# Energy density of the silicon ball-lightning-like luminous balls

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**Abstract** – The energy density of the silicon luminous balls is calculated. The mean values obtained are comparable to the estimated values from different natural ball lightning records.

Previously we have performed electric arc discharges in pure silicon to generate silicon luminous balls (SLB) with lifetime in the order of seconds and several properties usually reported for natural ball lightning (BL). The $SiO_2$ heat of reaction is determined, using ab-initio coupled cluster method and basis sets CCSD(T)/cc-pVTZ, as the difference of electronic energies between product and reactants in the ground state, according to: $\Delta H = E(SiO_2) - [E(Si) + E(O_2)]$, where $E(SiO_2)$, $E(Si)$ e $E(O_2)$ are the electronic energies (including the zero-point energy correction) plus thermal enthalpies contributions for $SiO_2$ (-439.3166897 Hartree), Si (-288.9000116 Hartree), and $O_2$ (-150.1254283 Hartree), respectively. Thus we found $\Delta H = -755$ kJ mol$^{-1}$. All calculations are performed by using the Gaussian03 Program. As resulted, we found $H = 88.1$ J as the released energy during the SBL oxidation process. Thus the total energy liberated by the SLB will be $H_t \sim H = 88.1$ J. Taking the mean radius of the SLB as $R = 1.25$ cm, $ED = 10.8$ MJ m$^{-3}$. On the other side, if we insert entropic effects in the enthalpy calculation, we can see that its value changes to $H = -273.4$ kJ mol$^{-1}$. Consequently, $ED$ will be reduced to 3.9 MJ m$^{-3}$. This fact shows that entropic effect is relevant to the energetic content of SLB. Still, this value is sufficient to justify the SLB in the class of BL. We can see in Tab. 1 that our calculated energy density of gas phase silicon oxidation in SLB is in the same range of those for BL estimated by Stakhanov, Imianitov & Tikhii, and Barry.

TABLE 1. Mean diameter of various BL associated with its mean energy and mean energy density from different literature sources.

| OBSERVATION CASE / AUTHOR | $D$ (m) | $H$ (J) | $ED$ (MJ m$^{-3}$) |
|---|---|---|---|
| (13) Stakhanov[a] | 0.08 | $0.69 \times 10^4$ | 25.85 |
| (30) Stakhanov[a] | 0.055 | $1.5 \times 10^4$ | $1.99 \times 10^2$ |
| Imianitov & Tikhii[b] | 0.07 | $1.0 \times 10^3$ | 6.25 |
| (the case of 1981, p. 65) Stenhoff[c] | 0.0175 | $6 \times 10^2$ | $2.4 \times 10^2$ |
| (the case of 1962 in Zakarpatie) Imianitov & Tikhii[b] | 0.075 | $2.7 \times 10^8$ | $1.55 \times 10^6$ |
| (a) Barry[d] | 0.098 | $4.4 \times 10^2$ | 0.8 |
| (b) Barry[e] | 0.090 | $5.3 \times 10^2$ | 0.4 |
| (the Smethwick event) Stenhoff[c] | 0.099 | $3 \times 10^3$ | 6 |
| This work | 0.025 | $1.2 \times 10^2$ | 10.8 / 3.9* |

\* including entropic effects

## References

[1] G.S. Paiva, A. C. Pavão, E. A. Vasconcelos, O. Mendes, Jr., E. F. Silva, Jr., Physical Review. Letters 98 (2007) 048501.