Microfluidization of graphite and formulation of graphene-based conductive inks

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Graphene inks are a rapidly expanding research area [1-2]. Applications include printable antennas [3], and electrodes in (opto)electronic [4] or energy storage devices [5]. However, the current production routes (sonication [6] and high shear-mixing [7]) give low concentrations of few layer graphene (<0.2 mg/ml) [2,7] and require time consuming centrifugation to remove non-exfoliated flakes [2,6,7]. Here we exfoliate graphite in an aqueous surfactant solutions (sodium deoxycholate) using a microfluidic processor (fig.1a). At a flow rate of 120 ml/min we get 1 mg/ml single/few layers graphene (20% of single layer) with a production rate of 65 mg/h. This rate, for the same energy input (100 MJ/m^3), starting graphite concentration (50 mg/ml) and volume (~200 ml) is 50% higher than shear mixing [7] and 1500% times higher than sonication [7]. Unlike sonication or shear mixing, in microfluidization all the material is uniformly exposed to intensive shear, thus the centrifugation step can be avoided and graphene nanoplatelets (GNPs) (mean thickness ~12 nm) can be produced (80 mg/ml at a rate of 7.2 g/h). Conductive inks are formulated by adjusting the viscosity in the range of hundreds of mPas suitable for blade coating, flexographic or screen printing. We employ sodium carboxymethylcellulose (CMC) (fig.1b) as a binder, stabilizer and rheology modifier, reducing the viscosity from 600 mPas at 100 s^{-1} to 160 mPas at 1000 s^{-1} (thixotropic behaviour) thus making the ink easier to coat or print. The inks are used for the fabrication of conductive fibers (fig.1c) using a wet spinning process, coatings (fig.1d) using flexo/screen printing, and aerogels (fig.1e) using freeze drying.

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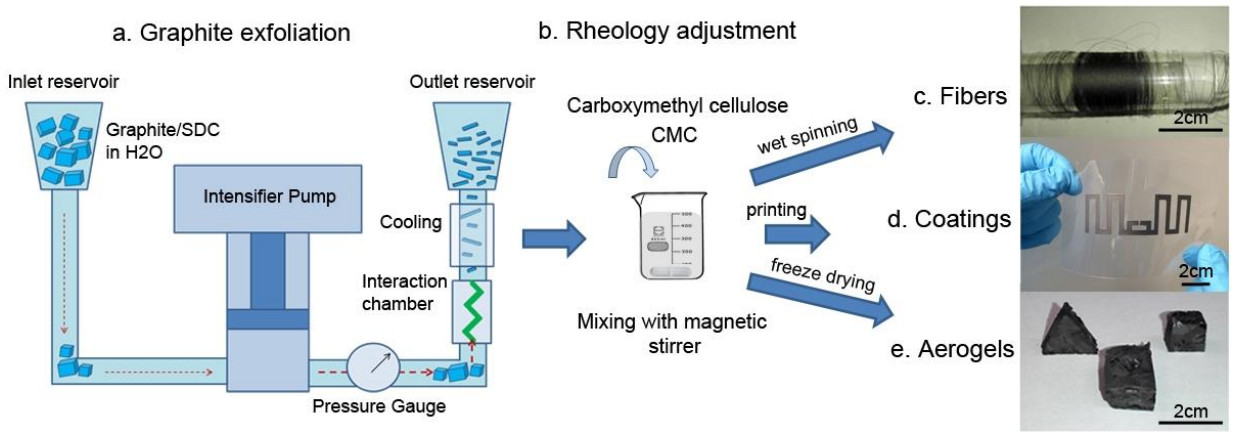

Fig. 1. a) Microfluidic processing of graphite, b) rheologoy adjustment by CMC and fabrication of c) fibers using a wet spinning process; d) coatings (antennas) using flexo/screen printing; and e) aerogels using freeze drying.