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# An Investigation of Germanium Properties Prepared by Laser Ablation in Liquid

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## ABSTRACT

In this work, fabrication and characterization of germanium (Ge) NP is presented. The germanium particles were prepared by pulsed laser ablation in liquid technique (PLAL) at different laser fluence using Q-switched Nd:YAG laser at (1.06 µm) laser wavelength with pulsewidth 10 ns .Atomic Force Microscopy(AFM) and Energy Dispersive Analysis of X-rays (EDAX) are utilized here to study the surface and sizes of Ge nanoparticles and the evidences for ablation of materials respectively and the spectrophotometer have been used to characterize the optical properties of the prepared nanoparticles .

**Keywords**: laser-ablation in liquid, Ge nanoparticles, nano-ablation, Colloids.

# دراسة خصائص الجيرمانيوم المحضر بطريقةالازالة بالليزر داخل سائل

## الخلاصة

في هذا البحث تم تحضير ودراسة خصائص جسيمات الجرمانيوم النانوية.هذه الجسيمات تم تحضيرها بواسطة استخدام تقنية الازالة بالليزر في الوسط السائل (PLAL) بكثافات طاقة ليزر مختلفة بأستخدام ليزر النيدميوم ياك النبضي عند الطول الموجي 1.06 مايكرومتر وامد نبضة 10 نانوثانية. تم أستخدام مجهر القوة الذرية (AFM) و (EDAX) لدراسة الخصائص التركيبية والطوبوغرافية وقياس حجم الجسيمات النانوية ولتحليل المواد المزالة على التوالي كما تم استخدام مطياف الاشعة فوق البنفسجية-المرئية الثنائية الحزمة uv-vis spectrophotometer لدراسة الخصائص البصرية للجسيمات المحضرة.

## INTRODUCTION

Pulsed laser ablation was first developed in the 1960s, shortly after the invention of the pulsed ruby laser. In recent decades, laser ablation of a solid target in a liquid environment has been widely used in preparation of nanomaterials and fabrication of nanostructures. Recently, pulsed laser ablation has been studied extensively because of its application to thin film fabrication [1]. Pulsed laser ablation in liquids (PLAL) affords the synthesis of pure nanoparticle colloids without impurities caused by chemical precursors or preservatives [2]. Semiconducting nanoparticles are well developed for applications ranging from biomedical and environmental sensors to energy-producing devices. Most work to date has focused on II–VI semiconductor systems that have bandgaps and luminescent properties vary systematically with nanoparticle size [3]. However, Ge nanoparticles have many applications, such as precursors for thin film formation [4–6], for porous germanium

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(Ge) [7], and, regardless of the origin of light emission, for bioprobes [8, 9]. Nanoparticles and nanocrystals are of great interest in the field of materials physics because they have unique size-dependent characteristics that are significantly different from those of bulk materials [10]. The semiconductor nanoparticles exhibit a change in their electronic properties relative to that of the bulk material. For example, when the particle size becomes smaller, the band gap becomes larger. This allows us to change the electronic properties of the material by controlling the particle size [11]. The investigation on semiconductor nanoparticles, or quantum dots, is one of the most attractive areas in semiconductor science and technology [12]. The laser ablation was chosen in this article to synthesize Ge nanoparticles because of its simple process. The aim of this work is to synthesis and to characterize Ge nanoparticles prepared by laser ablation in liquid.

## Experimental Work

Germanium nanoparticles were synthesized by laser ablation in liquid process, which is a combination of focused pulsed laser and a piece of *Germanium* semiconductor plates placed at the bottom of a plastic vessel containing deionized water. A pulsed Nd-YAG laser Q-switched mode system type (HUAFGI), providing pulses at 1064nm wavelength with pulse duration 10 ns, repetition frequency of 1 Hz, and energy 500 - 800 mJ was used for Ge target. 10 cm long plastic cylindrical tube of 5cm diameter was used as a cell, filled with 5 ml deionized water. *Germanium* targets were polished, washed in ethanol and DIW and cut off to pieces with dimensions (2×2) cm to suite the experimental arrangement. A double-beam Uv-vis-210A Shimadzu spectrophotometer from model (SE 7200) was used in order to investigate the optical absorption spectra of the germanium colloidal NPs within the spectral range (200-800 nm). Surface morphology, particle size distributions and root mean square roughness of germanium layer prepared under different laser fluences were analyzed using atomic force microscope (AFM) model (AA3000). The evidences for ablation of Ge NPs were investigated by using EDAX model (FESEM, SUPRA TM 35 vp Zeiss, Germany product, Malaysia university).

## Results and Discussion

The optical properties of Ge NPs formed via PLAL show variation in energy gap at different laser fluences. UV-visible measurements showed that a blue shift in the absorption spectra of Ge NPs is obtained with increasing laser ablation fluence. This can be related to the change of the size of NPs which in turn changes the band gap of Ge as shown in fig (1). This blue shift indicates the quantum confinement property of nanoparticles. The optical band gap found to be varied from (1.8- 2) eV depending on laser fluence as shown in table (1).

Morphological analysis was carried out using atomic force microscope (AFM), which produces topographic images of surfaces at very high magnification and facilitates the observation the atomic structure of crystals.

The surface morphology of germanium colloidal NP prepared by PLAL at different laser fluence was obtained using atomic force microscopic images. Fig (2 a, b, c) reveals the 2D and 3D AFM images of Ge prepared at different laser fluences. For Ge prepared at low fluence no significant variation in size of particles were observed. The increase in laser fluence results in increasing the root mean square of surface roughness, average particle size, and height of ten points (sz) as shown in table (2).This could be attributed to changing in the cooling and solidification rates.

It has been demonstrated that the size of Ge NPs produced in water increases with increasing laser pulse energy. In fact, increasing the fluence means delivering more energy that implies ablating larger amount of material. And this fact was also observed while monitoring the ablation process. As we increase the laser energy and by consequence the fluence, the Ge colloidal nanoparticles cloud becomes denser [13]. The evidences for ablation of materials were checked using Energy Dispersive Analysis of x-rays (EDAX) as shown in Fig (3).

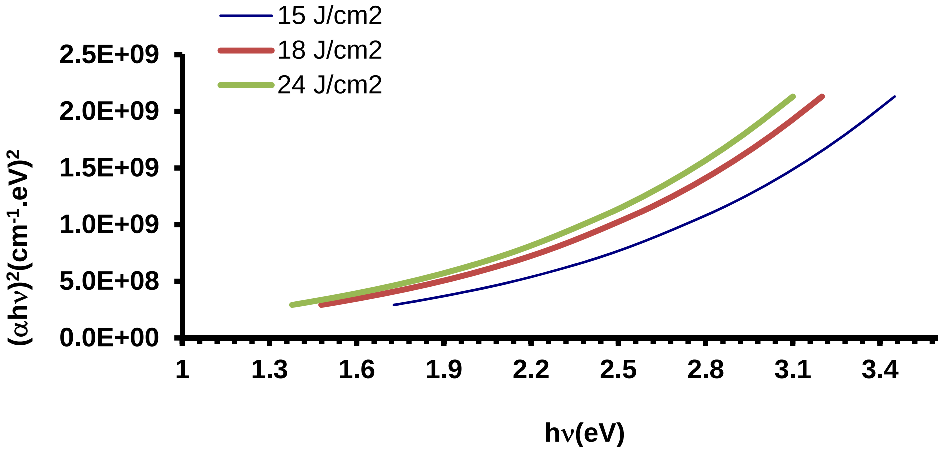
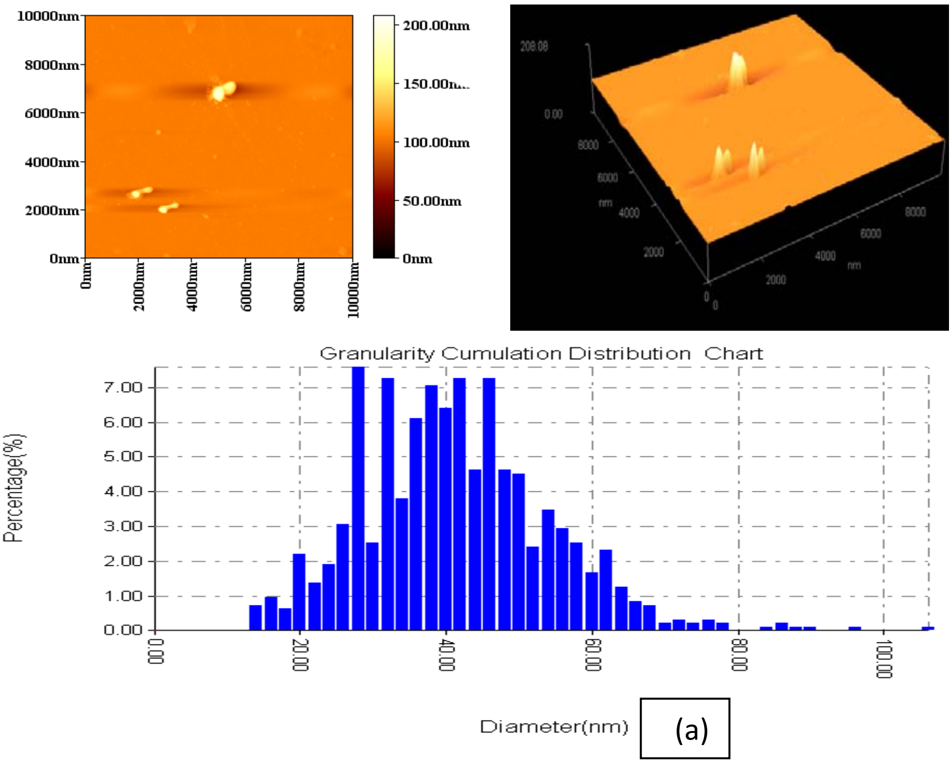
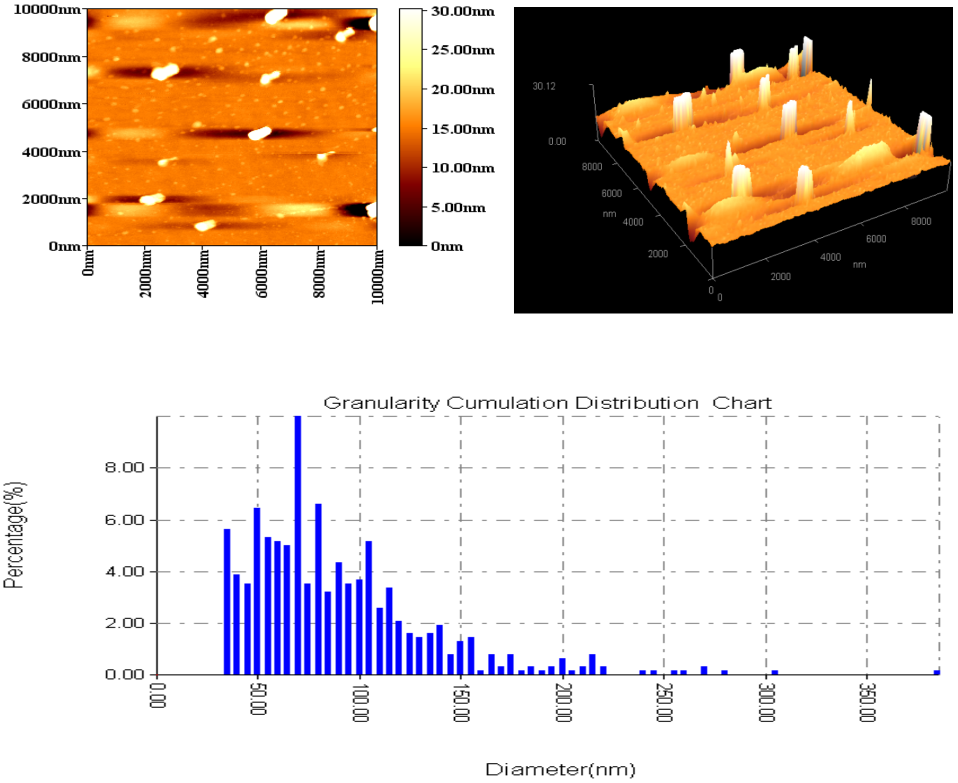
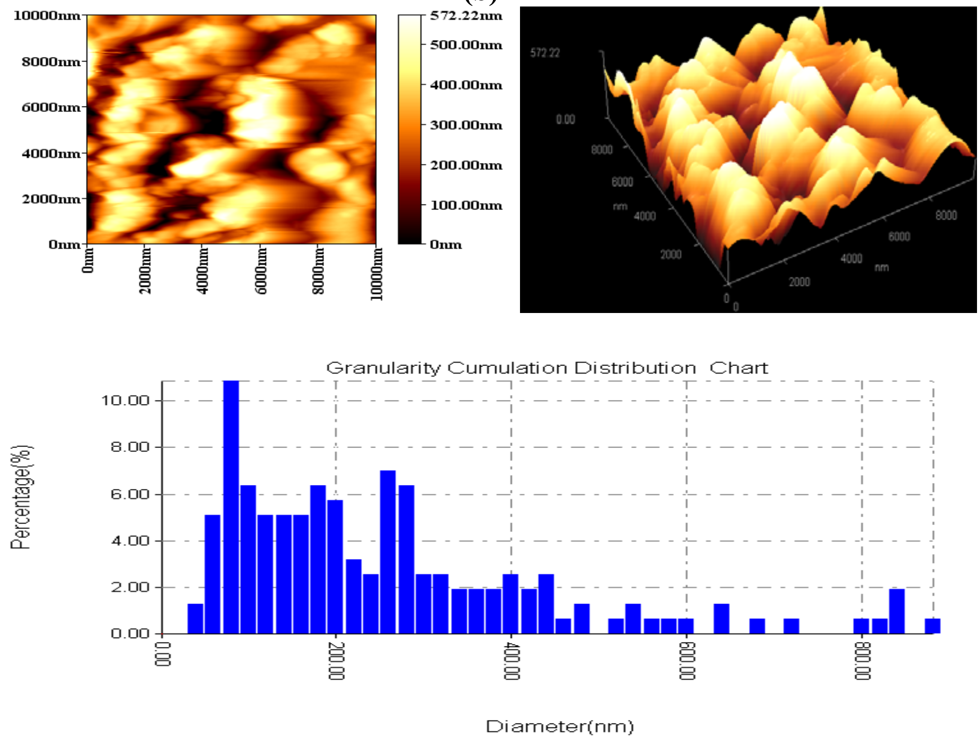


**Figure (1) The $(\alpha h\upsilon)^2$ as a function of incident photon energy for Ge NPs prepared at different laser fluences, 100 laser pulses and 1.06 μm laser wavelength.**





**(b)**



**(c)**

**Figure (2a, b, c) Surface morphology of Ge NPs prepared at different laser fluences (a=15, b=18, and c=24 J/cm$^2$)**

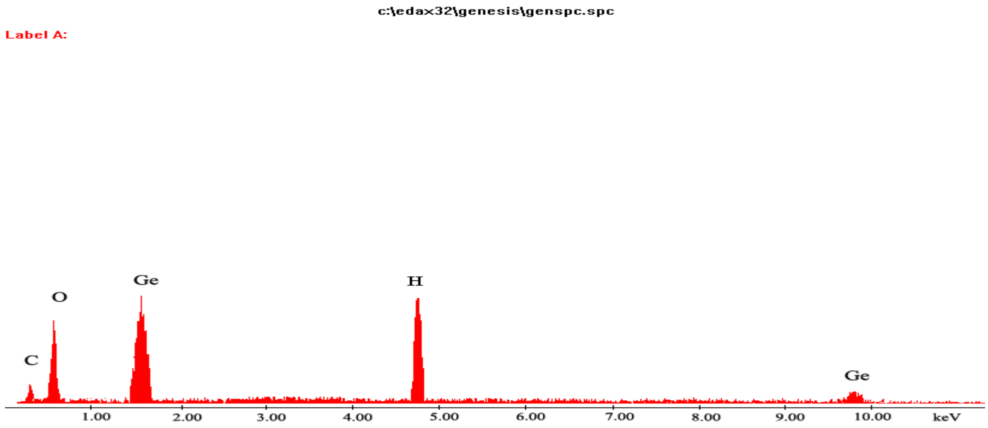


**Figure (3) EDAX spectrum of Ge NPs prepared at laser fluence =18 J/cm**

**Table (1) Values of optical band gap as function of laser fluence for Ge NPs.**

| Laser fluence (J/cm$^2$) | Band gap energy (eV) |
|---|---|
| 15 | 2 |
| 18 | 1.85 |
| 24 | 1.8 |

**Table (2): Listed the RMS, average size and Sz of Ge NPs**

| laser fluence (J/cm$^2$) | Avg. Diameter (nm) | RMS (nm) | Sz (nm) |
|---|---|---|---|
| 15 | 40.34 | 3.18 | 24.5 |
| 18 | 86.89 | 5.35 | 113 |
| 24 | 247.66 | 33.3 | 180 |

## CONCLUSIONS

The UV-visible measurements showed that a variation in energy gap in the absorption spectra of Ge NPs is obtained with increasing laser ablation fluence. The variation of laser fluences and the corresponding morphological characterization of the nanoparticles have revealed that:

The increase in the laser fluence results in increasing the root mean square of surface roughness, average particle size, and height of ten points (sz).This could be attributed to changing in the cooling and solidification rates. Therefore, controlling the irradiation conditions allows obtaining particles of different diameters and allows us to change the electronic properties of the material controlling the particle size.

## REFERENCES

[1] S.R. Franklin, R.K. Thareja, J. Appl. Phys. 97 (2005) 123303.

[2] Dahl, J. A.; Maddux, L. S.; Hutchinson, J. E. *Chem. Re*V. 2007, *107*, 2228.

[3] Andrew J. Pugsley, Craig L. Bull, Andrea Sella, Gopinathan Sankar, Paul F. McMillan, Journal of Solid State Chemistry 184, 2345–2352 (2011) .

[4] H.W. Chiu, S.M. Kauzlarich, E. Sutter, Langmuir 22, 5455–5458(2006).

[5] A. Watanabe, M. Unno, F. Hojo, T. Miwa, J. Mater. Sci. Lett. 20, 491–493(2001).

[6] E.V. Johnson, G. Patriarche, P.R.I. Cabarrocas, Appl. Phys. Lett. 92, 103–108(2008).

[7] J. Shieh, H.L. Chen, T.S. Ko, H.C. Cheng, T.C. Chu, Adv. Mater. 16, 1121–1124(2004).

[8] T.N. Lambert, N.L. Andrews, H. Gerung, T.J. Boyle, J.M. Oliver, B.S. Wilson, S.M. Han, Small 3, 691–699 (2007).

[9] B.A. Hernandez-Sanchez, T.J. Boyle, T.N. Lambert, S.D. Daniel-Taylor, J.M. Oliver, B.S. Wilson, D.S. Lidke, N.L. Andrews, IEEE Trans. Nanobiosci. 5, 222–230(2006).

[10] H.R. Yoon, W. Jo, E.H. Lee, J.H. Lee, M. Kim, K.Y. Lee, Y. Khang. Journal of Non-Crystalline Solids 351, 3430–3434(2005).

[11] Trindade T, O'Brien P, Pickett NL Chem Mater 13:3843(2001).

[12] Huang J, Ye Z, Wang LJ Mater Sci Lett 21:129(2002).

[13] S. Besner, A. V. Kabashin, F. M. Winnik, and M. Meunier, Journal of Applied Physics A, Vol. 93, p. 955, (2008).