Electronic Supplementary Material (ESI) for Lab on a Chip.

Supplementary material

Figure S1 shows an array of piezoelectric element units that are electrically connected to EP electrodes in the matrix. Each unit incorporates two (or potentially more) piezoelectric elements to generate sufficiently high bias voltages.

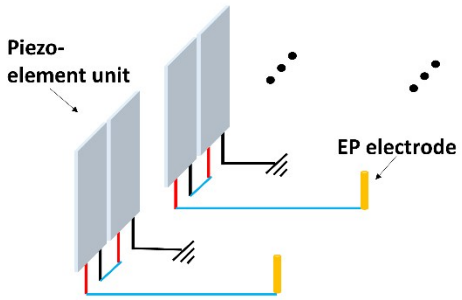

Figure S1: Electrical connections for biasing the EP electrodes using pairs of serially connected piezoelectric elements.

Figure S2 illustrates two possible paths for transporting and merging two droplets using the same electrode connection scheme as in Figure 11(A). For a synchronous actuation of one droplet from Electrode A to Electrode B and the other from Electrode C to Electrode D, we need to ensure that A $\neq$ B; B $\neq$ C; Electrodes A, B, C and D do not form a closed square; and Electrodes D or B are not one of the four electrodes adjacent to Electrodes A and C.

As a concrete example, with two droplets initially at the electrodes labelled 7 and 4 on the first column, piezoelectric element units 7 and 2 and piezoelectric element units 4 and 5 are first actuated simultaneously. This is then followed by element units 2 and 1 and element units 5 and 6. The two droplets are merged at Electrode 6 and subsequently transported to Electrode 1. The number of piezoelectric element units required are 8 as before.

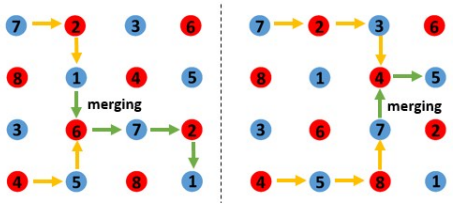

Figure S2: One possible implementation of the merging function using the base 4x4 electrode matrix.

A typical biochemical assay protocol involves multiple starting analyte droplets or requires incubation steps for intermediate reactant droplets. If extra droplets to be processed are kept on an active electrode matrix, they may interfere with the other droplets. One approach to circumvent this is to designate sites outside the active electrode matrix to store those droplets before and after each functional operation. The electrodes in these storage sites are connected to separate piezoelectric elements.

Figure S3 shows one example of combining storage sites with two linked base electrode matrices for the transportation and merging of multiple droplets. In Step 1, two pairs of droplets, each deposited at Sites 10 and 11 or at Sites 12 and 13, are first transported (purple paths) for merging. The two resulting droplets are transported back to Sites 10 and 12, respectively, for later use (green paths). In Step 2, the droplet stored in Site 10 is transported to the edge of the left base electrode matrix (yellow path). In Step 3, the said droplet and the other droplet stored in Site 12 are transported (purple paths) and merged (green path). Through repetitive uses of the functional electrode matrices, we can implement multiplexed protocols in our microfluidic platform.

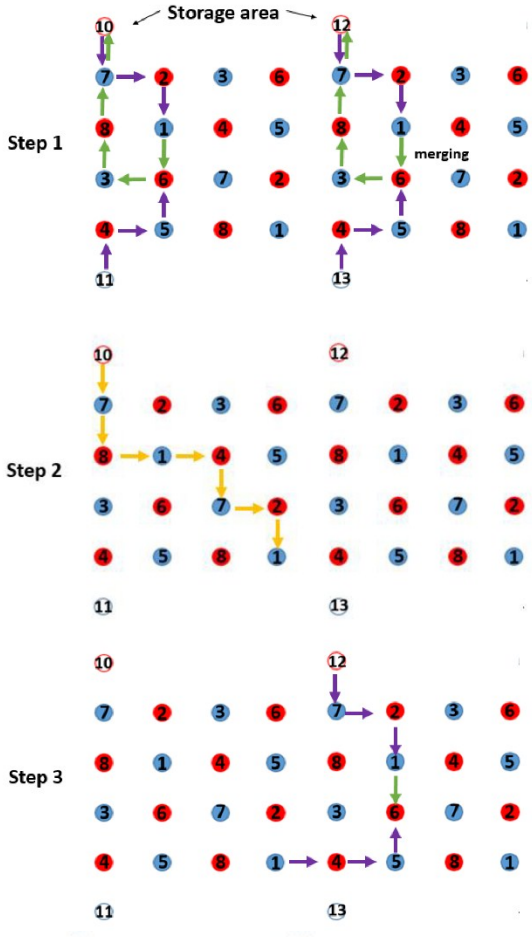

Figure S3: An example integration of storage sites and the base functional electrode matrices to process multiple droplets.

Connecting multiple electrodes to a single piezoelectric element unit may result in interfering forces on a droplet during actuation. Figure S4 shows the predicted interfering forces at various positions between two driving electrodes for different values of the *r*/*p* ratio under a typical electric field strength used in our experiments. The magnitude of predicted interfering forces is less than 10% of the main driving force for electric fields as small as 0.16 MV/m and *r*/*p* ratios as large as 0.45. The normalized magnitude of the

interfering forces is larger for larger droplets (larger radius-to-electrode pitch ratios) and for smaller electric fields.

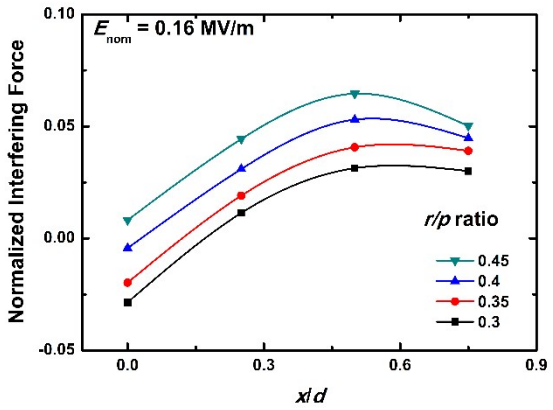

Figure S4: Predicted normalized interfering forces at different positions between two driving electrodes under different values of the ratio between the droplet radius and the electrode pitch, r/p.