A Review for Luminescence Property of Materials, Its Detection and Probabilities for Embedding of Luminescence with MEMS Technology

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Herein review work for luminescence property of materials, their detection techniques and the possibilities for combining the Luminescence properties of materials & MEMS technology is reported. The core objective of this review work is to through light on the probable areas and prospects of integration of microelectromechanical systems (MEMS) dependent sensing and actuating devices with using the wide-ranging properties of luminescent substances, which can be able to symbolize a new species of genetically engineered sensing and actuating devices. This work discusses about the various visible features and advantages with the applications of such genetically engineered micro-organisms/systems as environmentally friendly bio-correspondents. In this work the various fabrication technique for luminescence material-based semiconductors are discussed, which are similar to the fabrication of MEMS devices.

Introduction

About luminescence

Luminescence, which is the course of action of emission of light ray/beam through some substance or materials when it has been brought to the exposure of light of ultraviolet-infrared radiation, continuous bombardment of electrons, X-rays beam or another tactic of excitation, has mesmerized individuals ever since past. During the early decade of 1900s, researchers & inventors Thomas Edison and E. L. Nichols interpreted that except somebody find out an approach of creating luminescent devices that are immensely sharp and brighter than that of simplest accepted now, luminescence can be expelled as an element in synthetic and artificial lighting. In spite of this, within the session of mid age of nineteen thirties' a little cluster of ingenious researchers at a company known as G. E., were polished lamp tubes which are linearly incandescent, with an earthen inorganic phosphor, willemite, made evacuated the small diameter pipes, treated these by little quantity of mercury, stuffed than by little amount of Torr of argon then packed the end portions with the help of electrodes. During the year of 1933-34 the company General Electrical introduced the first kind of industrial mercury based fluorescent lamps. Now a days' commonly available fluorescent bulbs use unnaturally/artificially produced phosphors; because of excessive effectiveness, these fluorescent bulbs develop higher glow while comparing with other available diversities of lamps.

The catalog of authors contributing and heading for the domain of luminescence incorporated ample of authors [**1**] which are before handed peoples of modern luminescence along with fabricated or synthetic phosphor advancement. They have additionally determined the opportunities of the Luminescence Segment; declaring fresh new phosphors, bestowing distinct fabrication, classification & description, in what way the phosphors were energized, and the wave-lengths they produced within the assured compelled activators and the effectiveness of the phosphors. A few additional researchers dealt in addition to employability of those phosphors, ins and outs (Physical and chemical behaviour) of luminescent substances with diversified usages.

Luminescence is that the development in which the emission or discharge of light ray from any earthen substance or material turn up after its state of electrically excitement. The expressions of Luminescence were made accessible in to the text literature by Wiedemann (1888). He in addition bestowed primarily, even though not utterly & accurately acceptable, clarification of luminescence because the excess emission over and better than thermionic emission background [**2,3**]. This definition replicated an important and necessary property, however it didn't differentiate luminescence from different type of glow that also are surplus emission over and on top of thermionic emission background, among that are mirrored/reflected and refracted light. Vavilov (1951-52) counseled complimenting Wiedemann's rationalization by accumulating the rectification of period and victimization the concept of luminescence to surplus ejection which is higher than that of thermionic ejection from a matter and the ejection contains a surpassing amount of light/glow fluctuations [**2-4**]. Luminescence is a concept in which whole or a portion of captivated energy is re-issued inside all kinds of electro-magnetic wave within the noticeable or near to evident zone of the band. The concept of luminescence consists of 2 phases, the stimulation/arousal of the electronic arrangement of substance and additionally ulterior secretion of photons. An illustration of luminescence is that the light or glow released through a luminous watch dial. Luminescence dissimilarities with luminosity that is the creation of glow through scalding substances [**2-6**].

Whereas definite finite substance absorbs various forms of power supplied to it, few parts of this power could also be discharged/ejected as glow. This procedure consists of 2 stages:

1. An accompanying power source which causes the electrons of the molecules of the fascinating substance to be energized and shifts through the internal circular path to the external circular path.
2. Once electrons collapse with actual state, a quantum of light is secreted. Interval amongst stages could also be inadequate (down from that of 1/10000 second) else extended (many hours). In case that intermission lasts brief, method utilized here termed as fluorescence, if the interval is time-consuming, the method is termed phosphorescence. In both case the light formed is nearly invariably of lesser energy and of longer wavelength than the exciting light [**2,4,5**].

Table 1. Table of Luminescence Types, Excitation source and their Applications.

Type	Excitation source	Applications
Photoluminescence	UV photons	Fluorescent lamps
X-rays luminescence	X-rays	X-rays intensifier
Cathodoluminescence	Electrons	TVs, monitors
Electroluminescence	Electric field	LEDs, EL displays
Thermoluminescence	Heat	Age determination
Chemiluminescence	Chemical reaction	Emergency signals
Bioluminescence	Biochemical reaction	Fireflies, jellyfish
Sonoluminescence	Ultrasound	---
Mechanoluminescence	Mechanical energy	Crack detection

Categorization of luminescence property

There are many kinds or categorization or classifications of luminescence property of substances [**2,7**] every named consistent with that from where and how the energy is coming out from a substance, or which is the type of the activating mode for the development of luminescence property is, for an illustration how luminescence develops:

(a) The Bioluminescence concept (BL)

Bioluminescence behaviour is in additionally called or recognized as "living light" in addition therefore the greatest outstanding illustration of this development or concept is found within the lower depth of seas. Within the areas located at higher depth of sea where the sunlight is not available in proper amount, many incarnate organisms turn out glow/light just because of the consequences of some reactions at chemical level.

(b) The Thermoluminescence (TL)

This category of luminescence which is furthermore termed as thermally aroused or stimulated type of luminescence (TSL). It is one of the kinds of the luminescence which gets actuated thermally subsequently because of initial primary irradiation through supplementary alternative resources of energy sources in form of beam or ray as α-ray, β-ray, γ-ray, Ultra-Violet-ray or X-rays. Here one must not be mixed up this with the thermal radiation: as in this concept, the falling thermal perturbation solely triggers the liberation of energy, when strikes the substance or material coming out via alternative origin or provision of excitation.

(c) The Mechanoluminescence / Triboluminescence (ML)

While dealing with this accidentally discovered or innovated kind of luminescence, light is generated or developed by the application of energy created through mechanical activity. Some of the processes like ripping activity, scratching or crushing using force, or fretting may outcome in the violation of bonds which are chemically created inside the matter that provokes light ejection like in crystals of element of silica or sugar. This concept is additionally referred to as mechanoluminescence.

(d) The Photoluminescence (PL)

This is the phenomenon or process of ejection of the brightness or glow developed due to the energization by electro-magnetic irradiance/photons. This is a lesser explicit word that encompasses both of the concepts fluorescence and phosphorescence. Photo-luminescence found employability from brightening substances in soap dust to screens for giant sized demonstration. An extraordinary category of luminescence which contains an extremely slow deterioration in addition with secretion continued for minutes to hours which is titled as long lasting or persistent luminescence who has got applications in roadside safety and other emergency signs in many places.

(e) The Electroluminescence (EL)

In this process the light/glow is cultivated in reply to an impinged electrical field or voltage on to a particular matter/substance. The foremost developed electro-luminescent appliances in everyday existence are actually diodes who ejects light (LEDs).

(f) The property of Radio-luminescence (RL)

In occurrence of this glow/light is formed or developed in a substance by the invasion with specially of radiations of ionizing in nature such as β-molecules, X-rays or γ-rays.

(g) The characteristic of Chemi-luminescence

The ejection of glow/light beam through discharge or secretion of potency from a chemical process or technique is termed or named as chemi-luminescence. The chemical reaction of Luminol ($C_8H_7N_3O_2$) with a suitable oxidant gives the outcome in a striking blue luminosity.

(h) The Sono-luminescence (SL)

It is the method or process or phenomenon by the use of which light is created or developed or formulated because of the agitation by utilizing ultrasonic waves.

(i) The Cathodo-luminescence (CL)

This is the process of the ejection of glow due to electron beam energization. As in cathode ray tube (CRT) of old age televisions or monitor screens computer and inside a scanning electron microscope (SEM), which is employed by an electron blowgun.

About MEMS Technology

Microelectromechanical based sensing and actuating devices (MEMS) are technological tool of minute or tiny or little devices; it unifies at the level of nano-scale (of the order of $1/10^9$) into nano-electro-mechanical (NEMS) and nano-engineering-technology. In addition they are also termed as micro-machines (Japanese country), or micro-systems-technology (MST) (European country).

From the beginning era of mid-1970, MEMS (microelectromechanical systems based devices) have materialized as an state-of-the-art technology by creating new preambles in the physical [**8**], in the chemical [**9**] and in the biological [**10**] sensors and actuator solicitations and utilizations. Albeit MEMS technology transpires from IC manufacture techniques, assessment approaches [**11**] of both technologies expressively differ from one another. This can be as a result of MEMS based devices reply to both the electrical and the nonelectrical (physical, chemical, biological, and optical) urges.

Microelectromechanical based sensing and actuating devices are diminutive united devices which associate the various electrical based and the mechanical based mechanisms. These structures can be able to intellect, govern and stimulate mechanical processes on the small or micro scale and perform individually or in arrays to produce sound effects on the macro or large scale. The micro production or fabrication technology enables production of large and huge arrays of devices, which independently perform modest or simple tasks, but in collaboration or group efforts can achieve intricate functions.

Piezoresistive based silicon type strain measurements probes were acquainting during Nineteen Fifties by Semiconductor manufacturing company known as Kulite. The well-known Bell Lab's was the beginners who have taken rights of patents on semi-conductor based piezo-resistance which is published in the year 1954 [**12**]. Kulite's strain measurement device exemplify very earlier marketed micro-electro-mechanical-systems (MEMS) [**13**]. Even though investigation on microsystems nurtured over the succeeding decades [**14,15**] moderately little became extensive commercial yields until manufacturing processes improvements were ordinarily accessible.

MEMS based structures cannot be taken as any single application or device, also they cannot be defined by a single manufacturing process or restricted to some limited materials. They are a manufacturing attitude that expresses the benefits of shrinking, numerous constituents to the plan and creation of associated electro-mechano regimes'. MEMS devices are not only about smallness of mechanical systems; they are correspondingly an innovative paradigm for creating mechanical newly flexible kinds of devices and systems. Illustrations of MEMS device claim contain inkjet-printer cartridges for printing, accelerometers for various applications, tiny robots, micro-engines, intelligent locks, inertial sensing devices, micro-transmission systems, micro sized mirrors, micro level actuators, optical type scanners, liquid pumps, transducers and various flow sensors & chemical and pressure sensors. New areas for applications are emerging as the present technology is useful for the miniaturization of structures and collaboration of conventional devices.

The planning and fabrication methodologies starts with expressing of output necessities and needs on behalf of MEMS based sensing and actuating devices. Such a necessities were resolute because of consultations and enquiries & reviews of customers or end product users, also assessments of competitive and available merchandises and they can be defined in terms of consumer specifications. The instrument or tool termed as Quality function deployment (QFD) which validates process of the product definition, design and planning phase. Theories with geometric and substantial property feature are investigated to forecasted accomplishment & planning can be polished on basis of outputs from methodical, mathematical or FEM based data from in-house procedures or collected works available. Representations for ins and outs of MEMS grounded transducers are accessible at various places [**16-18**].

A lot of illustrations demonstrate the benefits of utilizing the design approaches [**19-22**] and planning & proposal procedures were frequently useful in Engineering & Technology. So far planning practices have a smaller amount of utilization of MEMS merchandises [**23**].

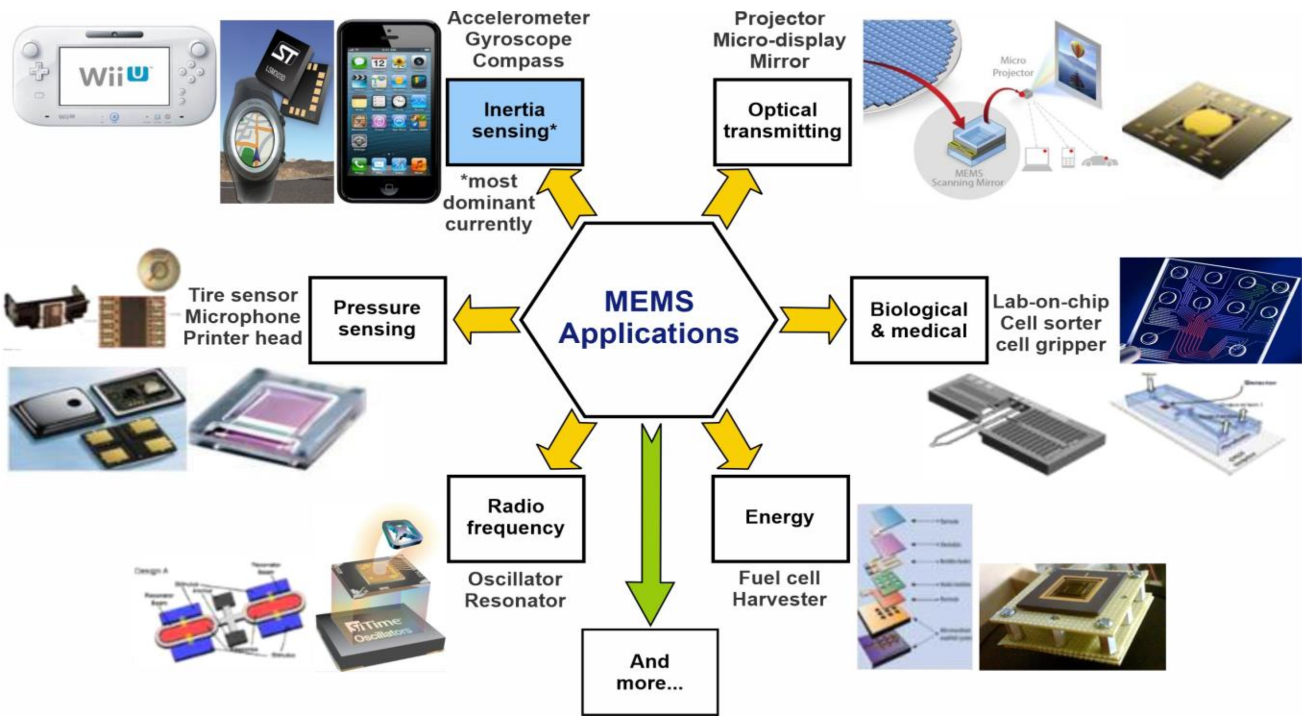

Fig. 1. Schematic of the Extensive arenas of MEMS sensors and actuators-based device applications [24].

Higher in frequency circuits are advancing considerably from the beginning of RF-MEMS technology. Electrical modules such as inductors and tunable capacitors can be upgraded meaningfully related to their integrated equivalents if they are prepared by using MEMS structures and Nanotechnology. By means of the incorporation of such constituents, the effectiveness of communication circuits will advance, while the whole circuit area, power depletion and cost will be abridged. In accumulation, the mechanical control, as developed by several research clusters, is a key element with enormous potential in numerous RF and microwave circuits. The established illustrations of mechanical control switches have excellence factors much sophisticated than anything earlier accessible. An additional effective application of RF-MEMS is in resonators as mechanical filters for betterment of communication circuits.

In broader aspects, numerous advantages associated with MEMS Technologies and systems are [**25**]:

- Minimize energy and materials requirements with the Improved reproducibility, Improved sensitivity, accuracy and reliability of operations.
- Low cost production (When Produced in Mass) with Low power is requirement for working/operations and with easiness to alter the parts of a device as compared to its macro counterpart.
- Exceptionally small dimensions, mass and volume.
- Reduced consumption of power as compared to other systems and flexible for collaboration into systems or modify.
- Lesser value of thermal constant also Can be exceedingly tough to vibration, shock and other falling radiations with Enhanced thermal enlargement tolerance.
- Can be fabricated in huge arrays and Parallelism in operations (Sensing & Actuations).

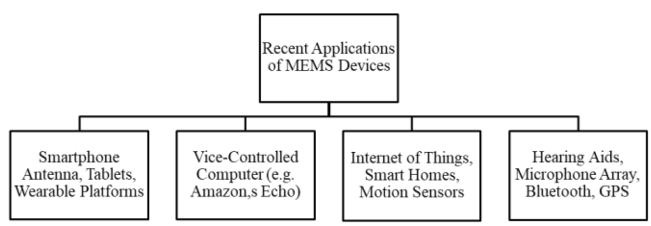

Fig. 2. Some Recent applications of MEMS based device.

Some of the few illustrations of physically available MEMS technology-based products are [**25**]:

- Adaptive kind of Optic systems for Ophthalmic Applications. Optical type Cross Connects, Accelerometers of Air Bag. Sensing devices for Pressure sensing.
- Arrays of Mirror for electronic Displays and Televisions.
- Extraordinary Performing Steerable Micro-mirror systems.
- Radio Frequency MEMS Devices (numerous switches and tunable filters for communication systems).
- Throwaway Medical equipment's, Micro-machined ultrasound type transducers [**27,28**].
- Huge Force, Higher Displacement Electrostatic Actuating systems.

- Various Accelerometers and gyroscopic devices for inertial navigation. Micro sized power sources and tiny turbines. Devices for the Propulsion and altitude control.
- Specified Bio-reactors and Bio-sensors for Microfluidics.
- Devices for Thermal control in industries.
- Energy harvesting at small-scale including or using the piezoelectric [**26**] electrostatic and electromagnetic tiny size harvesters.
- Applications of Bio-MEMS devices in medical supplementary devices, for example stents [**29**].

Literature review

Yotter *et. al.* [**30**] and Hamstra *et. al.* [**31**] have suggested that if the noise floor is substantially low (usually 3 to 5 orders of the amplitude / magnitude) for the photodiodes, the optical modulation is purely dependent on placing of low intensity quasi static signals upside in the spectrum. Yotter *et. al.* [**30**] had presented an assessment of ophthalmic type, chemical type and organic type detectors to identify anabolic movement or event at one cell stage, in the perspective of the establishment of complete lab-on-a-chip investigation arrangement. Yotter *et. al.* [**30**] had mentioned that for single-cell detection, 2 common categories of optical-chemical sensors are accustomed, to get information on the activities in alive cells. The Luminescent probes have the advantage that they will be located straight at intermissions of unit to sight intra-cellular surroundings.

Gomez *et. al.* [**32**] discussed regarding alternative methodology to discover the metabolic movement of the available single cells is to quantify the electric resistance (impedence) modification because of the formation of metabolic by products by the individual cell. Lidstrom *et. al.* [**33**] reported about studies related to the specific biological applications to recognize the responces at the cellular level. In order to correlate cellular activities with genomic information's, the center for small scale life sciences at the washington university developed some microsystems for the purpose of measurement and detection of multiple constraints in the distinct living cells as in case of bioluminescence.

Lansford *et. al.* [**34**] reported for the development of procedures to figure the fluorescent proteins within one unit. In the California Institute of Technology, the Beckman institute had developed these kinds of biological imaging techniques. Schwartz *et. al.* [**35**] suggested about the improvement and utilization of fluorescent protein developers in living cells. Johnson [**36**] suggested that the utilization of deconvolution capacity in the signal conditioning of fluorescence signals are considered during the monitoring of multiple complex cellular interfaces. By using this, at maximum resolution and sensitivity, the emissive outcomes from the multiple fluorophores can be distinguished.

Brogan *et. al.* [**37**] reported that to quantify conformational variations prompted by adenosine triphosphate (at the level of single-cell density of 0–120 μM) FRET quantities are utilized in collaboration of bio-cyclo-mycin fluorescent sensors when combining with a primary interaction. Belkin [**38**] has the objective of his research work that micro systems based upon the combination of solid-state photodetectors with the complete cell sensors, emits a bioluminescent signal when exposed to environment at some toxicity levels. According to the medical dictionary [**39**] a generalized meaning of the word biosensor is representing the connection of an organic substance to micro-electro-mechanical-systems (MEMS) based mechanisms which will be able for speedy, precise, small grade exposure of numerous matters.

Simpson [**40**] found that there is a huge challenge associated with the real time recognition of the bioluminescent property in the low cell volumes. Phiefer *et. al.* [**41**] suggested the comparability of noise levels with the low photon rate per cell for the recognition of bioluminescence behaviour. Mochtenbacher [**42**] reported that generally the photo-diodes have to undergo with various mechanisms associated with noise like shot noise, thermal noise and low frequency noise.

Elman *et. al.* [**43**] suggested a novel modulation device based on the microelectromechanical systems (MEMS), which is technically known as the integrated heterodyne optical based system (IHOS). In this introduces denominated integrated heterodyne optical system (IHOS) the significant part in an add on microelectromechanical system-based device (which is the modulator basically) is built of a miniature shutter of trans-missive type, is positioned in amongst the optical source and the photodetector.

Elman *et. al.* [**44**] introduced the process of fabrication termed as multiple feature ratio structural incorporation in single crystal silicon which needs two photo-masks for the determination of MEMS actuators and shutters at the forward-facing side and to exposed the optical vias shutters from the backward side. Legtenberg [**45**] reported that the grouping of enormous displacement is restricted by electrostatic side pull-in unpredictability.

Mousavi *et. al.* [**46**] focused on the materials and devices emitting the light. They discussed about the principles of working of LED and introduces some materials for this applications. They had reported about various inorganic semiconductors of group III - V (Example GaN & AlN) and of other group II – VI (example ZnO & ZnS) as the significant wide bandgap semiconductors for generation of LED's. They had discussed about Electroluminescent lamps which are applications of light emissive materials. The wide bandgap semiconductor ZnO with its exclusive optical property can be used as semiconductor for optical detectors, emitters and lasers. The nanostructures ZnO and AlN can be synthesized using a chemical vapor condensation technique which is one of the fabrication technique for MEMS wafers also and their luminescent activities are explored at room temperature.

De Acha *et. al.* [**47**] mentioned the importance of luminescence as a powerful tool for various sensing-based applications from agriculture field to the biology while including the treatment and environmental considerations. They had utilized the layer-by-layer nano-assembly technique for fabrication of optical luminescent sensors, which permits fabrications of sensors at nanometer scale. The noteworthy features of the sensors showed in this work recommend that the grouping of luminescence and the layer-by-layer nano-assembly technique is a capable approach for the manufacture of sensing devices for several real time applications. Additionally, a physical answer for sensing applications in unsafe and harmful atmospheres can be acquired by merging luminescence and the Layer-by-Layer method with the exclusive properties of optical fibers.

Swart H. C. [**48**] has reported that several types of phosphors with their all types of possible inorganic hosts and various dopants can be manufactured for all kind of requirements and needs. In his work he has discussed about the phosphor, Bandgap transition phosphor, Luminescence property from nano phosphors, Luminescence behaviour from Persistence Phosphors and their variety of applications like Field emission displays, Fluorescent Lamps, X-ray Screens and Scintillators, Plasma display panels. He has also suggested for future work to create the extremely efficient white light emitting phosphors, to optimize the time of afterglow of the persistent phosphors for lighting up in the night hours with the features of day light harvesting.

Aleksandr *et. al.* [**49**] utilized a grouping of dip-pen nanolithography & scanning optical confocal microscopy to produce and predict luminescent nanoscale patterns of numerous constituents on glass substrates. They also found that this technique can be implemented successfully to thrust the limits of dip-pen nanolithography lower to controlled deposition of single molecules as shown in **Fig. 3**. they also prove that this technique is able to produce and predict protein patterns on surfaces also it can be utilized to manufacture polymer nanowires of controlled size by means of conductive polymers.

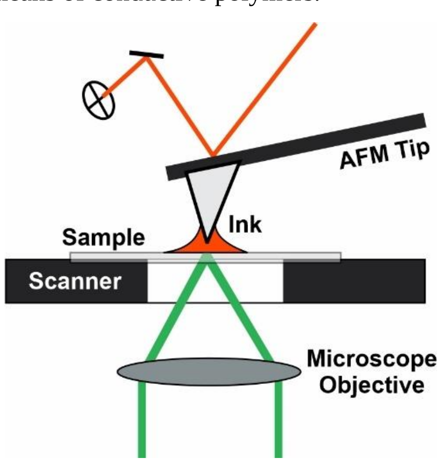

Fig. 3. Schematic of the experimental setup used for dip-pen nanolithography. The instrument combines atomic force microscopy and scanning confocal microscopy functionalities [49].

Wei Liu *et. al.* [**50**] shows, Solid-state-lighting (SSL) technologies are progressively substituting conventional lighting resources due to their benefits in energy efficiency and reduced environmental impact. high-performance luminescent materials can be fabricated as either phosphors or emissive layers or coatings for light-emitting diodes (LEDs) or organic light-emitting diodes (OLEDs), which can be utilized in various sensing and actuating applications.

Qiu *et. al.* [**51**] have discussed about the use of MEMS based sensors and actuators for various types of fiber-optical endoscopy such as two photon imaging, optical coherence tomography, photo-acoustic, confocal and fluorescence. In this author have discussed about the piezo-electric tube-based scanning fiber endoscope (SEF) and about the electro-thermal scanner which are being utilized for multiplexed fluorescent imaging of molecularly targeted imaging. Herein they also discussed about the utilization of custom-made micro-optics lens group with quite minute outside diameter is utilized in the front of SFE probe as shown in the **Fig. 4**, in which **Fig. 4**(**a**) shows the SFE with the scanning illumination fiber moving in the spiral scan pattern, the coaxial scanner design is represented, which contains of the central single-mode optical fiber that is cantilevered from the tip of a tubular piezoelectric MEMS based actuator, held by a mounting collar. **Fig. 4**(**b**) Photograph of the Outside Diameter 1 mm catheter endoscope scan head.

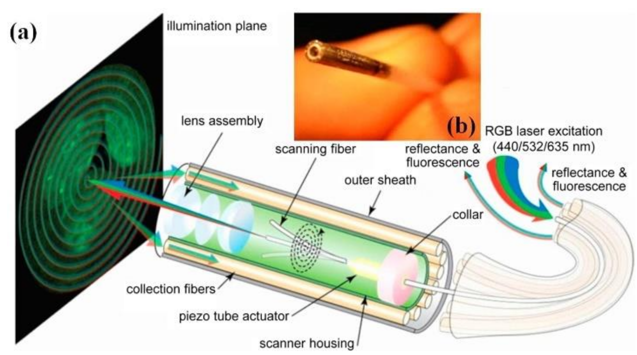

Fig. 4. Wide-field multiplexed fluorescent imaging using Scanning Fiber Endoscopy is shown [51,52].

Flusberg *et. al.* [**53**] discussed about that the between separate locations optical fiber used to guide the light beam which enables new type of fluorescence imaging. The fiber optic fluorescence imaging system consists of several portable components like microscope, flexible endoscopes and micro-endoscope for high resolution imaging which are all now a days MEMS based devices. They have discussed clearly that forthcoming generation of imaging devices based on fluorescence property will be assisted by MEMS based actuators and sensors (micro fabricated device components).

Lee *et. al.* [**54**] as shown in **Fig. 5**, have discussed about the scanning fiber endoscope (SFE) or catheter scope which empowers high-superiority, laser-based, video imaging for small sized clinical uses, these high-resolution fluorescence imaging techniques utilizes the MEMS based Sensing and actuating devices and components.

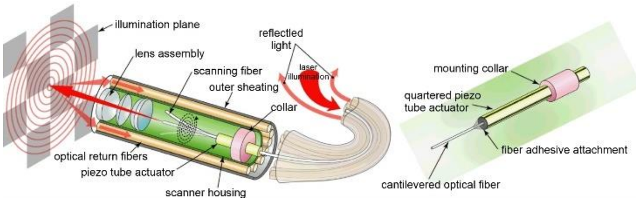

Fig. 5. Functional diagram of the SFE with the scanning illumination fiber moving in the spiral scan pattern [54].

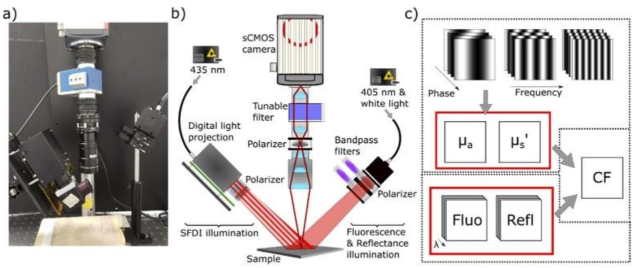

Fig. 6. (a) Photograph of the MEMS sensors & actuators based robotic-assisted surgical systems utilized for multimodal imaging system. (b) System schematics highlighting coupling optics and the two imaging branches allowing diffuse reflectance & fluorescence spectroscopy, single-wavelength SFDI and profilometry. (c) Flowchart representing the data acquisition and processing workflow [55].

Beaulieu *et. at.* [**55**] discussed about the generation of a multimodal optical imaging system which combines the diffuse reflectance and the endogenous fluorescence. The technique discussed by the authors could be combined with MEMS sensors & actuators based robotic-assisted surgical systems which can minimize the risk of damages.

Hoy *et. al.* [**56**] discussed about the two-photon luminescence imaging via a miniaturized probe which is utilizing a two axis MEMS scanning Mirror and crystal fiber. They have discussed about the combination of TPL imaging with probe has potential ability for distinguishing cells in tissue for the diagnosis purpose.

Cerda *et. al.* [**57**] have enlighten about the achievements in the field of Bio-MEMS devices which operates based on the luminescence detection techniques. They have also discussed about the development and working of the luminescence detection techniques-based Bio-MEMS devices.

Pfeiffer *et. al.* [**58**] discussed about the fluorescent or luminescent chemical sensors based microfluidic platforms, which can be employed in miniaturized oxygen and pH sensing. They have also discussed about the MEMS based Integrated microsystems along with bio sensing abilities and also for monitoring of metal ions.

Table 2. Table of Luminescence and MEMS based techniques and their Applications.

Reference No.	Authors & Year	Title	Work carried out / Description
[21]	Douglass M.R.: (2003).	A MEMS Success Story	Various benefits behind utilization of MEMS based devices and technology.
[24]	Cheng-Hsiang Liu*, Hong-Da Chang, Kuo-Hsiang Li, Chen-Han Lin, Chia-Jung Hsu, Tse-Yuan Lin, Hsin-Hung Chou, Hsiao-Chun Huang, and Hsin-Yi Liao. (2013)	Adaptable and Integrated Packaging Platform for MEMS-based Combo Sensors utilizing Innovative, Electronic Components & Technology Conference,	Described about various applications of MEMS devices
[25]	https://www.eeherald.com /section/design-guide/mems_application _introduction. html, (2017)	Design Guide Details,	Numerous applications of MEMS based sensors and actuators
[27]	Hajati, Arman, (2012).	Three-dimensional micro electromechanical system piezoelectric ultrasound transducer	MEMS based transducers for numerous applications
[29]	Louizos, Louizos-Alexandros, Athanasopoulos, Panagiotis G., Varty Kevin, (2012).	Microelectromechanical Systems and Nanotechnology, A Platform for the Next Stent Technological Era,	Applications of Bio-MEMS devices in medical supplementary devices, for example stents
[30]	Yotter R. A., Lee L. A., Wilson D. M.: (2004).	Sensor technologies for monitoring metabolic activity in single cells	assessment of ophthalmic type, chemical type and organic type detectors to identify anabolic movement or event at unit cell stage, in the perspective of the establishment of complete lab-on-a-chip investigation arrangement
[32]	Gomez R., Bashir R., Bhunia A. K.: (2002).	Microscale electronic detection of bacterial metabolism,	alternative methodology to discover the metabolic movement of the available unit cells is to quantify the electric resistance (impedence) modification
[35]	Schwartz J. Lippincott, Patterson G. H.: (2003).	Development and use of fluorescent protein markers in living cells,	the improvement and utilization of fluorescent protein developers in living cells
[37]	Brogan A., Widger W. R., Kohn H.: (2003).	Bicyclomycin fluorescent probes: synthesis and biochemical, biophysical, and biological properties,	Utilization of FERT quantities along with fluorescent sensors

[40]	Simpson M. L., Sayler G. S., Patterson G., Nivens D. E., Bolton E. K., Rochelle J. M., Arnott J. C., B. M., Applegate S. Ripp, Guillorn M. A., (2001).	An integrated CMOS microluminometer for low-level luminescence sensing in the bioluminescent bio reporter integrated circuit,	Discussed about challenges associated with recognition of the bioluminescent property in the low cell volumes
[43]	Elman Noel M., Krylov Slava, Sternheim Marek, Diamand Yosi Shacham (2006).	Bioluminescence Detection Using a Novel MEMS Modulation Technique	suggested a novel modulation device based on the microelectromechanical systems (MEMS), which is technically known as the integrated heterodyne optical based system
[46]	Mousavi S.H., Jafari Mohammdi S.A., Haratizadeh H. and de Oliveira P.W.: (2015)	Light-Emitting Devices – Luminescence from Low-Dimensional Nanostructures	focused on the materials and devices emitting the light.
[47]	De Acha Nerea, Elosua Cesar, Matias Ignacio and Arregui Francisco Javier: (2017).	Luminescence-Based Optical Sensors Fabricated by Means of the Layer-by-Layer Nano-Assembly Technique,	importance of luminescence as a powerful tool for various sensing-based applications from agriculture field to the biology
[48]	Swart H. C. and Ntwaeaborwa OM: (2013).	Compound Luminescent Semiconductors: Their Properties and Uses,	discussed about the phosphor, Bandgap transition phosphor, Luminescence property from nano phosphors, Luminescence behaviour from Persistence Phosphors and their variety of applications like Field emission displays, Fluorescent Lamps, x-Ray Screens and Scintillators, Plasma display panels
[49]	Aleksandr Noy, Abigail E. Miller, Jennifer E. Klare, Brandon L. Weeks, Bruce W. Woods, and James J. DeYoreo: (2002).	Fabrication of Luminescent Nanostructures and Polymer Nanowires Using Dip-Pen Nanolithography,	utilized a grouping of dip-pen nanolithography & scanning optical confocal microscopy to produce and predict luminescent nanoscale patterns of numerous constituents on glass substrates
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[55]	Emile Beaulieu, Audrey Laurence, Mirela Birlea, Guillaume Sheehy, Leticia Angulo-Rodriguez, Mathieu Latour, Roula Albadine, Fred Saad, Dominique Trudel, and Frédéric Leblond, (2020).	"Wide-field optical spectroscopy system integrating reflectance and spatial frequency domain imaging to measure attenuation-corrected intrinsic tissue fluorescence in radical prostatectomy specimens,"	discussed about the generation of a multimodal optical imaging system which combines the diffuse reflectance and the endogenous fluorescence
[56]	C. Hoy *et al*., (2008)	"Two-photon luminescence imaging using a MEMS-based miniaturized probe,"	discussed about the two-photon luminescence imaging via a miniaturized probe which is utilizing a two axis MEMS scanning Mirror and crystal fiber
[57]	Cerda-Kipper A.S., Hosseini S. (2020)	Bio-microelectromechanical Systems (BioMEMS) in Bio-sensing Applications-Luminescence Detection Strategies.	Discussed about the achievements in the field of Bio-MEMS devices which operates based on the luminescence detection techniques

Conclusion

There are abundant possibilities to grow new MEMS based sensing technology using the properties of luminescence materials. MEMS technology can be taken to a new era of energy harvesting by fabricating them using the properties of luminescence materials. Further developments in sensor material, manufacturing methods and recognition techniques will extend the obtainability of tiny sensors, decrease the reaction time, minimizes the cost. Semiconductors can be fabricated by the same techniques as required for manufacturing of MSMS devices. Semiconductors can also be fabricated by using luminescence materials/phosphors to avail new features of MEMS based applications. MEMS based pressure sensors, strain gauges etc. can be developed by using luminescence materials to obtain new features in the devices possessing multiple flexibilities and applications.

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Keywords

Luminescence, bioluminescence, thermoluminescent, mechanoluminescent, photoluminescent, Microelectromechanical systems (MEMS).

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