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On electromagnetic wave ignited sparks in aqueous dimers

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Dimer interactions with electromagnetic waves offer a research tool to obtain microscopic insights into macroscopic matter behavior. They also generate a popularly-known household phenomenon in the form of fiery sparks between two closely-spaced grapes in a microwave oven. However, the cause has not been scientifically examined until recently. In a detailed study on aqueous dimers [1], Khattak, Bianucci, and Slepkov concluded that the merging of resonant modes in two closely-spaced watery spheres results in a hot electromagnetic spot in their gap, which causes the sparks. This work has put a long-standing household puzzle on a rich academic basis. It has also been widely reported [2-5] because of its novelty and public interest, in particular, the claimed demonstration of optical writing with a resolution better than $\lambda_0/80$.

However, the current study points to an independent cause of a much different nature. Both theory and experiment indicate that, with the wave polarized along the dimer axis (same model as in Ref. [1], mutual enhancement of polarization charges on both sides of the narrow gap can result in an electric field hundreds of times greater than that of the incident wave, hence triggering the sparks through air arcing [5]. This is evidenced by (1) the predicted and observed sparks in an essentially magnetic-field free environment at 27 MHz (Fig. 1), (2) the negligibly small magnetic field in the dimer gap even when the dimer body is in strong electromagnetic resonance with a 2.45-GHz microwave (Fig. 2), and (3) a video display of the attraction by electric force between the two spheres of the dimer [6], rather than the repulsion expected from the radiation pressure of an electromagnetic hotspot.

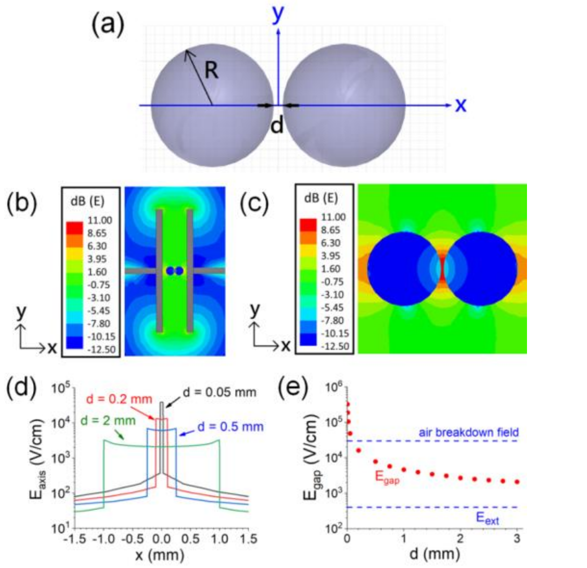

Figure 1. Simulation model and results at 27 MHz under E_{ext} = 400 V/cm. (a) A dimer composed of two R= 7 mm water spheres separated by gap width d. (b) A capacitor loaded with a dimer (with d = 0.5 mm). (c) Close-up view of the dimer in (b), $E(\mathbf{x})/E_{ext}$ in logarithmic scale. (d) E_{axis} profiles. (e) E_{gap} as a function of d.

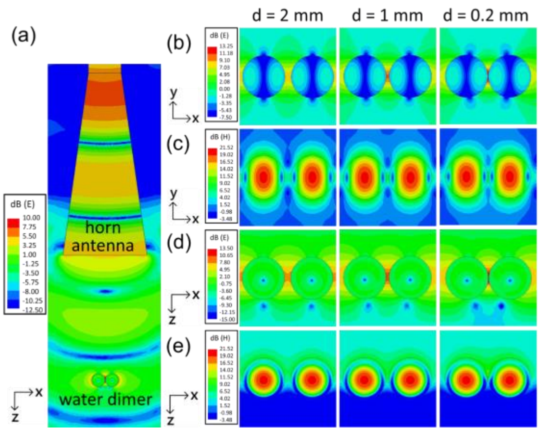

Figure 2. Simulation model and results at 2.45 GHz. (a) The simulation model and instantaneous E-field pattern on the x-z plane. (b) x-y plane E-field. (c) x-y plane B-field. (d) x-z plane E-field. (e) x-z plane B-field. For all figures, the dimer with $\varepsilon = (77.5+10i)\varepsilon_0$ is exposed to E_{ext} = 400 V/cm. The color code gives E/E_{ext} and H/H_{ext}, in logarithmic scale.

References

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