Scanning Acoustic Microscope (Sam)- A Review

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Abstract:Scanning Acoustic Microscope, known as SAM, is a device that is used to investigate, measure or image an object. It is widely used for a non-destructive evaluation which is its biggest plus point. A Scanning acoustic microscope is useful for detection of defects in multilayered structures by a low time consuming process. The aim of this review is to understand the applications, uses and structure of this microscope. A systematic search strategy was employed and articles were found using keywords. Literature was taken from databases like PubMed and Google Scholar. Articles that discussed the use of SAM and its uses were included. Other articles which had data regarding the structure and its applications in different fields were also included. A total of about 100 articles were collected initially. Multiple articles were added later from other sources. After eliminating articles that did not meet the inclusion criteria, more than 50 studies were finally obtained. This review summarized the use of a Scanning Acoustic Microscope. Its structure, and other applications among different fields were also discussed in detail.

Keywords: Microscopy; SAM; Dentistry; Non-destructive analysis; Light microscope.

1. INTRODUCTION:

Scanning Acoustic Microscope, known as SAM, is a device that is used to investigate, measure or image an object. It is widely used for a non-destructive evaluation which is its biggest plus point. Failure analysis includes the use of this type of microscope extensively. Understanding the morphological features of a specimen is very essential. In diseases, examining the structure is necessary to arrive at a suitable pathogenesis [1]. Histological examination helps understand the state of a disease under treatment[2]. Usually Light microscopy is employed for such examinations, but for detailed investigation, SAM is also being used[3]. It is employed in the medical field for various purposes like imaging of gastric cancers, atherosclerosis, amongst others. Atherosclerosis is often seen in patients that have diabetes mellitus and is seen as a complication in patients of older age[4][5][6]. The use of Scanning Acoustic Microscope is also seen in dentistry, to check for etched dentin and analyze carious lesions.

Another advantage of this type of microscopy is that it gives information of the morphology and mechanical properties simultaneously of the specimen under study [7]. Scanning acoustic microscopy is useful for detection of defects in multilayered structures by a low time consuming process and quantitative analysis that is based on its measurements.[8] As discussed earlier, it is known that Scanning Acoustic Microscopy is a non-destructive method. It permits visualization of the interior of the materials and examines the properties of materials that are optically opaque. [9] As applied in many studies, SAM is used to investigate the properties of various organs and their diseased states. For example, it can be used in Myocardial infarction, renal diseases, Aortic Atherosclerosis, Diseases of ligaments, lungs, etc.

SAM has been used across a range of fields, applied to various studies, and has also been successful in observing different properties. It was used to characterize neoplastic and inflammatory lesions in lymph nodes. [10] These studies may also facilitate the use of SAM in characterizing cancerous growths. [11] In another study, during the manufacturing process of ultrasound probes, it was used to detect defects. The elastic properties of osteons and osteon lamellae were observed using a Scanning Acoustic Microscope. A study using SAM was conducted to analyze the surface cracks in a sample of glass. [12] Out of the various applications of SAM in the medical field; one was to analyze the ultrasonic properties of gastric cancer affected tissues. [13] And another, was the characterization of infarcted myocardium. [14] Acoustic Microscopy was employed to measure cells in culture, and to measure elastic properties of cells.[15][16] In dentistry, the widest application of Acoustic Microscopy is imaging of carious lesions. [17]

Despite the wide range of applications, various challenges were faced while conducting the research studies. The drawbacks included a slow processing time, failure to adapt easily, difficulty in maintenance of the microscope and cost of the apparatus. The major challenge was that the Acoustic Microscope is extremely sensitive to vibration and magnetic fields.

This review is done to analyze the Non-destructive technique of Scanning Acoustic Microscopy that has a wide range of applications. It is useful in detection of cracks, bubbles, voids etc. in a variety of surfaces. It helps in the study of lymph nodes, heart diseases, arterial properties amongst many others. The Acoustic Microscope obtains images from deeper layers of the specimen and allows visualization of the interior of the object. This review alsoincludes the benefits of Scanning acoustic microscopy over the conventional Light Microscope.

Applications of Scanning Acoustic Microscope:
As mentioned earlier, the applications of SAM are plenty in number. It may be used to investigate disbanding, delamination and blister formation in polymer coatings for multiple layered structures.[18] This method of non-destructive observation is effective in identifying and detecting cracks. Acoustic microscopy has also been used to measure the thickness of tissue.[19] Radiations like X-rays are used widely for investigative purposes. [20]Similarly, Scanning Acoustic Microscopy has an array of applications in the medical field. For example, it was used to image gastric tumors, characterize infarcted myocardium; it was used to observe the properties of a dialyzed kidney. Before employing this kind of microscopy, it is necessary to know the normal conditions of the tissue and normal values to understand the pathological condition.[21] The endothelial cells of the human umbilical vein were viewed using acoustic microscopy. Another application of SAM was to observe the mechanical properties of human bone. [22][23][24][25]For investigation of tumours, conventional methods like biopsy, blood tests and scans are used.[26] There are various modes of

investigations depending on the condition.[27] The method used to investigate should be appropriate pertaining to the condition. [28][29] Accurate diagnosis after investigation is an extremely essential process.[30] For example in cases of Stye, just looking at the eyelid can help in diagnosis. But conditions like tumours require a detailed process of investigation.[31] Another example is Myeloid Sarcomas wherein Fine needle aspiration cytology is carried out for investigative purposes. [32] Lately even Scanning Acoustic Microscopy has been employed to image these tumours.[33][34]Dental applications of SAM include; observing carious lesions and imaging of human teeth. [35][36] Acoustic microscopy has been implemented to observe the growth of cracks in ceramics.[37] Another use of this method of observation is in material characterization. [38] Apart from all of these applications, acoustic microscopy also plays a role in determination of elastic constants.[39] SAM has also successfully been utilized to observe living cells. [40]

Structure and Function:

Scanning Acoustic Microscope is an instrument that subjects the object under study to ultrasound. It detects variations in the elastic properties of the specimen. The working of the microscope includes a process in which waves are received from the object, after penetrating the object and then it is converted to an image. Because of this mechanism the internal as well as external architecture of the object under study can be obtained. [41] The body of the microscope consists of a solid lens, which has two sections. These two subsections display different characteristics of sound propagation but similar acoustic impedances. [42] A converging sharp acoustic beam is used and this beam provides sufficient intensity to produce strong nonlinear effects. [43] As discussed previously, a convergent beam is used. The purpose of the convergent beam is to achieve a better resolution.[44] It is also a known fact that the resolution of the acoustic microscope is directly related to the wavelength used. [45]

Advantages and Disadvantages:

There are multiple benefits and drawbacks of this type of microscopy and of the microscope by itself. It is one of the finest tools known for its non-destructive failure analysis. [46] It has an extremely appreciable resolution capability. [47] It is the best possible apparatus for imaging and observing characteristics of materials. [48] It can also check the resorption of dental tissues, which can be important in the dental field. Amongst the few downfalls, one is that it can check only subjective and qualitative assessment. [49] Another drawback is that the images formed through an acoustic microscope, are formed through micro-mechanical scanners. It takes 10 minutes to image a 5mm2. Amongst the various positives, it can also be added that through the help of articulated probes SAM can be used on curved surfaces. It involved various risk factors as it is a very technique sensitive and requires meticulous work. [50][51] Conventional methods of microscopy require staining which is very technique sensitive, whereas analysis done using SAM does not require any sort of staining. [52] A Scanning Acoustic Microscope can give to the point, accurate details and features of the structure that is being analyzed. An added plus point that adds to the uniqueness of SAM is the way in which the ultrasonic waves interact with the solids.[53] There have been proven benefits of using a scanning acoustic microscope over the conventional light microscope. The following list consists of the advantages:

- The images reflect the tissue elasticity of each lesion
- The data so obtained as a result of acoustic microscopy can be compared
- No special staining is required and the results can be obtained in a shorter period of time

Scanning Acoustic Microscopy in Dentistry:

Scanning Acoustic Microscopy has multiple applications in the dental field. It can monitor the two dimensional color distributions of human molars without any caries. The

measurements that are done by using acoustic microscopy help to overcome the problems faced by other methods of conventional microscopy. By using this, it is possible to measure and detect acoustic reflectance at the same location. One of the studies used SAM to compare dentin before etching and after etching. Acoustic Microscopy can be employed over a large region and at high resolutions as well. The earliest effort to employ this kind of microscopy in dentistry was done to image a carious lesion on the tooth. Dental caries that are deep result in migration of pulp cells to the affected area. These carious lesions can be imaged using SAM. [54] Certain developmental defects of the teeth can also be analysed under a Scanning Acoustic Microscope.[55] As already known, observation is made easy and rapid by using a Scanning Acoustic Microscope. Since decalcification is a major phenomenon, it is necessary to detect decalcification in a given specimen. This can be done by using a Scanning Acoustic Microscope. [56][57][58] Earlier, X-rays were conventionally used to detect changes in bone and loss of bone, but now in recent advancements, SAM has also been applied to note changes in the bone in certain cases where possible. [59]

Present to Future:
After a long period of research, SAM is being considered superior in resolution when compared to the conventional optical microscope. [60] Acoustic microscopy has been gaining repeated attention from various medical and industrial sectors. The commercial interest has increased over the years. [61] The interest in this field has been increasing because of the unique property of SAM which allows the imaging of the interior of optically opaque objects.At a high resolution of the acoustic microscope it can observe elastic properties of the specimen at a cellular level and that too without causing any damage to its natural structure. What makes the microscope a unique tool are the fundamental differences in the interactions of sound and light. [62]

2. CONCLUSION:

The Scanning Acoustic Microscope is the one of the recent techniques of microscopy amongst various scientists. It is popularly known for its non-destructive observational method. It facilitates viewing the internal architecture of the specimen without causing any damage and it does not require special staining either. The microscope allows the ultrasonic waves to penetrate the object under study and obtain a clear view of its interior. It has various advantages like it can penetrate through multilayered structures, can check the extent of a crack on a substance, and can obtain an image. Multiple updates are still under research to diminish the drawbacks of acoustic microscopy. The disadvantages are slow processing time, higher cost, failure to adapt and very large size. Scanning Acoustic Microscopy is important in various fields like medical, biomechanical, microelectronics and dentistry. The most widespread use of SAM is to facilitate failure analysis of various products. It is employed by various companies. The Scanning Acoustic Microscope has been in use from the 1980s but still it requires some major scientific breakthrough to reach its full potential. Even after extensive research, it is still an underused tool due to its few major drawbacks and it is yet to get its proper recognition.

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Author Contributions:

Karishma Desai executed the research work, collected data and drafted the manuscript. Dr. Leslie Rani validated the collection of data as well as did the proof reading of the manuscript. Dr. M.P. Brundha was involved in revision and proof-reading of the review.

Conflict of interest:
None to declare

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