60 years the method generally known as solid state nuclear track detector-SSNTD has grown and is now a distinct branch of science and technology. The science of solid-state nuclear track detectors was born in 1958 when D.A. Young discovered the first tracks in a crystal of LiF. The etch pits, later called ‘‘tracks’’, were found in a LiF crystal which was previously placed in contact with a uranium foil, irradiated with slow neutrons and treated with a chemically aggressive solution. The thermal neutrons led to fission of the uranium nuclei and the fission fragments bombarded the LiF crystal and damaged it. The damaged regions constituted more chemically active zones than the surrounding undamaged areas, so several books and many articles published in scientific journals and were published on the field of solid state nuclear track detectors - SSNTDs [1, 2].

In 1957, the First conference on this field was named, International Colloquium on Corpuscular Photography in 1957 in Strasbourg, France. Silk and Barnes (1959) reported the finding of damaged regions in mica. They used the Transmission Electron Microscope - TEM to investigate tracks of heavy charged particles in mica. In 1965 Fleischer conducted extensive investigations of this technique and using in these materials like minerals, plastics and glasses for this technique. CR-39 Polyallyl diglycol carbonate was discovered as nuclear track detector - NTD in 1978 by Cartwright et al. CR stand for Columbia Resin [2-4].

And the final conference was 25st International Conference on Nuclear Tracks in Solids held in Puebla, México in 2011, and the coming one will be the 26nd International Conference on nuclear tracks in solids to be held in Kobe, Japan in 2014, and 27th International Conference on Nuclear Tracks and Radiation held in Strasbourg, France in 2018.

**1.2 Types of solid state nuclear track detector**

The following are two kinds of solid state nuclear track detector:

**1.2.1 Inorganic detectors**

Inorganic detectors are compounds where carbon and hydrogen do not enter in its structure and created an "ionic bond" between its atoms. Table (1-1) displays some kinds of inorganic nuclear track detectors and their chemical composition [5].

Table (1-1) Chemical composition of inorganic nuclear track detectors [5]

|  |  |  |
| --- | --- | --- |
| **No.** | **Detectors** | **Chemical Composition** |
| 1 | Zircon |  |
| 2 | Quartz |  |
| 3 | Mica( Biotite )  Mica (Muscovite) |  |
| 4 | Fluorite |  |
| 5 | Soda Lime Glass |  |
| 6 | Olivine |  |
| 7 | Calcite |  |

**1.2.2 Organic detectors**

Organic detectors are compounds where carbon and hydrogen enter in their structures, and created a "covalent bond" between its atoms, this type of SSNTDs has a sensitivity larger than inorganic detectors because the bonds of C-C, C-H which are easily broken after exposure to the radiation, also the organic detectors have a high analytic power larger than inorganic detectors, the threshold energy for organic detectors is less than inorganic detectors. Table (1-2) shows some kinds of organic detectors and their chemical composition [6].

Table (1-2) Chemical composition of organic nuclear track detectors [6].

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **Detectors** | **Chemical Composition** |  |
| 1 | Polyester ( HB Pa IT) |  | --- |
| 2 | Polyimide |  | --- |
| 3 | Cellulose,  Cellulose Nitrate  Cellulose Triacetate |  | (CN )  ( CT ) |
| 4 | Polycarbonate ( Lexan, Makrofol ) |  | ( PC) |
| 5 | Plexiglass |  | --- |
| 6 | Polyallyl diglycol Carbonate |  | (CR-39) |

**1.3 Radiation**

Radiation is energy given off by matter in the form of rays or high-speed particles. Radiation travels from its source in the form of energy waves or energized particles. These atoms constantly seek a strong, stable state. As they convert from an unstable to stable form they release excess atomic energy in the form of radiation. All matter is composed of atoms, atoms are made up of various parts, the nucleus contains minute particles called protons and neutrons, and the atom's outer shell contains other particles called electrons. The nucleus carries a positive electrical charge, while the electrons carry a negative electrical charge. Radiation is part of our environment; it comes from both natural and man-made sources. Natural sources include cosmic radiation from space, radioactive rocks and soils, and other radioactive materials found in food and water. Humans have been exposed to these natural radiation sources since the dawn of humanity. Man-made sources of radiation include medical diagnosis and treatment, the nuclear power industry, scientific research, consumer products, and nuclear weapons testing [7, 8].

Radiation can come from as far away as outer space and from as near as the ground that you are standing on. Because it is naturally all around us, we cannot eliminate radiation from our environment. We can, however, reduce our health risks by controlling our exposure to it [9].

**1.4Types of radiation**

Radiation has so much energy it can knock electrons out of atoms, a process is known as ionization, but there is another radiation has no much energy to knock electrons out of atoms known as non-ionization radiation.

**1.4.1 Non ionization radiation**

Non-ionizing radiation has less energy than ionizing radiation; it does not possess enough energy to produce ions. The non-ionizing radiation spectrum is divided into two main regions, optical radiations and electromagnetic fields. The optical can be further sub-divided into ultraviolet, visible, and infra-red. The electromagnetic fields are further divided into radiofrequency (microwave, very high frequency and low frequency radio wave). Non-ionizing radiation originates from various sources: natural origin (such as sunlight or lightning discharges etc.) and man-made (seen in wireless communications, industrial, scientific and medical applications) [7, 10].

**1.4.2 Ionization radiation**

Ionizing radiation is capable of knocking electrons out of their orbits around atoms, upsetting the electron / proton balance and giving the atom a positive charge. Electrically charged molecules and atoms are called ions. Ionizing radiation includes the radiation that comes from both natural and man-made radioactive materials. There are several types of ionizing radiation Alpha radiation α, Beta radiation β, photon radiation (gamma γ and x-ray) and neutron radiation n. These were collectively called ionizing radiation because of their ability to strip one or more electrons away from atoms in whatever material they pass through [7, 11].

**1.5 Some properties of SSNTDs used in this study CR-39 track detector**

Polyallyle diglycol carbonate - PADC which is generally referred to as CR-39 the most sensitive of the nuclear track recording plastics. It was first discovered by Cartwright, this detector consists of short polyallyle chains joined by links containing carbonate and die ethylene glycol groups into a dense three dimensional network [12]. The chemical form of CR-39 is it is illustrated in figure (1-1) [13].

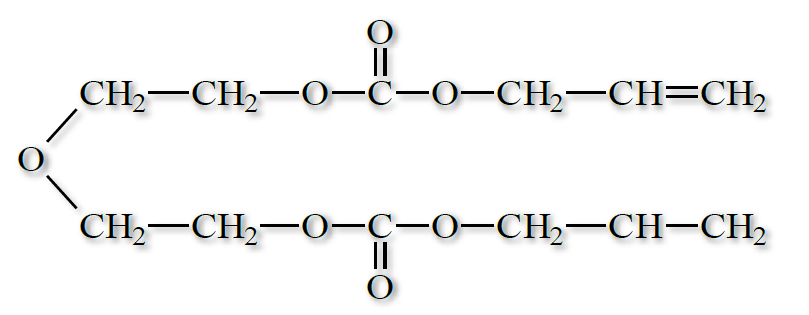
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Figure (1-1) Chemical form of CR-39 detector [13]

The general characteristics of CR-39 can be summarized as [14]:

1. Amorphous polymer.
2. Optically clear.
3. Environmentally very stable.
4. Having a closed packed and uniforms molecular structure.
5. Having non – solvent chemical etchant.
6. Highly cross – linked thermoset.

**1.6 Thermal neutron source**

Neutron sources vary in intensity and in the energy of the neutrons emitted. They can be classified into three groups: nuclear fission reactors, radioisotopes, and particle accelerators. Nuclear reactors are obviously not portable, and not suitable for nuclear well logging sources. Radioisotopes are the most commonly used neutron source in well logging applications. Particle accelerators have seen relatively limited (although growing) use in well logging. The (α,n) neutron source contains an α-emitting radioisotope, with low mass nuclei as a target. As it compared to other isotopes where the beryllium is the most important target because it has the highest neutron yield. The long half-life (~433 years) of would provide an almost constant level of neutron flux from the source over the lifetime of the equipment (~20 years) the energetic neutrons are generated following an interaction (1.1) between the alpha particle and the target material’s nucleus.

-particle Beryllium Carbon neutron energy

The alpha particles were emitted by Americium decay, impinge on a target, producing neutrons over a broad range of energies with average energy around 4.2 MeV and a maximum of around 10 MeV [15, 16, 17].

**1.7 Image processing software for SSNTDs**

Many previous studies on accounting of nuclear tracks of alpha particle by image processing techniques and improving lightness microscopy, the following are the most important existing researches with image processing techniques.

**Radomirand and Mitja (1990)** [18] used a physical model of image formation in solid state nuclear track detectors has been formulated. By using this model the large area signal function (optical density over a large area) is calculated. The theoretical calculations are verified by experiments with LR-115, CA-8015 and CR-39 detectors using the reaction.

**Boukhair A. et al. (2000) [19]** used a code for the numerical analysis of images from a CCD camera, including the correction of acquisition system defects, has been written and applied to the visualization of α-particle tracks in the solid state nuclear track detectors CR-39 and LR-115. A standard mask having different diameter holes permitted the calibration of the imaging system.

**Patiris et al. (2007)** [20] used A computer program named TRIAC written in MATLAB has been developed for track recognition and track parameters measurements from images of the solid state nuclear track detectors CR39. The program using image analysis tools counts the number of tracks for dosimetry proposes and classifies the tracks according to their radii for the spectrometry of alpha-particles as used same computer program named TRIAC II has been developed for recognition and parameters measurements of particles’ tracks from images of solid state nuclear track detectors.

**Fuminobu et al. (2007)** [21] used observation system was developed to record time-lapse images of etch pits formed on the surface of a solid-state nuclear track detector - SSNTD CR-39. Pit-evolution images were constructed by digital image processing of the data of the time-lapse images. In addition, a finite element model of SSNTD was used to simulate the etch pit formation. Pit-evolution image analysis and computational simulation were performed to reveal the etch pit formation obtained via the incidence angle of energetic particles on a CR-39.

**Pugliesi et al. (2011)** [22] studied the comparison of the results together with the feasibility and rapidness in data acquisition have demonstrated the viability of the digital system to characterize SSNTD.

**Mostofizadeh et al. (2008)** [23] used MATLAB software as method to study edge detection, all measurements carried out in two cases of before and after improvement of track images. Considering the overlapping phenomenon –including double and triple tracks- experimental and statistical results showed that not only each particular edge detection method affects the accuracy of measurements.

**Law et al. in (2008)** [24] used TRACK\_TEST computer program to explain differentiation among recorded tracks for which the grey levels, major and minor axes values were used as inputs and from which the angle and energy of the incident alpha particles were given as the outputs.

**Nikezic and Yu in (2009)** [25] used a computer program was developed to calculate the light scattered from an assembly of alpha particle tracks in a CR-39 detector. The tracks were randomly seeded on the film to simulate the irradiation by alpha particles emitted by the naturally occurring radon gas and its short-lived progeny. The ray-tracing method was applied to simulate light propagation through the tracks. The total amount of scattering increased linearly with the track density and quadratic ally with the removed layer during chemical etching of the irradiated CR-39 detector.

**Palacios et al. (2010) [26]** used STATISTICA software to analyze and correct the track overlapping on nuclear track detectors - SSNTD by A model for the track overlapping process.

**Hadad et al. (2011)** [27] using of an automated counting system which was based on a high resolution scanner and related image processing software. Once the electrochemical etching was performed, the etched CR-39 films were scanned and counted by developing software (called NTC) with high accuracy.

**Zylstra et al. (2011)** [28] SRIM software used to study track formation process is explored with a Monte Carlo code, which shows that the track formation difference between frontend.

**Felice et al. (2012)** [29] used the novel ENEA-INMRI image analyzer system has been tested in a semi-automated mode for a computer-assisted alpha track counting of electro-chemically etched-ECE and chemically etched CR-39 solid state nuclear track detector - SSNTD chips.

**Osinga et al. (2013)** [30] used (: C, Mg)-based fluorescent nuclear track detectors-FSSNTDs and confocal laser scanning microscopy as a semiautomatic tool for fluency measurements in clinical ion beams.

**Firas et al. (2013)** [31] used MATLAB software to determine parameters of nuclear track detector, such as nuclear track diameter DT(μm ), number of track-N and area of track-AT.

**Lore G. et al. (2015)** [32] used image processing to recognize pores provide information and furthermore the software was able to supply the operator with color maps of the different size range of the porous structure in order to analysis of the device.

**Azar N. et al. (2016)** [33] studied in a novel method for detecting and counting overlapping tracks in SSNTD by image processing techniques.

**Aryeh et al. (2017)** [34] explain about fission tracks detection using automated microscopy.

**Siqueira D. S. et al. (2018)** [35] studied in the automatic separation of overlapping fission tracks in apatite and muscovite using image processing.

**Elazhar H. et al. (2019)** [36] search in light particle spectroscopy using CR-39 detectors an experimental and simulation study.

**1.8 Research aim**

The main purpose of the present work is to an analysis of nuclear track detectors –SSNTDs parameters as total numbers, areas and depth of tracks and others for CR-39 detector after irradiated by many sources. The analysis included the image processing of these irradiated detectors by using the MATLAB program. The possibility of using this technique in an accurate diagnosis of the particle radiation effect on SSNTDs through six steps:

* Design a new irradiation technique is characterized by very cheap, easy transportation. In addition, the distance between the radiator source and the detector can be changed easily.
* The modification illumination system of the optical microscope by placing light emitting diode instead of tungsten light.
* Using modern no reference quality scale to analyze the surface of detector and count tracks, and it was compared with another no reference quality scales.
* A provable digital image processing in this study data and information relation to the parameter of tracks to determine the proper tin of track, resolution seven of energy and track efficiency through an acount of tracks beside developing some statistic results.
* Design a new algorithm to procuration on the features of the micro particle represented by Alpha particle employment CR-39 solid state nuclear track detector.
* Eliminate from a routine (manually) method of calculating the number of tracks by the automatic method in image processing technique and it obtained high accuracy of the results in a time not exceeding 60 seconds.

**1.9 Structure of a thesis**

The organization of the rest of the thesis is as follows: chapter two details

of the theoretical principles of the light, light emitting diode, tungsten light, quality, wavelet transform, contrast and visibility, enhancement, colour space, and chromatic properties. The instruments and programming details are introduced in chapter three. Chapter four includes the results and discussions. Conclusions and future works are also given in chapter five.