Preface

Electric sparks have been known for a long time and studied extensively. Sparks that emanate when a wire explodes was used for the first time in 1774 by E. Nairne as a current estimating device, similar to a fuse. In the 1930s, a great mystery centered around the observation that sparks sometime break down in time intervals of about $10^{-8}$ sec after application of electric fields, and the voltage across a spark gap in such short time intervals drops from its initial high value to a low value characteristic of arcs. The possible use of exploding wires as source of plasma for confinement experiments, provided the impetus for accelerated research in this line. Around the end of the last century, however, it was realized that explosion of wires leaves behind residues which are nanometer sized particles. Thus the innocuous wire fuse has turned into a production tool of nanotechnology in a space of a little over 200 years.

The work presented in this thesis is a modern interpretation of the traditional exploding wire process in a new geometry, called the needle-plate geometry. Such geometries are important from the point of view of production of these extraordinary nanomaterials in large quantities, for use in basic and applied research. Using contemporary techniques for data recording, material analysis and numerical interpretation, the thesis tries to establish the dynamics involved in this geometry in some detail.

The thesis is spread over seven chapters. Chapter 1 is a study of the literature and a historical account of the evolution of the electro-explosion phenomena from discovery to the status at present. This is followed by the adaptation of the phenomena in the new needle-plate geometry, in Chapter 2. Time evolution of current through the needle-plate geometry is studied next with nanosecond resolution. Various needle and plate material combinations together with the size of the needle has allowed ascertain a certain scaling behaviour of the current, inherent to the process. This is presented in Chapter 3. As this process takes place far away from equilibrium, similarities with other natural systems such as biological, chemical, hydrodynamical and nonlinear optical systems are expected. One such observation is that of concentric ring patterns in metals, which is a rare occurrence. Using spectral density plots derived from the recorded plasma currents, and
correlating these with the observation of nanometer scale surface modification of the metallic plate, in Chapter 4, a signature of self-organisation is shown as the underlying basis towards the formation of concentric ring formation in metallic plates. Chapter 5 is a study of pattern formation in detail whose appearance and disappearance is established by a careful choice of the electron-phonon coupling of the metal. This allows a control over the dissipation of energy imparted in the explosion to the lattice atoms. In Chapter 6, theoretical modelling of the concentric ring pattern formations in the needle-plate exploding system is presented, based on the Korteweg-de Vries-Burger’s (KdVB) equation. A strong correlation between the experiments presented under various conditions and theoretical simulations are found allowing association of experimental parameters such as applied voltage and wire diameter to a theoretical parameter such as shock amplitude in the KdVB equation. Chapter 7 concludes the thesis.