Analysis of Ultrasound Transducer Probe and Alternate Material for Its Foot Print

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Abstract. A 128-element color ultrasound transducer probe (Sonoray – DS50PLUS-C352UB) compatible with any machine is analyzed. Various coating methods were discussed; the footprint is coated with TiO$_2$ by the dip coating method, and characterization is done simultaneously. Curvilinear ultrasound transducer probe is most used to scan the abdomen part of the human body. Its characteristics were analyzed to find an appropriate alternate nanomaterial to be coated over its footprint to make the device a cost-effective one with even better output. Before and after the nanomaterial is coated, Fesem, EDS, and XRD tests were done over the transducer footprint. The dip coating method is easier, quicker, and cheaper but less effective among various coating methods.

Keywords: Ultrasound transducer, nanomaterial, dips coating, EDS, XRD

1. Introduction
Medical imaging creates a visual representation of the body's internal organs to be analyzed for disease diagnosis and treatment. X-ray, Ultrasound, Computer Tomography (CT), Magnetic Resonance Imaging (MRI), and Poisson Emission Tomography (PET) are the modalities through which the medical images can be obtained [1]. These images help in diagnosis, therapy planning, and therapy execution. X-rays emit electromagnetic rays. Since it uses ionizing radiation, the exposed human will face skin reddening, hair loss, etc. A computerized procedure in which X-rays are aimed at a patient around the whole body is called CT. MRI imaging uses a magnetic field to obtain a picture of the body’s internal organs to know more about the tissues [2]. Sound waves (High frequency) help to view the internal organs of the body in ultrasound imaging. Non-ionizing radiation is exposed in this case. It is one of the most widely used imaging modalities, especially for pregnant women.

Nanocomposite material being a multiphase solid material will have at least one phase with one, two, or three dimensions of nanoscale (less than 100 nm). It is light-weighted and performs better in terms of mechanical strength, toughness, electrical or thermal conductivity, and surface appearance [3]. Yttrium oxide (Y$_2$O$_3$), commonly known as yttria, is a white solid substance, air stable. Its melting point is 2425°C, and its boiling point is 4300°C [4]. Al$_2$O$_3$ is a chemical compound of aluminum and oxygen. Its melting point is 2072°C, and its boiling point is 2977°C [5]. TiO$_2$ has a melting point of 1843°C and a boiling point of 2972°C. It has lower toxicity, high oxidation power, and chemical stability [6].
Electron beam (e beam) evaporation coating method, a sputtering method, spray pyrolysis method are found to be good in coating nanomaterials but are found to be expensive and complex. The contact angle is larger in the e-beam evaporation process than in the film done by the spin coating technique. Its deposition rate is 3 nm/s. The power required for e-beam evaporation is 8 KW, and the beam current controller's pressure is supposed to be 3.0 x 10^{-6} m.bar [7]. The rest of the paper is organized as follows: Literature review on ultrasound imaging, Figure 1 in ultrasound transducer probe, Lead Zirconate Titanate & graphene is discussed in section II, analysis of existing transducer – characterization results of outer & inner coating of the footprint in section III, Identification of alternate nanomaterial – Justification for alternate nanomaterial TiO₂ over graphene in section IV, the impact of the alternate material coating in section V and finally ends with a conclusion in section VI.

2. Literature Review
A sonogram is obtained from the ultrasound machine. An ultrasound machine uses a probe that transmits sound waves generated by it into the tissues of the human organ to be imaged, and it returns in the form of an echo. This information is converted into the required image that helps in diagnosis. The need to analyze an ultrasound transducer's design and architecture is to gain knowledge and information about the same. It helps to come out with a new low-cost device that produces even better output than the existing one. A patient-friendly device with more biocompatibility and low adverse effects is the target.

The internal structure of the transducer that has been studied comprises two major parts. One is the piezoelectric element. One hundred twenty-eight such elements are present, made of Lead Zirconate Titanate (PZT) [8]. The second concerns the footprint of the device that gets in contact with the patient to be diagnosed. It has two layers in which both layers, the outer and the inner coating, are done with material rich in graphene [9]. The footprint is that part of the device, which deals with electrical energy and sound energy during transmission and reception.

![Figure 1: Model of ultrasound curvilinear transducer probe](image)

Lead-free ceramic dielectric capacitors can replace the piezoelectric element made of Lead Zirconate Titanate. The footprint can be coated by alternate nanomaterials like TiO₂ [10], Carbon Nanotubes, or polymer composites. The identified nanomaterial can be coated either by an e-beam evaporation method or a sputtering method [11].

3. Characterization of Transducer
Field emission scanning electron microscope (FESEM) and Energy-dispersive X-ray spectrooscope (EDS) results of the transducer s footprint (both outer &inner coating) are obtained for analysis Figure 2 and Figure 3.
The inference of FESEM and EDS results of both the coating reveals that graphene is the most prominent material coated element. Figure 4 shows the thickness measurement of both outer and inner coatings of the footprint.
4. Identification of Alternate Material

(a) TiO₂ Nanomaterial:
Applications of TiO₂ based nanostructured material include bone scaffolds, vascular stents, drug delivery systems, and biosensors [12]. Good reproducibility and high sensitivity to certain elements are the requirements of an ideal biosensor. TiO₂ is found to possess these features to a good extent. SEM and TEM analysis can be made to study the morphology of TiO₂ nanomaterial coated on any surface [13].

(b) TiO₂ coating
After a detailed study made, TiO₂ is found to be an alternate material to be coated over the footprint since it is cheap, non-toxic, efficient semiconductor photocatalyst, Strong oxidizing power, and with corrosive resistance [14]. It has good electrical, optical, and chemical properties as well. General applications of TiO₂ are that it can be used in Photocatalysis, optical coating, gas sensors, and humidity sensors [15].

TiO₂ was coated by a dip coating method. The procedure is as follows:
1. Removed the outer coating from the footprint of the existing transducer.
2. Cleaned the surface to be coated with isopropanol.
3. Immersed in Polyethyleneimine (PEI) (Precursor)
4. Immersed in polystyrene sulphonate (PSS)
5. Immersed in Poly-Diallyl dimethyl ammonium chloride (PDAMAC)
6. Immersed in PSS
7. Immersed in Titanium dioxide (TiO₂)
8. Immersed in PSS
9. Immersed in TiO₂
10. Immersed in PSS
11. Immersed in TiO₂
12. Immersed in PSS
13. Immersed in TiO₂

PEI solution is obtained by adding 5ml PEI in 45 ml H₂O.
PSS solution is obtained by adding 60 mg of PSS salt in 60 ml of H₂O.
pDADMAC solution is obtained by adding 157µl of pDADMAC in 60 ml of H₂O.
TiO₂ solution is obtained by adding 60mg TiO₂ powder with (APS: 20nm) in 60 ml of H₂O.
Immersion is done for 15 minutes in each step. After each immersion except in TiO₂, the surface to be coated is washed with distilled water. After immersing in TiO₂, it is washed with distilled water with a pH value of 3. After the coating is done, the substrate must be kept in a dry condition for almost 12 hours for further characterization.
5. Result and Discussion

As shown in Figure 5 is the liver & gall bladder ultrasound image of a 28-year-old female, captured using 128 element color ultrasound transducer probe (Sonoray – DS50PLUS-C352UB) with its existing footprint coating.

![Ultrasound image captured with existing footprint coating.](image)

Figure 5: Ultrasound image captured with existing footprint coating.

After capturing the image, the outer coating is removed, and the identified alternate nanomaterial TiO₂ is coated over the footprint by a dip coating method. The dip coating method resulted in a partial coating of TiO₂. Hence, the image captured after the coating contains very less information with plenty of granules, proving the dip coating method to be very less effective in medical devices.

6. Conclusion

A new cost-effective 128 element color ultrasound transducer probe can be developed based on the information obtained from the study of the existing one. FESEM, EDS, and XRD results of the existing transducer obtained after characterization provide relevant information for analysis. The existing transducer contains two important portions, namely PZT transducer for transmission & reception of signals and footprint that gets in contact with the patient to be diagnosed. In this paper, an alternate transducer element (lead-free dielectric capacitors) instead of a PZT transducer is proposed based on the review. An alternate nanomaterial (TiO₂) is proposed coated over the existing device's footprint, replacing graphene by a dip coating method and then characterized for assessment. The image obtained does not contain much information, and hence dip coating method is less effective in the case of medical devices. The same work can be done by different coating methods like e-beam evaporation and sputtering, and the device can be characterized for further analysis.

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