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ALYUMINIY NANOZARRALARINING DISPERS MUHITDA SOCHILISHI EFFEKTIV KESIMINI HISOBLASH

Ashurov Sindorjon Axmadjon o‘g‘li
Mirzo Ulug`bek nomidagi O`zbekiston Milliy Universiteti Fizika fakulteti Yadro fizikasi kafedrasi o`qituvchi

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Annotatsiya. *Bu maqolada alyuminiy nanozarralarining suvdagi harakati uchun Mie nazariyasidan foydalangan holda sochilish va yutilish effektiv kesimlari hisoblangan. Bunda MiePlot dasturidan foydalaniladi.*

***Kalit so`zlar****: Mie nazariyasi, sochilish effektiv kesimi, kompleks nur sindirish ko`rsatkichi.*

РАСЧЕТ ЭФФЕКТИВНОГО СЕЧЕНИЯ ДИСПЕРСИИ НАНОЧАСТИЦ АЛЮМИНИЯ В ДИСПЕРСНОЙ СРЕДЕ

Аннотация. *В этой статье рассчитаны эффективные сечения рассеяния и поглощения с использованием теории Ми для движения наночастиц алюминия в воде. Делается это с помощью программы MiePlot.*

Ключевые слова*: теория Ми, сечение рассеяния, комплексный показатель преломления.*

CALCULATION OF THE EFFECTIVE SECTION OF THE DISPERSION OF ALUMINUM NANOPARTICLES IN A DISPERSIVE MEDIUM

Abstract. *In this article, the effective scattering and absorption cross sections are calculated using the Mie theory for the motion of aluminum nanoparticles in water. This is done using the MiePlot program.*

Keywords: *Mie theory, scattering cross section, complex refractive index.*

KIRISH

Ma’lumki, moddalarni nanoo`lchamlargacha qisqartirib borilsa, ularning fizik va kimyoviy xossalari keskin o`zgarib ketadi. Bu hodisadan tibbiyotda ham foydalanish fikri olimlarda o`tgan asrning 20-yillaridayoq paydo bo`lgan[1]. Shu tariqa, asta-sekin nanotibbiyot fani shakllangan. Hozirgi kunga kelib esa, nanozarralardan tibbiyotda keng qo`llanilmoqda. Ayniqsa, zararli o`simtalarni aniqlash va yo`q qilishda nanozarralardan foydalanish o`zining ishonchliligi, effektivligi, o`simta atrofidagi sog`lom hujayralarga zarar yetkazmasligi jihatidan nur terapiyasining qolgan usullaridan ajralib turadi.

Nanozarralar bilan saratonni aniqlash uchun biron elementning nanozarrasi (masalan oltin yoki kumush) organizmga kiritiladi. Immun tizimi unga qarshilik ko`rsatmasligi uchun ularning sirti glyukoza bilan qoplanadi[2]. Keyin esa lazer nuri bilan nurlantiriladi. Kerakli to`lqin uzunligi va nanozarra o`lchamining optimal qiymatini tanlash orqali oldimizga qo`yilgan maqsadga erishish mumkin. Agar zarraning organizmda sochilish effektiv kesimi katta bo`lsa, demak bu zarradan saratonni aniqlashda foydalanish mumkin. Agar yutilish effektiv kesimi katta bo`lsa, zararli o`simtani yo`q qilishda juda yaxshi samara beradi[3].

TADQIQOT MATERIALLARI VA METODOLOGIYASI

Nanozarraning sochilish va yutilish effektiv kesimlarini hisoblash uchun MiePlot dasturidan foydalanildi[4]. Bu dastur shar shaklidagi zarralarda yorug`likning sochilishi uchun Mie nazariyasidan foydalanilgan holda effektiv kesimni hisoblaydi. MirPlot dasturi Windows operatsion tizimida ishlashga mo`ljallangan. Ushbu dasturni quyidagi havola orqali yuklab olish mumkin: http://www.philiplaven.com/mieplot.htm

Shu vaqtga qadar, [1],[5], [6], [7] larda oltin va kumush nanozarralarining suvda va dispers muhitda sochilishi uchun yutilish va sochilish effektiv kesimlari hisoblangan. Bu ishda esa alyuminiy nanozarralarining suvda sochilishi uchun yutilish va geometrik effektiv kesimlari hisoblangan.

TADQIQOT NATIJALARI

Mie nazariyasi

Lazer nurlanishining optimal to'lqin uzunligi va saraton hujayrasini lazer nurlanishi bilan samarali yo'q qilish uchun nanozarrachalarning optimal o'lchamlari diapazoni Mie difraksiya nazariyasidan foydalanib, sochilishning yagona yaqinlashuvida topilishi mumkin. Eng umumiy holatda, Mie nazariyasiga asoslangan hisob-kitoblar j zarrachalarning tarqalish matritsasi izlash uchun qisqartiriladi[1].

To'rtta murakkab funksiyadan tashkil topgan $S^j(\theta,\varphi)$, $S_i^j(\theta,\varphi)(I=1,\dots,4)$, istalgan yo'nalishdagi tarqoq skalyar to'lqinning amplitudasi va fazasini tavsiflaydi. Oldinga sochilish $\theta = 0°$ elektromagnit to'lqinning zaiflashuv jarayonini o'z ichiga oladi va sferik zarralar uchun $S_3^j = S_4^j = 0$. Biz tavsifni bitta tarqalish amplitudasi funksiyasi bilan cheklashimiz mumkin[1]:

$$S^j(0) = S_1^j(0) = S_2^j(0) = \frac{1}{2}\sum_{l=1}^{\infty} \quad (2l+1)\left(a_l^j + b_l^j\right) \qquad (1)$$

Bu erda Mie koeffitsientlari a_l va b_l dispers muhitning xarakteristikalarini o'z ichiga oladi va birinchi tur silindrik Bessel funksiyasi $\psi_l(y)$ va ikkinchi tur Hankel funksiyasi $\xi_l(\rho)$ aniqlanadi, shundan so`ng ikkalasi ham yarim integral indekslari bilan hisoblanadi[5]:

$$a_j = \frac{\psi_j'(y)\psi_l(\rho) - m\sim\psi_l(y)\psi_l'(\rho)}{\psi_l'(y)\xi_l(\rho) - m\sim\psi_j(y)\xi_j'(\rho)} \qquad (2)$$

$$b_j = \frac{m\sim\psi_j'(y)\psi_j(\rho) - \psi_j(y)\psi_j'(\rho)}{m\sim\psi_j'(y)\xi_j(\rho) - \psi_l(y)\xi_l'(\rho)} \qquad (3)$$

Bu yerda, $m\sim = \frac{m_0}{m_j}$ muhit nur sindirish ko`rsatkichining nisbiy qiymati,$m_0 = n_0 - i\chi_0$ va $m_j = n_j - i\chi_j$ lar esa, mos holda, zarra va eritmaning kompleks nur sindirish ko`rsatkichlari; $\rho = \frac{2\pi r_0}{\lambda}$ - Mie parametri. Boshlang`ich va chegaraviy shartlarga binoan

$$y = \frac{2\pi r_0 n_0}{\lambda}, \psi_i(u) = \left(\frac{\pi u}{2}\right)^{\frac{1}{2}} J_{i+\frac{1}{2}}^{(1)}, \quad \xi_i(u) = \left(\frac{\pi u}{2}\right)^{\frac{1}{2}} H_{i+\frac{1}{2}}^{(2)}$$

hamda

$$\psi_l' = d\psi_l(u)ldu.$$

$S^j(0)$ ning amplitudali sochilish funksiyasini bilgan holda zarrachalarning integral optik ko’rsatkichlarini ya’ni, yutilish $K_{|\;j|(\rho,m\sim)=\frac{\sigma_{|\;j|(\rho,m\sim)}}{\sigma_0}}$, sochilish sochilish $K_{soch}^j(\rho,m\sim) = \frac{\sigma_{soch}^j(\rho,m\sim)}{\sigma_0}$, $K_{att}^j(\rho,m\sim) = \frac{\sigma_{att}^j(\rho,m\sim)}{\sigma_0}$ ning o’lchovsiz effektiv koeffitsientlarini hisoblash mumkin. $K_{|\;j|(\rho,m\sim)=\frac{\sigma_{|\;j|(\rho,m\sim)}}{\sigma_0}}$ va susayishi $K_{att}^j(\rho,m\sim) = \frac{\sigma_{att}^j(\rho,m\sim)}{\sigma_0}$ berilgan bo`lsa, ma’lum bir to‘lqin uzunligidagi nurlanishi uchun quyidagi ifodani yozish mumkin:

$$K_{att}^{j}(\rho, m\sim) = \frac{4\pi}{k^2} R\{S^j(0)\},$$

$$K_{sca}^{j}(\rho, m\sim) = \frac{2}{\rho^2} \sum_{l=1}^{\infty} (2l+1)\left(\left|a_l^j\right|^2 + \left|b_l^j\right|^2\right),$$

$$K_{|}\ {}^{j}|(\rho,m\sim) = K_{ext}(\rho,m\sim) - K_{sca}(\rho,m\sim).$$

Bu yerda $k = \frac{2\pi}{\lambda}$ to‘lqin soni, $\sigma_{soch}^{j}(\rho, m\sim)$, $\sigma_{|}\ {}^{j}|_{(\rho,m\sim)}$, $\sigma_{att}^{j}(\rho, m\sim)$ va σ_0 lar esa mos holda zarraning sochilish, yutilish, susayish va geometrik effektiv kesimlari.

Yutilish va sochilish spektrlari

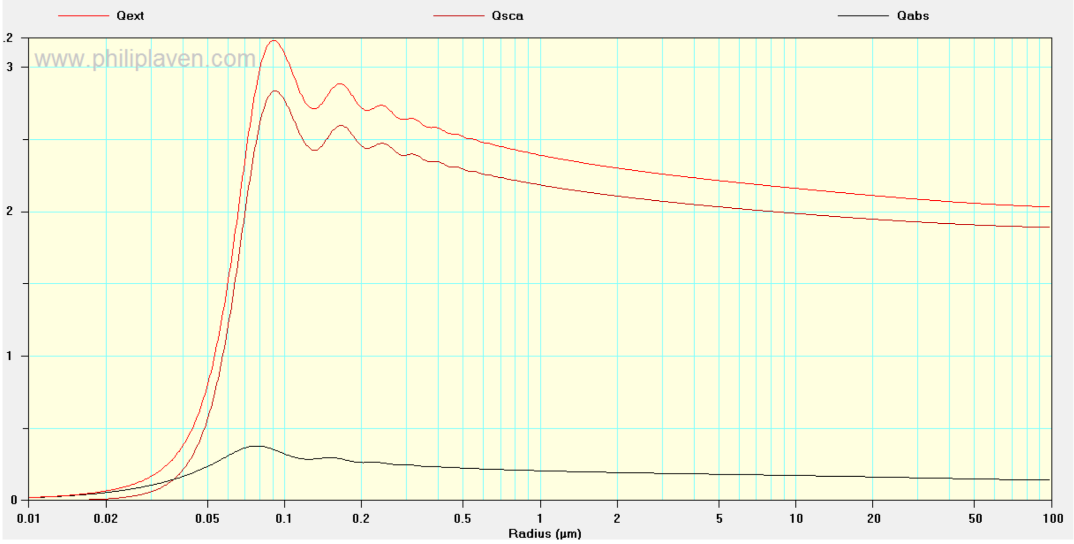
Dispers muhitda elektromagnit to'lqinlarning tarqalishini simulyatsiya qilishda [1] da ishlab chiqilgan effektiv algoritm ishlatilgan. Bu yerda a_l va b_l Mie koeffitsientlari uchun ifodalarda uchraydigan real va mavhum argumentlarning silindrik funksiyalari va ularning hosilalari to‘g‘ridan-to‘g‘ri va teskari rekursiyalar uchun takrorlanuvchi munosabatlardan foydalanib, funksiya va uning hosilasi nisbati sifatida hisoblangan. Bunday yondashuv Mie parametrlarining keng diapazonida, ya’ni $\rho = \frac{2\pi r_0}{\lambda} = 0.001 - 1500$, difraksiya chegarasidan past bo‘lgan dispers muhit optik xossalarini real n_0 va mavhum qismi χ_0 ning qiymatlari bilan bir vaqtda effektiv hamda bexato aniqlash imkonini beradi.

MUHOKAMA

Shunday qilib, Mie formalizmi ikkita o'lchamsiz parametrlardan foydalanishni talab qiladi $\rho = \frac{2\pi r_0}{\lambda}$ va $\delta = \rho m\sim$, bu erda $m\sim$ - λ to'lqin uzunligida muhitdagi nanozarralarning kompleks nur sindirish ko`rsatkichini nisbiy qiymati. Suvli suspenziyadagi alyuminiy nanozarralari uchun yutilish va sochilish koeffitsientlarining kompyuter hisob-kitoblari 1-rasmda keltirilgan.

1-rasm.

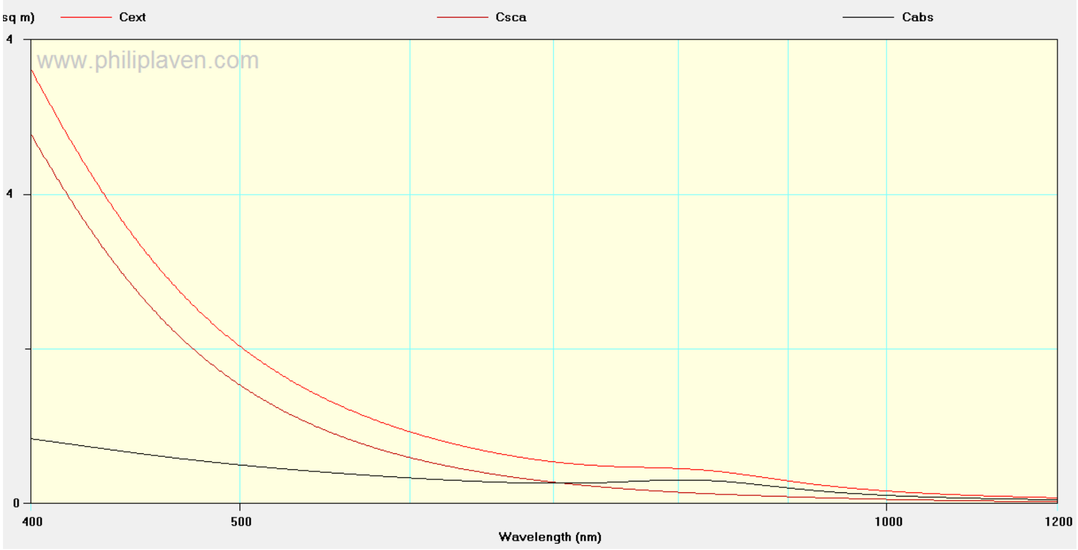
Sochilish, yutilish va to`la geometrik kesimning zarra o`lchamiga bog`liqligi



1-rasmda alyuminiy nanozarrachaning ko'rinadigan diapazon $\lambda = 400 - 700nm$ da yutilish, sochilish va to`la geometrik spektrlari ko'rsatilgan. 2-rasmda optimal to'lqin uzunligi uchun zarracha hajmi bo'yicha $K_{||}$ va K_{soch} orasidagi bog'liqlik ko'rsatilgan. 1 va 2-rasmlardan ko'rinib turibdiki, K_{yut} yutilish koeffitsienti $\lambda = 538.3nm$ to'lqin uzunligida, alyuminiy nanozarra radiusi 35 nm ga teng bo`lgan hol uchun yaqqol ajralib turgan maksimumga ega.

2-rasm.

Sochilish, yutilish va to`la geometrik kesimlarning to`lqin uzunligiga bog`liqligi



Alyuminiy nanozarralari 400 nm - 580 nm spektrdagi keng diapazonda lazer nurlanishini juda yaxshi yutadi, to'lqin uzunligi $\lambda = 538.3nm$ bo'lganda $K_{||}$=4,02 bo'ladi.

XULOSA

Olingan natijalardan xulosa qilish mumkinki, o`lchami yetarlicha katta bo`lgan alyuminiy nanozarralari to`lqin uzunligi ko`zga ko`rinadigan nurlanish sohasida bo`lgan nurlar bilan nurlantirilganda yutilish effektiv kesimi katta bo`ladi(2-rasm). Bu esa ularni nur terapiyasida qo`llash imkonini beradi.

2-rasmdan ko'rinib turibdiki, $K_{|\quad|\geq 1}$ darajasidagi yutilish egri chizig'i $r_0 = 10 - 210\ nm$ keng zarracha-radius diapazoniga ega. Bu shuni anglatadiki, bu o'lcham oralig'ida alyuminiy nanozarralarining yutilish effektiv kesimi $\sigma_{|\,nbn|}$ to`lqin uzunligi $\lambda = 538.3nm$ dagi geometrik effektiv kesimi qiymatidan katta bo`ladi.

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