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Research Article

Theoretical Insights Manifested by Wave Mechanics Theory of Microwave Absorption - A Perspective Based on the Responses from DeepSeek

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Abstract

A perspective is provided using a question-and-answer session with DeepSeek, which illustrates the common misconception dominant in the field and shows that the new wave mechanics theory is wrongly rejected because of these established wrong concepts. The purpose of the work is to draw the attention of material scientists to the fact that wrong theories continue to be published with little attention to the newly established wave mechanics theory for microwave absorption. It also shows that artificial intelligence can be a useful tool, but will often be biased in favour of established ideas from which it has learnt rather than new theories without precedent in the scientific literature.

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Introduction

It has been confirmed that interfaces between material particles behave differently from the two parallel front and end interfaces in a film. The function of interfaces between material particles is to average the relative permittivity ε_r and permeability μ_r [1], while the function of the two parallel interfaces of the film is to make wave superposition possible [2]. The confusion between the material and the device composed of the material was identified as a consequence of the confusing the input impedance Z_{in} and the characteristic impedance Z_M in current theories [3,4] where Z_{in} characterizes the film or the device and Z_M characterizes the material and the interface. It was further confirmed that the two parallel interfaces in the film behave differently from isolated [5]. The common errors that arise because of confusing the film and the interface in current publications have not been corrected [6]. It was proven that interface does not absorb microwaves even if the related material and film do absorb [7]. In this work it is argued that the wrong concepts about the interface have stonewalled the acceptance of the recently established correct wave mechanics theory based on energy conservation [2,8-10] and the wrong mainstream theories have been insisted upon.

Several papers with many downloads have been published to show that the current dominant microwave absorption theories are wrong and should be replaced by the new wave mechanics theory established in recent years. However, material scientists still insist on the wrong theories with many publications in various journals without mentioning the new theory, although fews [11-14] have mentioned the new theory. To draw attention to this subject, it [15] showed that the new wave mechanics theory of microwave absorption conforms to transmission line theory while the current dominant theories in the field of microwave absorption were developed from the misinterpretation of the transmission line theory, along with the perspectives previously presented from common errors appeared in publications [6]. This work presents new perspectives on the same subject of ref [15] from question kindly designed by Dr. Jiqing Zeng of South China Botanical Garden, Chinese Academy of Sciences and the responses offered from DeepSeek. DeepSeek is a free platform at https://www.deepseek.com/ which is closely related to ChatGPT. The question and answers are in Chinese and have been provided in the Supplementary Materials A with English translations presented at appropriate positions in this work.

The question asked was a good one since it represents the wrong concepts believed by material scientists, and a discussion about the responses offered by DeepSeek helped us to identify why many of the related papers do not mention the opposite theory at all. It also shows that only commonly accepted answers can be expected from AI and that innovative discoveries are difficult to be offered from machine intelligence at its current stage of development.

The question and the responses from DeepSeek

The question and the answer from DeepSeek demonstrate the wrong concepts hold by material scientists, that is material, film, and interface have been confused.

Question to DeepSeek

"Under what circumstances is microwave absorption only related to the interface of the material and not to the properties of the material itself?"

The correct answer to the question should be when there are front and back interfaces assembling with absorption material to form a device like film, the absorption mechanism of the device will be changed to wave superposition instead of the attenuation power of the material [9]. It should be noted that the film does not absorb microwaves if the material does not absorb, even though the absorption mechanisms of the film and the material are different [7]. However, as expected, the responses from DeepSeek were based on the wrong concepts from current theories, confusing film and material, interfaces between material particles and those of the film, and the interface of film and in its isolated state.

The response from DeepSeek

Two versions of the response have been provided from DeepSeek, and one of rather long is presented below, and the other version is provided in Supplementary Materials B.

"Well, what the user is asking is under what circumstances the absorption of microwaves is only related to the interface of the material, and not to the characteristics of the material itself. This question seems a bit challenging because microwave absorption is often closely related to the electromagnetic parameters of materials such as dielectric constant, magnetic permeability, etc. But users may want to know if there are special circumstances that make interface effects the dominant factor, while the properties of the material itself become less important.

Firstly, I need to recall the fundamental principles of the interaction between microwaves and materials. The absorption of microwaves mainly involves mechanisms such as dielectric loss, magnetic loss, and conductive loss, all of which are related to the inherent properties of materials. But users want to know if there is a situation where interface effects dominate, which may involve reflection, transmission, and interference phenomena. In this case, the design of the interface structure may be more important than the properties of the material itself.

For example, when the material is very thin, such as metamaterials or metasurfaces, the thickness of the material is much smaller than the wavelength of microwaves. Electromagnetic waves mainly interact with interface structures, such as periodic structures or subwavelength structures. The design of these structures can change the reflection and transmission characteristics of electromagnetic waves, while the dielectric constant or magnetic permeability of the material itself may have a smaller impact. In this case, interface effects may become the dominant factor.

In addition, it is also possible to enhance the absorption effect by designing impedance matching different layers in a multi-layer structure, so that the incident wave undergoes multiple reflections and interferences at the interface. At this point, although the material properties of each layer are important, through structural design, the overall absorption effect may depend more on the interactions between interfaces rather than the properties of a single material itself.

Another scenario is surface plasmon resonance, where electromagnetic waves interact with free electrons on the metal surface, exciting surface plasmon polaritons at the interface. In this case, absorption may be closely related to the interface structure, while the internal properties of the material have a relatively small impact.

However, it is necessary to verify whether these situations truly render the properties of the material itself irrelevant. For example, in metasurface design, although the structure is crucial, the choice of material (such as metal or dielectrics) still affects the performance of the structure, so it may not be completely unrelated. But the user's question may be whether there are certain extreme situations, such as when the material thickness approaches zero, or when the structural design completely compensates for the material's characteristics, where interface effects dominate.

It may be necessary to consult some literature or theories to see if such theoretical models exist. For example, in an ideal situation, if the thickness of the material approaches zero, but the interface structure is designed very cleverly, absorption may be mainly determined by the interface structure. Or at certain frequencies, structural design can make the internal losses of the material negligible, while multiple reflections and interferences at the interface lead to absorption.

The concept of impedance matching also needs to be considered. When the impedance of the material is perfectly matched with free space, microwaves will completely enter the material without reflection, and absorption may be determined by internal losses of the material. But if impedance matching is achieved through interface structure and the loss of the material itself is low, then absorption may depend more on the design of the interface structure rather than the loss characteristics of the material itself.

For example, using a multi-layer structure, the thickness

and material parameters of each layer are designed to cause destructive interference of the incident wave at the interface of each layer, thereby reducing reflection and increasing absorption. In this case, although material parameters are still important, the overall absorption effect may depend more on structural design, namely the interaction between interfaces, rather than the intrinsic properties of a single material.

In addition, under certain resonance conditions, such as Fabry-Pérot Resonance, electromagnetic waves may form standing waves after multiple reflections inside the material, resulting in strong absorption at specific frequencies. In this case, the position and intensity of the absorption peak may be determined by the thickness of the material and interface reflection, while the loss parameters of the material itself may affect the absorption bandwidth, but the resonance conditions themselves are determined by interface and structural parameters

In summary, possible scenarios include:

1. *Ultra-thin materials or metasurface designs are dominated by structural effects.*
2. *Multilayer interference structure, interface reflection, and phase matching determine absorption.*
3. *Surface plasmon resonance and interface excitation dominanted absorption.*
4. *Fabry-Pérot resonant cavity, thickness and interface reflection determine the resonance conditions.*

Further verification is needed to determine whether these situations truly render the properties of the material itself irrelevant, or whether the coordination of material parameters is still necessary. For example, in metasurface design, although structure is crucial, the choice of material (such as metal or dielectric) still affects performance. However, in some extreme cases, structural design may compensate for changes in material properties, making the absorption effect mainly determined by the interface structure.

In addition, it may be necessary to consider the limit cases in the theoretical model, such as whether absorption may only be caused by interference from interface reflection when material loss approaches zero. For example, in an ideal lossless medium, by designing a multi-layer structure to cancel out reflected waves and restrict transmitted waves, complete absorption can be achieved at a specific frequency. In this case, the absorption mechanism may be independent of the material's own losses and determined only by interface interference.

For example, in Coherent Perfect Absorption, the energy is completely absorbed by the interference of two coherent waves. In this case, the conditions for absorption may only depend on the reflection and transmission characteristics of the interface, but not on the loss parameters of the material. However, this may be a special case and requires specific experimental conditions.

In summary, the possible answer is: when the absorption of microwaves is mainly determined by the reflection, transmission and interference effects at the interface, and the loss inside the material can be neglected, for example, in the case of ultra-thin structure, multi-layer interference design or coherent perfect absorption, microwave absorption may be mainly related to the interface, and has nothing to do with the electromagnetic properties of the material itself (such as dielectric constant, magnetic permeability). In this case, structural design becomes the dominant factor, not the material's intrinsic properties. "

We have checked this question from ChatGPT and DeepSeek with the same question and obtain similar responses. The responses we obtained from DeepSeek also include the additional point that material property can be neglected for the perfect impedance matching for the wrong reason that for perfect impedance matching, the incident microwaves did not penetrate the film, and all waves were absorbed by the front interface.

Discussions with respect to the response from DeepSeek

Reflection loss *RL*/dB for metal-backed film is always used wrongly in publications to characterize the absorption from material. *RL* is a parameter for film rather than material [16] and thus it can only be used to characterize film and not material. The film is a device from a material with a front interface and a back interface. A block of material behaves as a film since it has two parallel interfaces [9] and thus *RL* can be used to characterize a block of material even though it cannot be used to characterize material. Therefore, a block of material can have properties not possessed by a material. Only parameters such as the relative permittivity ε_r and the permeability μ_r can be used to characterize material [4]. It should be known that microwave absorption of a material is characterized solely by ε_r and μ_r of the material even there are other parameters of derivatives of ε_r and μ_r such as attenuation power constant α_p and the dielectric and the magnetic loss tangents have the similar function.

The interfaces between material particles have often been used to explain the absorption characterized by *RL*/dB and were believed to have a dominant effect on material absorption [17,18]. Indeed, there is a clear relationship between *RL* and the values of ε_r and μ_r by the formula of *RL* derived from transmission line theory and the values of ε_r and μ_r are determined by material structure, but there is no clear relationship between *RL* and material structure or the interface structure of the material. Thus, the research on the relationship between *RL* and material structure is not scientific. The scientific design of a research program should first determine what values of ε_r and μ_r are required to achieve the desired value of *RL*, and which material structure might have these values [19]. However, the key research on the relationship between material structure and the values of ε_r

and μ_r has been seldom done. It should be noted that uniform material with interfaces between material particles is still a single-phase material with averaged values of ε_r and μ_r [1] and the same is true for a multi-layered film when averaged values of the device is referred [10]. The effects of material structure such as split-ring resonators and the Maxwell–Wagner interfacial polarization effect, affect the values of ε_r and μ_r, and thus absorption of the film is affected by these effects through ε_r and μ_r. The sensible research should investigate the relationship between the material parameters of ε_r and μ_r and the effect of split-ring resonators or of the Maxwell–Wagner rather than the relationship between the value of *RL* and those effects, since other device parameters, such as film thickness, also contribute to the value of *RL*. These conclusions demonstrate that discussing the relationship of absorption represented by *RL*/dB and interfaces between material particles makes little sense, and without exception, any correct results conforming to the newly established wave mechanics theory can always be obtained from any reported values of the material properties of ε_r and μ_r.

The functions of the two parallel interfaces for film are quite different from those of material particles for microwave absorption. The two interfaces of the film offer wave superposition [2,5,8,20-22], while the interfaces between material particles only provide the average values of ε_r and μ_r [1]. It should be noted that the interface does not absorb microwaves [7]. The effects of the interfaces between materials on absorption do not arise because an interface absorbs microwaves, but because the values of ε_r and μ_r are affected by material structure. Thus, the interface only changes the average values of ε_r and μ_r rather than absorbing microwaves by itself. Material attenuation is of monotonic function while *RL*/dB has a wave shape since there are angular effects for film [2]. Film behaves as material only when the front interface disappears under the condition $Z_M = Z_0$ where all incident microwaves enter the film.

Thin film has apparent angular effects on absorption [2,19] and thick film behaves more like material with monotonic attenuation power [19]. However, thin material, metasurfaces, and subwavelength structures were used in these responses related to interfaces within material other than the concepts of thin and thick films. The concepts of thin and thick film were developed to differentiate film and material [19]. The concept of the interface structure of material in publications often neglects the fact that the interface does not absorb microwaves [7] and the reflection coefficient of an interface is often wrongly used to evaluate absorption from film [6,23-25].

The absorptions of material and film have not been differentiated in DeepSeek's responses which represents the common mistake of confusing film with material in current mainstream microwave absorption research. The responses represent the common practice of using interface structure within materials to account for the absorption peaks represented by *RL*/dB. Such practice has never achieved any valuable conclusions since it has also wrongly attributed the effect of film thickness on *RL* to the effect of interface structure. The responses also reflect the fact that the interfaces of film and the interfaces within material have been confused in current theories. The interfaces within the material change the average values of ε_r and μ_r. The interfaces of inner layers within a multi-layered film function the same as the interfaces within the material [10] and using a multi-layered film does not diminish the effects of ε_r and μ_r on absorption. On the other hand, the two parallel interfaces of the film are only responsible for wave superposition rather than changing the values of ε_r and μ_r.

The confusion between film and material has led to the establishment of the wrong impedance matching theory, which was also involved in the responses. Impedance matching theory is used to explain the absorption peak of film when the input impedance of the film Z_{in} is not equal to the characteristic impedance of free space Z_0. However, at perfect impedance matching ($Z_M = Z_0$) where all the incident microwaves enter the film, the front interface of the film disappears and there is no absorption peak at all since the film behaves as a material under these circumstance [5,19,21,26,27]. It should be noted that the impedance matching theory in microwave absorption is not the same as the correct and rigorous impedance matching theory in circuit theory.

Indeed, the absorption peak with $|Z_{in}|$ the closest to $|Z_0|$ is the strongest absorption among all the absorption peaks for a film, but the reason is not the greatest microwaves penetration when $|Z_{in}|$ is the closest to $|Z_0|$ [3,5]. The real reason is that the two reflection beams from the two parallel interfaces at front and back of the film have complete canceled each other when $|Z_{in}| = |Z_0|$ with the phase difference of the two reflected beams is π [2,8].

It should be noted that Fabry-Pérot Resonance relates to film rather than material and the resonance referenced by Fabry-Pérot Resonance is in fact the complete wave cancellation rather than real resonation. Almost all the absorption reported in microwave absorption papers were from damped oscillations rather than from the resonance absorption, that is, the intensity of the total beam reflected from the back interface of the film $|R_2|$ is a decay function of frequency or film thickness in polar coordinate system[28,29].

The response from DeepSeek that "*in an ideal lossless medium, by designing a multi-layer structure to cancel out reflected waves and restrict transmitted waves, complete absorption can be achieved at a specific frequency*" represents a common mistake in current theory concerning relationship between interface structure of material and absorption. When material does not absorb microwaves, the film cannot absorb

microwaves even if the relevant two reflected beams are out of phase by π [2,21,30]. The principle that a film composed of lossless material does not absorb microwaves is ensured by energy conservation [7].

Without correct theoretical guidance, experimental data were used to support the wrong theory. A theory that has been repeatedly "verified" by experiment can still be a false theory. Until the geocentric theory was disproved by the heliocentric theory, all experimental observations were used to support the false geocentric theory; Until the phlogiston theory was finally disproved by mathematical logic, all previous experimental results had been used to support the phlogiston theory; Until the new wave mechanics theory of microwave absorption is established, all experimental reports had been supporting the erroneous prevailing theory of microwave absorption.

In the past, experimental data was used to support the current wrong theories of microwave absorption because the correct theory was not available. Now, the correct new wave mechanics theory of microwave absorption is ignored, and therefore, the mainstream scientists still adhere to the current erroneous mainstream theories because wrong concepts have already been established.

It was revealed that inconsistencies in established theories cannot easily be identified without theoretical understanding because of the ingrained misconceptions [15]. AI can be very successful when the mainstream theories are correct; otherwise, it is difficult to devise an appropriate question, and it is difficult for AI to sample the correct information, overwhelmed by the dominant views. The AI modes are trained by common views from current theories, and it cannot be expected that Artificial Intelligence is currently able to recognize inconsistencies in current theories. In this work, the responses of DeepSeek to a question are analyzed to clear up the concepts hindering material scientists in appreciating the newly established wave mechanics theory for microwave absorption. Since there are no comments on the new mechanics theory, the responses from DeepSeek represent what the mainstream scientists think. It reveals that the misconceptions, such as using the reflection coefficient of the interface to characterize microwave absorption, the film with lossless material absorbing microwaves by wave cancellation, are responsible for the fact that material scientists are reluctant to give up the theories that have been proved wrong. Neglecting the fact that the effects of film thickness on absorption have also been mistakenly described as being caused by the effects of interface structure of material on absorption has made the research community insist on the unscientific investigation of the fake relationship between interface structure of material and the peak values of RL/dB. Artificial intelligence can be helpful in identifying what misconcepts have prevented the acceptance of the correct wave mechanics theory, but it will be difficult to require it to identify problems within current theories.

Wrong theories cannot become correct just because they have survived for a long time and have been supported by a majority of scientists [31-34]. The wrong concepts not only have led to wrong theories; they also have made it difficult to recognize the wrongness of the theories as revealed from the responses of artificial intelligence. "Yes, error detectors can make research less comfortable — but that discomfort is healthy … journals need to make clearer and firmer commitments to self-correction [35]". However, "Scientists are often tardy in fixing basic flaws in their sciences despite the presence of better alternatives" [36] and "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it" [37]. That scientists are reluctant to accept new ideas is an unsolved problem that has repeatedly occurred in history and thus is important to be addressed through concrete examples. It is relevant to conclude with Nobel laureate Ding Zhaozhong's words: "Every one of my experiments has been opposed by many people, especially the experiments on the space station … First-rate scientists can look forward and make judgments about the future … Opposition is not a bad phenomenon, but it is meaningless to solve scientific problems by voting. The progress of science is that the majority obeys the minority. Only when a very small number of people overthrow the views of the majority can science move forward [38]".

Conclusion

The current theories have confused the film with the material, which has led to the wrong absorption mechanism that has dominated microwave absorption research. The impedance matching theory is a wrong theory based on a wrong interpretation of transmission line theory. The quarter wavelength theory is a wrong theory, and has led to many common mistakes in publications. The experimental data published to support the wrong theory have recently been proved to disprove the theory. These conclusions are firmly established from the rudiments of physics and can be confirmed by the correct analysis of the data published.

While data picked from experiments may conform to current impedance matching theory, the logic of the theory applied to these data is still wrong. The impedance matching theory cannot explain all the absorption peaks from the reported experimental data and cannot offer a logical explanation why almost all the reported absorption peaks do not occur exactly at $Z_{in} = Z_0$, a result not caused by experimental error. In contrast, all the absorption peaks reported can be precisely predicted by the new wave mechanics theory without exception. However, the current wrong theories still dominate current publications, and thus, the issues concerned here are important. Under such solid theoretical results established from the rudiments of physics and the firm experimental evidence already published in the literature, it will be inexplicable to future scientists why corrections of the erroneous theories have taken so long.

To achieve a broadband absorption, the important question to ask, according to the wave mechanics theory, is what kinds of $\varepsilon_r(\nu)$ and $\mu_r(\nu)$ can ensure the fullest cancellation of the two reflections from the two parallel interfaces of the film [19]. That is, it is important to know what material structure change can increase or decrease the values of $\varepsilon_r(\nu)$ and $\mu_r(\nu)$. $\varepsilon_r(\nu)$ and $\mu_r(\nu)$ are respectively the permittivity and the permeability at frequencyν. However, under the influence of the wrong theories in the field, little has been done on the relationship between material structure and the values of $\varepsilon_r(\nu)$ and $\mu_r(\nu)$ in this valuable direction, though thousands of papers have been published over a long period of time [39].

Preprint

The preprint of this work has been presented at:

https://www.preprints.org/manuscript/202504.0447/v2

Supplementary Materials A: Information provided by Dr. Jiqing Zeng of South China Botanical Garden, Chinese Academy of Sciences

Supplementary Materials B: More information.

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